# CHAPTER 4 PRESENT WATER SUPPLY CONDITIONS

## 4.1 Available Data

Out of 1,779 water supply schemes in the country, 579 and 188 schemes are currently run by MWR and NWCPC, respectively. Information on these schemes are not immediately available except some key design factors listed in the MWR's "Project Status Reports" and NWCPC's "Activities and Present Status Reports". Assessment of the performance of these schemes are hardly possible.

To supplement these data and information, a series of questionnaire surveys and field reconnaissance were carried out at selected districts and schemes under the current Study. Parameters and factors obtained are summarised in the Data Book and incorporated in the present report. Due to time constraint under the Scope of Work for the Study, however, these survey activities are not sufficient to clarify existing conditions particularly of small scale NGO or community based schemes.

## 4.2 Existing Water Supply Schemes

### 4.2.1 Classification of Water Supply Schemes

As specified in the Scope of Work, all water supply schemes shall be classified into two; urban water supply and rural water supply.

There are, however, many types of water supply schemes developed in the country. Most typical types are: i) urban schemes that mainly cover urban centres and their peripheral areas, ii) community based rural water supply schemes that mainly serve rural communities, and iii) regional water supply schemes that cover several urban and rural areas simultaneously. In addition, there are many small schemes constructed in urban centres. It may not be appropriate to deal with these water supply schemes on the basis of the administrative unit, but may be more practical to formulate development plans based on supply area.

In view of the current status and size of the developed schemes, rural water supplies are classified into two: large and small scale schemes in terms of served population. This classification is considered most appropriate for the present Study. For clarification, these three types of schemes are defined below;

1) Urban Water Supply Scheme (UWS): schemes that have major demand zones in the urban centre and will have more than 5,000 served population by the year 2010

2) Large Scale Rural Water Supply (LSRWS): schemes that mainly serve rural communities and will have 5,000 served population or more by 2010

3) Small Scale Rural Water Supply (SSRWS): schemes that supply water to rather small communities which will have population less than 5,000 in 2010

Depending on needs, LSRWS and SSRWS will be separately dealt with under heading "Rural Water Supply" in the present report. It is, however, to be noted that the above definition, merely for the current Study, is no more applicable to other projects and studies.

### 4.2.2 Urban Water Supply Schemes

Each urban centre is usually served by one scheme. The Study Team inventoried the water supply schemes as shown in **Table - 4.2.1.** Eight (8) out of 141 urban centres do not have any existing schemes. All of the the urban centres not serviced are small in population. Kerugoya/Kutus in Kirinyaga District is an exceptional case, served by two schemes: one operated by DWO and the other receiving water from the NWCPC scheme. Kangundo/Tala has also two schemes, but both are operated by a municipal council.

Total population in 141 urban centre was about 5.2 million in 1995. Population served by the UWS reached to 5.0 million or 95.6%, including population in the peripheral rural areas. This percentage is very high. Actual service coverage in the urban centres is around 90% according to Welfare Monitoring Survey II. **Table - 4.2.2** shows the estimated served population by UWS.

### 4.2.3 Rural Water Supply Schemes

There are a large number of rural water supply schemes in the country. As for the large scale rural water supply, relevant reports and documents provide some aspects of the schemes. **Table - 4.2.3** presents a list of LSRWS existing in respective district. There are 295 LSRWS in the country. These schemes service approximately 4.2 million population.

Because of a lack of comprehensive surveys and proper records, outline features of the small scale rural water supply are unknown. From the Welfare Monitoring Survey II done nationwide, it is assumed that 5.5 milion population are served by the SSRWS. Thus, nearly 10 million population (4.2 + 5.5 = 9.7 million) or 43% of the rural population are supplied by RWS.

### 4.2.4 Estimate of Present Safe Water Supply Quantity

The Welfare Monitoring Survey II provides overall information as to the sources of safe water supply over the entire country. It is, however, difficult to grasp the sources of piped water supply and quantity of water supply by the water source. Analysis of existing data identified, the water sources for 130 urban centres out of 141 urban centres and 283 out of 295 LSRWS as summarised below:

Sources of Water Supply

| Water Supply Schemes | Surface Water | | | | Ground water | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | River | Lake | Offtake from Pipeline | Sub-total | Borehole/ Shallow W | Spring | Rock Catchment | Sub-total | |
| Urban Water Supply Schemes | 70 | 2 | 11 | 83 | 40 | 7 | 0 | 47 | 130 |
| Rural Water Supply Schemes | 133 | 17 | 0 | 150 | 91 | 40 | 2 | 133 | 283 |
| Total | 203 | 19 | 11 | 233 | 131 | 47 | 2 | 180 | 413 |

Source: JICA Field Survey Results in 1998 and MWR Operation and Maintenance Report, 1997
Note: River water source includes river, stream, dam and irrigation canal.

The main source of piped water is the surface water of the rivers and groundwater.

It is important to reveal the quantity of safe water supply under present conditions. Safe water, according to the Kenyan definition, comprises pipe water, roof catchment, protected springs, protected wells and boreholes. The Study Team attempted to estimate the quantity of safe water supply of 141 urban centres and 50 districts. The methodology and detailed process of this analysis are described in Supporting Report III. Their outlines are briefly explained as follows:

(1) Urban Water Supply Quantity

The quantity of urban water supply is mostly based on the MWR Status Report, NWCPC Status Report, MWR's Survey for Rehabilitation of Existing Systems and Water Supply Sector Survey conducted by the Study Team.

(2) Rural Water Supply Quantity

Water production by LSRWS is derived from the same data sources as those of UWS.

For the SSRWS, the existing data source such as the MWR Project Status Report 1996 does not list up all SSRWS schemes. It is therefore assumed that the total water supply capacity of SSRWS is in a similar level to the estimated water demand because of the following:

1) Registered members are major customers in case of SSRWS. A sudden increase of the customers is very rare.

2) Normal water supply schemes apply safety side of design values to cope with future population growth.

3) Population growth rate in rural areas is generally lower than that of urban centre population.

For the ongoing and planned/designed SSRWS, the water supply capacity is mainly derived from the MWR Project Status Report 1996.

Roof catchment is one of the major water supply methods, especially rural area, and it is included in small scale rural water supply. Although the water supply capacity is subject to the amount of rainfall and water tank capacity, it is estimated based on the number of households resorted to the roof catchment and water consumption per capita. The water consumption per capita is assumed to be 5 litter per day. The water supply capability by roof catchment is assumed to remain constant throughout the planning horizon.

(3) Livestock Water Supply Capacity

According to the analysis of the existing data used for the present water supply capacity, the existing water supply facilities cater to 80% of the livestock water demand in 1995. This figure is, therefore, assumed to be the present livestock water supply quantity.

(4) Present Water Supply Quantity

The present water supply quantity is estimated by the above method for 141 urban centres and 50 districts as shown in **Table - 4.2.4**. The summary is given in the table below:

Estimated Quantity of Water Supply

| Service Area | Supply System | Quantity (1,000m³/day) |
|---|---|---|
| Urban areas | UWS | 709 |
| Rural areas | LSRWS | 449 |
| | SSRWS(*) | 301 |
| | Sub-total | 750 |
| Total | | 1,459 |

Source: The Aftercare Study Team
Note: * Roof catchment water supply 4,220 m³/day

These figures do not include livestock water supply. On the basis of these figures and the estimated water supply quantity, water consumption per capita is estimated as follows:

| Service Area | Total Population (1995) | Service Coverage (%) | Water Served Population | Water Supply (m³/day) | Per Capita Consumption (lpcd) |
|---|---|---|---|---|---|
| Urban centre (141) | 5,280 x $10^3$ | 94 | 4,974 x $10^3$ | 709 x $10^3$ | 143 |
| Rural areas | 22,240 x $10^3$ | 44 | 9,724 x $10^3$ | 750 x $10^3$ | 78 |
| Total/Average | 27,520 x $10^3$ | 53 | 14,640 x $10^3$ | 1,459 x $10^3$ | 100 |

Source: The Aftercare Study Team

## 4.3 Physical Conditions of Existing Water Supply Facilities

### 4.3.1 Water Source Facilities

As noted above, surface water of river and the groundwater is the main source of the piped water supply. The outlines of existing water source facilities are briefly explained below.

(1) Surface Water Source Facilities

The surface water source facilities can be grouped into: (i) run-of-river intake on the river, (ii) a large dam with a reservoir having storage capacity enough to regulate the river runoff throughout the year, (iii) pumping facilities on lake and river, (iv) small dam/pan.

The run-of-river intake is the predominant source facility, and use unregulated surface water of the river.

A large urban supply scheme like in Nairobi and Eldoret depends on the large dam for their raw water source.

Pumped facilities are widely used for lifting the water up from lake and rivers. The most typical is the one in Kisumu, resorting to Lake Victoria.

According to "Inventory of Dams and Pans in the Country, July 1997, MWR", there are 1,359 small dams and 825 water pans.

(2) Groundwater Source Facilities

These could be divided into (i) boreholes and (ii) dug wells.

As reported in the subsection 2.4.2 of this reports, 8,448 boreholes have been registered with water right and approximately 57 million $m^3$ annually are abstracted for various purposes, of which more than 50% is supposed to be used for the domestic and livestock water supplies. The operation of borehole pump is dependent on such power supply facilities as commercial electric power, diesel engine, wind mill, and solar energy. The operation and maintenance issues identified are discussed in the subsection 2.4.2 of this report.

No country wide statistic is available on the number of dug wells. But the dug wells sustain 11.8% of the total households in Kenya. The operation and maintenance issues identified are also reported in subsection 2.4.3 of this report. It is supposed that the majority of dug wells are not equipped with pumping facilities.

### 4.3.2 Treatment Process

In most MWR's projects, treatment process is composed of conventional chemical coagulation, flocculation, sedimentation and filtration, and finally chlorination is applied for filtered water.

Chemicals used are: sulphate aluminium as coagulant, caustic soda as coagulant aid, and tropical chloride of lime as disinfectant. Chemicals are dosed by dripping from a solution tank and mixed by hydraulic cascade from a weir. Flocculation is of horizontal baffled chamber type. Most of the sedimentation tanks are up-flow type for easy de-sludging and cost saving. The filter is conventional type of rapid sand filter with a filtration rate less than 5 $m^3/m^2/hr$.

The treatment works in local authorities' projects are well operated and the chemical dosing process is controlled by applying a Jar-tester twice a day. Most of the treatment works have few laboratory apparatus or Jar-tester, so that alum dosing is made without any consideration to suitable dosing rate. Filters are washed by air scouring and backwash water every 24 hours. Because of poor sedimentation efficiency, filter is washed twice a day.

When turdidity of raw water is low in the dry season, no chemical is dosed according to operator's decision. Due to lack of enough budget allocation to purchase chemicals, small scale treatment works rarely perform the chemical dosing so that water quality of produced water is poor.

Groundwater sources of boreholes, dug-wells, and springs received only chlorination as a treatment process. Low turbid water from rivers, streams, and small dams in rural schemes also receives chlorination. However, treatment works shall be constructed for those schemes using surface water, to avoid the danger of no chlorine dosing.

### 4.3.3 Storage Reservoir

Storage capacity of the existing reservoirs is quite small. Out of 343 water supply schemes surveyed, only 37 schemes have sufficient capacity for continuous supply (24 hour storage). The remaining 306 schemes have storage capacity less than 50% of the required. The less capacity, the less water storage during night time when water demand decreases to a minimum level. This may limit operating hours, resulting in serious water shortage in the supply area.

### 4.3.4 Transmission and Distribution

Galvanised steel and/or uPVC pipes are used for transmission and distribution. Those pipe materials are produced in Kenya. uPVC pipes of push-in type and steel pipes of coupling joint type are most common. Steel pipes are used for high pressure lines.

In general, no master meter meters are installed, though they are essential to control flow and leakage on the pipeline network. Most of the water supply schemes do not exercise leakage control to detect and repair leaks from the distribution pipelines and service connections.

### 4.3.5 Service Connections

Galvanised steel pipes with screw joint and uPVC with solvent cement joint are utilised for service connections less than 25 mm in diameter. Individual house connections are 1/2" in diameter.

Accessibility to meters is generally good but they are not encased with meter boxes. Despite needs, there are many water supply schemes that do not adopt the metering system. Some local authority schemes adopt the full metering system.

## 4.4 Operation and Maintenance Practice

### 4.4.1 Operation Hours

Operation hours of the treatment works affect amount of water production. It is noteworthy that, out of 302 schemes, 171 schemes or 57% are not operated continuously. Further, 122 schemes run less than 12 hours a day as shown in the table below.

Operation Hours of Water Supply Projects

| Operation | Surface Water Sources (Nos.) | | | Groundwater Sources (Nos.) | | | Total | |
|---|---|---|---|---|---|---|---|---|
| | River/Lake | Dam | Sub-total | Borehole | Well/Spring | Sub-total | Nos. | % |
| 6 ~ 18 hrs | 5 | 1 | 6 | 8 | 2 | 10 | 16 | 5 |
| 10 ~ 12 hrs | 17 | 4 | 21 | 7 | 5 | 12 | 33 | 11 |
| 8 ~ 9 hrs | 17 | 4 | 21 | 16 | 7 | 23 | 44 | 15 |
| 6 hrs > | 21 | 6 | 27 | 18 | 33 | 51 | 78 | 26 |
| Total | 60 | 15 | 75 | 49 | 47 | 96 | 171 | 57 |

Source : MWR Water Supply Schemes Operation Status (1997)

The reasons for these restrictions are: (i) obsolete and malfunctioning facilities, (ii) improper attendance by operation and maintenance staff, (iii) saving of chemicals and fuels, and suspension of electric power supply, and (iv) decrease in river discharge or borehole/dug well production.

Intermittent and unreliable water supply causes inconvenience for customers. Various sectors of the economy are seriously affected, including dairy processing, leather factories, restaurants, hotels, health care facilities, etc.

Provided that there are sufficient water resources available, the scheme could be restored to its original function by rehabilitation. Effective rehabilitation will increase water production and supply areas could be accordingly expanded.

MWR currently lays stress on urgent implementation of the rehabilitation plan. Because of this and the recent damage caused by El Nino phenomena.

### 4.4.2 Flow Control and Metering System

To ensure sustainable development of the schemes, metering, billing, and bill collection are most important aspects of the water supply. The survey done by the Team indicates that a lack of effective metering system is causing an extraordinary low efficiency of accounted-for water (AFW).

To attain accountability of the schemes, functional metering system and flow control are indispensable.

(1) Flow Control

Master meters are normally installed at treatment works or pump stations for measurement of water production and distribution. Only a few schemes, however, have functional mater meters whereas the majority of the schemes have malfunctioning meters or none at all. Once meters are broken, they are usually left without repair. Therefore, effective flow control to reduce wastage, minimise water losses, and to operate storage reservoirs cannot be achieved at present.

(2) Metering

The Government's policy and strategy toward metering system accelerated customer meter installation. There are still many schemes (about 40% of all schemes) that have flat rate tariffs due to a lack of customer meters. Meter installation is urgently required to normalise water supply operation and management at all schemes.

### 4.4.3 Water Quality Control

Water quality control is hardly recognised in most schemes. In addition, no routine testing is being done. When raw water is rather clean in dry season, no chemical is added. This is done according to operators' decision. Due to a lack of finds, many treatment works can hardly afford to procure and add chemicals to ensure safety of produced water. Unknown quality of water is being supplied to consumers. This is seen particularly in small scale community based water supply schemes.

### 4.4.4 Laboratory Testing

Major urban water supply schemes have their own laboratory and test water quality on turdidity, conductivity, pH and residual chlorine and Jar-test to manage the appropriate chemical dosing and the treatment process. Test apparatus are in general few and defective. It is recommended that simple test apparatus, at least turbidity, colour and residual chlorine and Jar-test equipment be provided immediately to maintain the water quality at the required minimum level so that any inconvenience due to degraded water quality could be eliminated.

## 4.5 Typical Organisation and Staffing for Operation and Maintenance

### 4.5.1 Typical Operation and Maintenance Organisation

The overall administration of water supply sector in Kenya is reported and discussed in Section 3.3 of this report. Apart from the issues identified at a national level, there are a number of practical operation and maintenance issues at a field level. The water and sewerage departments of Nakuru municipality are typical and its organisation chart is shown in **Figure - 4.5.1.**

The department is divided into a number of sections and a Water Superintendent is practically responsible for operation and maintenance of the Water Supply System in the municipal area, though the municipality purchases the water in bulk from NWCPC. Meter reading, billing, and collection are under the responsibility of a Deputy General Manager, Finance.

### 4.5.2 Staffing for Operation and Maintenance

In general, it appears that staffing for operation and maintenance is not adequately provided. This is one of the reasons that many of water supply systems are run inappropriately and it accelerates the deterioration of facilities. This situation is true for Nakuru municipality. The actual physical operation and maintenance have been done only by three staff (water superintendent, water technical production and foreman for borehole pumps), and 20 staff are working for meter reading, billing and collection. The general manager says that the department is suffering from acute shortage of staffing and accordingly there is not only a lack of proper operation and maintenance of the facilities but also problems in collecting water charges effectively and rationally.

In general, operation and maintenance staff work a three-shift system. The number of experienced staff is very limited and normally only one operator, is assigned for system operation and supported by unskilled labour. Effective operation could be hardly achieved.

### 4.5.3 Staff Training

Staff is not periodical trained for operation and maintenance of treatment works other than short term training for assignment of new staff. Most DWO don't supervise treatment process and involve in operation and maintenance of treatment works and pump station. It is recommended that periodical training shall be done to upgrade technical skill of staff so that more efficient and effective system operation can be achieved and safe water supply served.

## 4.6 Operation and Maintenance Expenditure

The revenue collection and budget allocation for MWR projects are reported in Section 3.5 of this report. It is, however, not possible to collect more detailed data as to revenue and expenditure for operation and maintenance for the entire water supply scheme and/or service area, while it is commonly known that every project and/or service area are actually facing habitual financial constraint.

As an example, the financial situation of Nakuru municipality is referred to as shown in the table below:

Revenue and Expenditure of Nakuru WSD

| Description | 1989/90 | | 1990/91 | | 1991/92 | | 1992/93 | | 1993/94 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Amount (Kshs $10^3$) | Share (%) | Amount (Kshs $10^3$) | Share (%) | Amount (Kshs $10^3$) | Share (%) | Amount (Kshs $10^3$) | Share (%) | Amount (Kshs $10^3$) | Share (%) |
| Whole Council | | | | | | | | | | |
| Revenue | 4,891.8 | 100.0 | 4,593.1 | 100.0 | 5,177.8 | 100.0 | 7,367.7 | 100.0 | 9,423.3 | 100.0 |
| Expenditure | 4,144.8 | 100.0 | 5,182.1 | 100.0 | 5,647.3 | 100.0 | 7,250.1 | 100.0 | 9,097.8 | 100.0 |
| Water Supply | | | | | | | | | | |
| Revenue | 749.8 | 15.3 | 608.9 | 13.3 | 151.0 | 2.9 | 1,075.1 | 14.6 | 1,700.8 | 18.0 |
| Expenditure | 700.3 | 16.9 | 859.2 | 16.6 | 932.7 | 16.5 | 1,040.6 | 14.4 | 1,761.2 | 19.4 |
| Sewerage | | | | | | | | | | |
| Revenue | 386.6 | 7.9 | 341.7 | 6.9 | 355.6 | 6.9 | 644.5 | 8.7 | 874.6 | 9.3 |
| Expenditure | 167.1 | 4.0 | 253.0 | 4.9 | 212.8 | 3.8 | 246.9 | 3.4 | 296.3 | 3.3 |

Both revenue and expenditure in water supply are actually increasing year after year. However, approximately 60% of the annual expenditure is spent for salary costs of staff. Nakuru Municipality actually suffered from shortage of water for several months due to a break down of borehole pumps in 1997. This could have been avoided if sufficient financial support had been secured.

## 4.7 Summary of Problems and Constraints of Existing Water Supply Schemes

Through the review of the Water Supply Sector Survey, available data and information from the government authorities concerned, and field reconnaissance by the Study Team, a number of constraints and problems were identified as summarised below:

(1) The water supply sector is one of the strategic infrastructures in view of achieving the national development target and plan and so far a large number of the urban and water supply projects have been realised by the government organisations, NGOs, and communities. Unfortunately, there is no inventory of such projects and features of the projects are incomplete in most cases. To proceed with water supply project planning and bring into effect rational and efficient management of the completed projects, it is strongly recommended to build-up a database as a part of NAWARD.

(2) A large number of the existing water supply projects have been deteriorated and damaged to a great extent by adverse effects of the El Nino weather phenomena, reducing water supply and causing intermittent operation of the waterworks. MWR places great importance on implementation of rehabilitation works of such projects.

(3) A large number of urban and rural water supply projects are inevitably forced to reduce operation due to deterioration of facilities, financial constraints, lack of storage capacity of service reservoir, and lack and incompetence of operation and maintenance staff. It is obvious that a 24-hour continuous operation could be successfully achieved, provided such constraints and problems are eliminated, and this would increase water production. Therefore, adequate measures to eliminate the constraints and problem are recommended to be taken immediately.

(4) It appears that many water undertakers are also facing human resources and financial constraints. These are also accelerating deterioration of the facilities and reducing revenue collection.

(5) The quality of water produced is far from satisfactory for the consumer. In association with intermittent water supply, this will negatively effect various sectors of Kenyan economy and public hygiene.

(6) In general, the rate of un-accounted for water is very high, probably more than 40% on will average, owing mainly to lack of flow control and metering. A reduction of this rate greatly improve the financial situation of water undertakers concerned. Leakage control and metering campaign should precede future development activity.

(7) Rural population are, in general, spending a long time every day, especially during a dry period for water fetching. Women and children are normally and traditionally engaging in such severe water fetching. It is absolutely necessary to provide safe water within a reasonable distance of habitats, so that women and childrens can contribute to other development activities.

# CHAPTER 5 PRESENT SANITATION CONDITIONS

## 5.1 Existing Sanitation Systems and Population Served

### 5.1.1 Domestic Sewerage

Relatively little information exists on the state of sewerage development and sanitation practices in Kenya's urban centres. Statistics are available from only two sources:

1) 1989 Census providing figures on total urban populations by type of sanitation.
2) Welfare Monitoring Report II providing statistics on accessibility to sanitation by type.

In 1995, a JICA expert (Mr. Morita) was seconded to MWR. He compiled the first ever inventory of the sewerage schemes in operation for each urban centre in Kenya. The inventory describes the treatment facilities process and capacity, and assesses their condition. Hpwever, estimates of sewer coverage are incomplete.

To provide a better picture of the current status of sewerage development and conditions 30 existing sewerage schemes in 26 urban centres were investigated (the Sewerage Sector Survey).

All large population centres have (>100,000) some form of waterborne sewerage; however, most urban centres with a population less than 20,000 have no sewerage systems as summarised below:

Provision of Sewerage System in Urban Centres

| Population Range (000's) | No. of Urban Centres with Sewerage | No. of Urban Centres without Sewerage | Total |
|---|---|---|---|
| 300 < P | 2 | 0 | 2 |
| 300 > P > 100 | 8 | 0 | 8 |
| 20 < P < 100 | 16 | 8 | 24 |
| P < 20 | 4 | 177 | 181 |
| Total | 30 | 185 | 215 |

Source: Aftercare Study Team

The percentage of the population in each urban centre connected to sewerage ranges from 5 to 70% as shown below:

Urban Centres by Sewerage Connection Ratio

| Sewered Population Range (%) | Urban Centres | Number of Urban Centres in Group |
|---|---|---|
| 0-10 | Ngong, Machakos, Meru, Voi, Isiolo | 5 |
| 10-20 | Bungoma, Webuye, Busia, Embu, Kisii, Mombasa, Kapsabet, Homa Bay | 8 |
| 20-30 | Nyeri, Athi River | 2 |
| 30-40 | Eldoret, Kiambu, Nyahururu, Muranga | 4 |
| 40-50 | Nanyuki, Nairobi, Naivasha, Kitale, Kakamega | 5 |
| 50-60 | Kericho, Kisumu, Nakuru Thika | 4 |
| 60-70 | Limuru, Karatina | 2 |
| Total | | 30 |

Source: Aftercare Study Team

There is no definite relationship between population size and service ratio, but in general larger urban centres have inadequate service coverage.

It is estimated for 1998 that existing sewerage systems serve approximately 1.8 million people or 28% of the total urban population of 6.5 million. This leaves an estimated 4.7 million urban dwellers (72%) without the benefits or convenience of waterborne sanitation connected to a public sewer system. The population connected to sewers in each urban centre is presented in **Table - 5.1.1**.

### 5.1.2 On-site Sanitation

A Household Survey (see section 1.5) of 756 households in 39 urban centres obtained information on water use, sanitation practices and living conditions. In addition, a separate on-plot sanitation survey was done for 50 households in 5 urban centres where there are currently no sewerage facilities (Garissa, Malindi, Maragua, Mumias, and Wajir). The survey methodology and results are presented in the Data Book.

Results of the household surveys indicate that access to sanitation in 1998 has probably not improved much from the figures reported in the Welfare Monitoring Survey II and the 1989 Census. A rather high 46.6% of the urban population surveyed reported using pit latrines, while 47.1% reported access to waterborne facilities such as pour flush or cistern toilets.

It is difficult to make any firm conclusions from the results of the survey because the sample size is small. However, the following general observations can be made:

1) Water related diseases are prevalent in areas where shallow wells are the major source of drinking water.
2) About half of the people who receive piped water supply use pit latrine for sanitation indicating a large percentage of the population disposes of untreated wastewater to the environment.

(3) Latrines are rarely de-sludged and in several areas are prone to flooding and overflow during extended periods of wet weather.

Approximately 23% of the total urban population use waterborne toilet facilities connected to a septic tank or cesspool. Most septic tanks are concrete structures of various designs with effluent from the tank discharged into a soak-away pit or drainage tiles. These installations are suitable only in cases where the ground is permeable and where there is no danger of contaminating supplies.

Septic tank installations in Mombasa, Kilifi, Malindi, and Lamu are polluting groundwater supplies because the soak-away pits are usually dug down to the ground water table, the same water that is used to supplement piped water supplies during periods of rationing.

Sullage is domestic wastewater that has been used for washing or in food preparation. Generally in Kenya, sullage is discharged onto the ground or drained into shallow ditches or surface water drains. It is estimated that at least 85% of the urban population has a piped water supply. In sharp contrast only 28% of the urban population has a sewer connection. The obvious conclusion is that disposal of untreated wastewater into the urban environment is widespread creating a potentially serious health hazard as well as being a source of pollution.

### 5.1.3 Industrial Wastewater Disposal

The existing situation on industrial wastewater in Kenya is not well documented. There is very little data available on the number of industries in Kenya or the amounts of water used, treated and discharged. In general where public sewerage systems exist, industries usually discharge their effluents into the sewers. In most cases however, wastewater is discharged without pre-treatment into nearby watercourses. Enforcement of the National Trade Effluent Standards is the responsibility of each local authority. Sadly enforcement is non-existent because LAs are crippled by a lack of resources to inspect industries, monitor, collect and analyse data.

The GOK Sessional Paper No. 2 of 1996 "Industrial Transformation to the Year 2000" targets growth of highly capital intensive and heavy industries to achieve double-digit growth rates of 12 to 15%. This high growth rate, if it is achieved, will have serious implications for the water supply and sewerage sectors. The continued/uncontrolled disposal of industrial wastewater could degrade the water environment around large urban centres, and could seriously jeopardise the quality of drinking water supplies in the near future, making it difficult to treat and provide safe potable water.

## 5.2 Physical Condition of Sewerage Systems

### 5.2.1 General Features of Urban Sewerage Schemes

The Sewerage Sector Survey produced an inventory of sewerage infrastructure and assessed physical conditions in each of 26 urban centres. Information on the facilities in another 4 urban centres namely; Kisumu, Meru, Isiolo, Nakuru was obtained from recent JICA studies. A summary of urban sewerage schemes is provided in **Table - 5.2.1**. The data sheets located in the Data Book provide a physical description for each sewerage facility as well as observations on operation and maintenance, and rehabilitation needs. Sewerage schemes exist in 30 urban centres. Some urban centres have more than one sewage treatment works bringing the total number of treatment facilities to 38.

### 5.2.2 Sewer Reticulation

Unfortunately, Local Authorities surveyed in the Study provided very little information on the physical condition of sewer reticulation making it impossible to comment on actual sewer conditions and rehabilitation needs. Information is generally not available because sewer operators lack the sewer inspection programmees that are needed to collect the data. In fact most authorities do not even have accurate sewer inventories to identify pipe size, age, and location.

Most sanitary sewers are separate from storm water drainage facilities. In practice, however, surface water finds its way into most sanitary sewers and these operate more like combined sewers except no provision is made for relieving wet weather flows. The entry of storm water into sewers is uncontrolled and during wet weather contributes to frequent overflow of sewage out of manholes, and flooding of treatment works.

Newly constructed sewers (last ten years) are generally in good working order despite a general lack of preventative maintenance such as regular cleaning and inspection. New sewers are generally designed to achieve self-cleansing velocities based on projected existing wastewater flows. In addition, trunk sewers are usually oversized to provide spare capacity for future flows. Unfortunately, in many cases projected wastewater flows have not materialised because of water rationing or the unwillingness of consumers to connect to sewers. As a result, flows are too low to provide self-cleansing velocities. Low flows lead to operating problems such as accumulation of sedimentation, which reduces hydraulic capacity, and septic sewage, which causes pipe corrosion and treatment process difficulties.

The vast majority of sewers were constructed in the 1950s, 1960s, and 1970s, and have never been inspected. Local experience indicates that many are in poor structural condition. In several urban centres the trunk sewers installed in central areas over twenty years ago are only 150 mm in diameter. Development has exceeded the available hydraulic capacity of older sewers resulting in frequent blockages, overflows, and surface flooding.

The newly constructed sewers are generally in good working order and not overloaded. The sewers that were installed in the 1950s and 1960s are generally overloaded and many require replacement because they have collapsed, or have insufficient hydraulic capacity.

The average installed length per capita is 1.14 m. This value is low and indicates poor service coverage. This conclusion is also supported by the large number of persons per sewer connection in most urban centres.

Persons per Sewer Connection

| Range of Persons per Sewer Connection | Urban Centres | Number of Urban Centres |
|---|---|---|
| 0-10 | Webuye, Embu, Nnong, Kakamega, Limuru, Machakos, Homa Bay | 7 |
| 10-20 | Busia, Kiambu, Thika, Nanyuki, Nyahururu, Naivasha, Nyeri, Eldoret | 8 |
| 20-30 | Kisii, Kitale, Muranga | 3 |
| 30-40 | Kapsabet, Athi River | 2 |
| Over 40 | Bungoma, Kericho | 2 |
| Total | | 22 |

Source: The Aftercare Study Team

### 5.2.3 Wastewater Treatment Facilities

Based on existing information gathered during the Study it would appear that sewerage systems where they exist are designed with the intent of treating all the sewage that is collected. Of course there are conditions where overflows to the environment occur but in general most sewage flows to a treatment facility.

Waste stabilisation ponds are used in 25 out of 38 sewage treatment works. These generally operate problem free with the exception that most of the older ponds are filling with sludge and vegetation, which generally reduces retention times and thus treatment efficiency. The remaining treatment works use conventional processes such as biological attached growth filters, oxidation ditches, or aerated lagoons sometimes combined with maturation ponds to polish effluent and reduce fecal coliforms.

Per capita flow is relatively low and in many cases is insufficient for the proper operation of sewers. The sewage received at various treatment works varies widely from 23 to 628 litres per capita per day.

The per capita flow in seven urban centres is below 75 litres per day, which is the minimum acceptable flow required to keep sewers functional. This low flow can be explained in most cases by low per capita water consumption due to inadequate water supply systems.

In a few cases the quantities of water returned to the treatment works are larger than the quantities consumed. This is probably an indication of high levels of groundwater infiltration and/or industries that have their own source of water but discharge to the sewers.

The urban centres where water supply conditions appear to be unable to support waterborne sewerage and systems that appear to suffer from high inflow and infiltration are identified below:

Sewage Flow Characteristics

| Sewage Flow < 75 lpcd | |
|---|---|
| Water supply > than 100 lpcd | Water supply < 100 lpcd |
| Busia, Isiolo, Kitale, Nakuru, Nyeri, Voi | Bungoma, Homa Bay, Kericho, Mombasa, Naivasha |
| A high proportion of the water that is supplied is not returned to the sewer probably indicating high UFW. | Water supply conditions are inadequate to support waterborne sewerage system. |
| Sewage Flow > Amount of Water Supplied | |
| Machakos, Nyahururu, Nanyuki | |
| High levels of infiltration or contributions from sources that have private water supplies. | |

Source: The Aftercare Study Team

Most of the recently constructed sewage works are operating far below their design capacity. The low flow rates can be attributed to: (i) low rate of sewer connections, and (ii) inadequate water supply systems resulting in low per capita water consumption.

The older treatment works (1980's) are generally hydraulically and organically overloaded, a condition attributed to: (i) Population growth beyond design capacity, (ii) Reduction in designed treatment capacity due to sludge accumulation or mechanical failure of the process, (iii) Aging sewer reticulation resulting in more infiltration of ground and surface water.

Status of Treatment Works

| Status | Urban Centre | Number |
|---|---|---|
| Overloaded | Embu, Homa Bay, Kisumu conventional, Meru, Machakos, Mombasa (both), Nanyuki, Ngnong, Nyahururu, Nairobi (both), Eldoret (both), Thika | 15 |
| Operating at design capacity | Busia, Kapsabet, Kakamega (both), Karatina, Kericho, | 6 |
| Not Operating | Limuru, Voi, | 2 |
| Operating below capacity | Athi River, Bungoma, Isiolo, Kiambu, Kisii, , Kisumu ponds, Kitale (both), Muranga, Naivasha, Nyeri (both), Nakuru (both), Webuye | 15 |

Source: The Aftercare Study Team

### 5.2.4 Treatment Works Performance and Surface Water Quality

The Water Pollution Control Section (WPCS) of MWR is the body responsible for setting of effluent standards that are required for the discharge of effluents to a watercourse. The National Effluent Standards for the direct discharge of an effluent into a watercourse are shown in **Table - 5.2.2.** The National Standard for discharge to a receiving stream specifies two main effluent parameters that must be considered in the design of sewage treatment works:

1) $BOD_5$ not to exceed 20 mg/ℓ, and
2) Fecal coliform not to exceed 5,000 MPN per 100 mℓ.

More specific standards are developed as the need arises for discharges from various agriculture, industrial, and commercial sources of wastewater to public sewers and watercourses.

Since Local Authorities own and operate sewage treatment works, they have the legal responsibility to ensure that effluent from the treatment works complies with those standards. Most LAs have, therefore, adopted the National Standard into their local bylaws.

A limited sampling programme of wastewater treatment plants throughout Kenya was done in January 1998 as part of the Sewerage Sector Survey. One sample was taken of the influent and effluent at 26 sewage treatment works. Results are provided in Supporting Report IV and effluent parameters are summarised below:

Statistics on Sampling of Effluent Parameters

(unit: mg/ℓ)

| Item | TN | SS | BOD | COD |
|---|---|---|---|---|
| Maximum | 197 | 1170 | 460 | 633 |
| Minimum | 5.2 | 20 | 12.5 | 80 |
| Average | 22 | 351 | 99 | 223 |

Source: The Aftercare Study Team

(1) Influent BOD

On average the influent BOD is strong at most treatment works indicating that individual water consumption is low. The samples obtained at the treatment works ranged from 875 mg/ℓ to 200 mg/ℓ. The average of 26 samples taken at different treatment plants is 480 mg/ℓ and is close to the value of 550 mg/ℓ often used in Kenya.

The estimated BOD per capita varies tremendously from 13 grams/day to 134 grams/day. The normal range in Kenya is 48 to 60 g/c/day with a value of 50 g/c/day used in design. No conclusions can be drawn from these results.

(2) Performance of the Treatment Works - BOD Removal

Only two treatment works, Bungoma and Kapsabet meet the required National Standard of 20 mg/ℓ BOD.

(3) COD

The BOD/COD ratio is an indicator of the biodegradability of the wastewater. Domestic wastewater is highly degradable with a typical ratio of 0.4 to 0.8. A comparison of data available for 27 facilities indicates that 9 facilities had a ratio greater than 0.5 indicating high organic content. The majority of treatment works had low ratios indicating high levels of non-degradable industrial wastes or acute water shortages causing biologically degradable solids to settle in sewers.

COD values ranged from medium to strong indicating that there is potentially a large component of industrial or toxic liquid waste being discharged into public sewers. Effluent COD's in all cases exceed standards.

(4) Performance of the Treatment Works – Pathogen Removal

The level of fecal coliform is an indicator of the amount of pathogenic organisms in the wastewater. The results of the survey ranged between 0 to 1,275 MPN per 100 mℓ of sample indicating that most treatment works are effective at reducing coliform counts. Only two treatment works exceed 1,000 MPN per 100 mℓ: Homa Bay and Kariobangi (Nairobi). In Kariobangi's case there are no maturation ponds and the high fecal counts are expected. In Homa Bay the treatment works have maturation ponds but the facility is hydraulically overloaded probably because of high storm water flows and accumulation of sludge.

(5) Receiving Streams

Samples were taken at 20 treatment facilities, upstream and downstream of the discharge point in order to gain a very crude measure of surface water quality issues. In 9 cases, the BOD of the receiving watercourse upstream of the treatment plant was higher than the effluent standard of 20 mg/ℓ indicating a serious surface water quality problem from other sources of pollution upstream. Samples of the Nairobi River taken upstream of the Dandora treatment works had BOD values that are similar to those of strong sewage. At 10 treatment works, the BOD downstream of the treatment plant was lower than the BOD upstream. This result appears to indicate that the effluent is contributing a significant amount of flow and diluting the natural watercourse.

### 5.2.5 Treated Water Disposal

In Kenya all treatment plant effluent is discharged into an inland stream or lake except for Mombasa where uncontrolled and untreated sewage is discharged into the ocean. Two urban centres (Kisumu and Homa Bay) discharge high BOD and nutrient rich waste directly into Lake Victoria. Treatment works in Nakuru and Naivasha discharge treated effluent into the sensitive eco-systems of Lakes Nakuru and Lake Naivasha.

The use of treatment plant effluent for agriculture/irrigation is not documented but is likely not widespread, occurring informally in a few isolated cases. In Nairobi there have been reported cases of diverting raw wastewater before it reaches the treatment plant for agriculture/irrigation .

### 5.2.6 Sludge Treatment and Disposal

De-sludging of ponds is rarely done and, as observed during the surveys most ponds are in desperate need of relief. The local authorities concerned have indicated that they do not have the required equipment such as sludge pumps. Where ponds are de-sludged, the sludge is normally dumped on the ground within the site and left to dry before being hauled to a disposal site.

Conventional treatment works generate much larger volumes of sludge than ponds. Sludge from conventional treatment works is normally not stable; therefore, it needs to be treated before disposal. The conventional works surveyed had digester facilities although some are not operating properly because of mechanical equipment failures. After it has been treated, digested sludge is usually sent to drying beds and then sold to farmers for agricultural use.

Septage from septic tanks and cesspools are removed infrequently and usually only when the tank is full and upsets the plumbing.

Sludge from septic tanks (septage) is normally removed by the Local Authority or by private operators using vacuum trucks. Tanks are de-sludged infrequently because service is unreliable, infrequent and the costs charged by private commercial companies is high (typically in the range of Kshs 3,000 to 5,000 per trip).

The disposal of septage is unregulated and often in a nearby drainage ditch, garbage dump, field, or where they exist at sewage treatment facilities. Most municipalities own at least one vacuum truck but in many cases it is old and often out of service. The uncontrolled collection and discharge of sludge is a health hazard and damaging to the environment.

## 5.3 Operation and Maintenance Practice

### 5.3.1 General Observations

Operation and maintenance practices vary widely from one urban centre to the next depending on the level of funding available, management, and staffing. It is observed that the following critical maintenance functions are currently not performed:

1) Inspection of sewers from the inside to determine physical conditions and maintenance needs
2) Assessment of sewer rehabilitation and replacement needs
3) Flow monitoring and sampling to identify planning and design criteria, and problems such as infiltration in leaking sewers
4) Routine cleaning and flushing to maintain hydraulic capacity and prevent foul odours and conditions that lead to corrosion
5) Preventive maintenance to mechanical and electrical components to minimise equipment failure and prevent the overflow of raw sewage to the environment
6) Monitoring and control of treatment process parameters to provide effective treatment

In several urban centres, sewerage systems are generally working below capacity due to water rationing, a condition that results in blocking of sewers and poor performance of treatment facilities.

Preventive sewer maintenance generally poor, and in many cases non-existent. Maintenance usually consists of clearing blockages, which occur frequently because of the many small 150 mm trunk sewers.

Sewers are not inspected or cleaned on a regular basis and there appears to be no effort to prevent conditions that will eventually lead to more serious and costly maintenance problems. There appears to be no awareness (or perhaps willingness) among sewer system managers that protecting existing investments with proper maintenance is in the long term less costly than replacement. With the exception of newer facilities (last ten years), most sewage treatment facilities have either fallen into serious disrepair or are non-operational and beyond repair.

Maintenance requirements for waste stabilisation ponds are very simple however they are neglected at most facilities. Although the treatment process is not immediately affected the pond environment will suffer, leading to odours, flies and mosquitoes.

There is a lack of process control and monitoring at most conventional treatment works. These treatment plants require constant monitoring and process adjustments in order to provide intended performance. The higher costs of more advanced treatment processes is difficult to justify when effluent quality is less than or equal to what can be achieved with lower cost technologies.

### 5.3.2 Tools and Equipment

The following list of general observations is compiled from discussions with superintendents at a number of Local Authorities:

1) In general vehicles for moving around town are unavailable, and the number of staff outweighs the number of vehicles.
2) Sewer cleaning equipment breaks down often and sometimes has to be borrowed from a neighbouring urban centre.
3) Small tools for removing obstructions are generally available but larger sewer cleaning equipment for dredging sediments out of sewers are not available.
4) Pumping equipment for by-passing sewers during repairs are not available or not used.
5) Trucks and heavy equipment required for repair of mains are generally too few to support the number of work crews.
6) Most local authorities do not have sludge pumps for cleaning ponds. The MWR has one pump that is always on loan.

## 5.4 Typical Organisation and Staffing for Operation and Maintenance

### 5.4.1 Typical Operation and Maintenance Organisation

Organisational charts showing the number of skilled and unskilled workers for each urban centre surveyed are shown in the Data Book. Unfortunately Mombasa and Nairobi did not provide the information requested.

Generally speaking, operations and maintenance is usually organised in one department under the direction of the Town or Municipal Engineer. A superintendent reporting to the engineer usually oversees actual day to day operation of the treatment works and sewer system. Where there is more than one treatment works then each treatment works will have its own maintenance staff and one foreman or superintendent in charge of operations. Sewer maintenance is usually organised under the treatment works superintendent and work crews are responsible for the sewers in the drainage areas that flow to the treatment works. Depending on the size of the operation, one or more foremen are involved in direct supervision of the maintenance work crews.

A typical organisational structure is shown in **Figure - 5.4.1**. Conventional treatment works usually require some form of process control and most often will have a technical group providing sampling and laboratory analysis of influent and effluent.

### 5.4.2 Staffing for Operation and Maintenance

Staffing levels in general are proportional to the size of the population served and for the urban centres surveyed varied from 0.2 to 3.1 workers per 1,000 persons connected with an average of 1.1 per 1,000. In general, smaller facilities tend to have a higher ratio because a minimum number of workers is required for maintenance regardless of how small the population is.

Staffing levels appear to be adequate in most cases where treatment is provided by waste stabilisation ponds but are inadequate at large conventional treatment works and in larger collection systems where pump stations are operated, especially in the numbers of skilled operators, mechanics and electricians. In all cases there appears to be an insufficient number of labourers involved in sewer maintenance (see **Figure - 4.5.1** for reference).

There is a lack of trained operators and process monitoring at most conventional treatment works which require constant monitoring and adjustment to process parameters to provide effective and efficient treatment.

## 5.5 Operation and Maintenance Expenditure and Financial Resources

In most local authorities there is a lack of revenue to support the on-going operation and maintenance of sewerage infrastructure. The Study Team surveyed the financial performance of the urban schemes for the period from 1995 to 1997. Of the 30 urban centres, 15 yielded the necessary data and these results are discussed in the Supporting Report IV. According to the data, only two schemes, Athi River and Nyeri have given a reasonable contribution to asset management having spent a significant amount on operation and maintenance.

Generally, the financial performance of sewerage schemes varies considerably depending on the success of the water supply system and the cost of operation and maintenance, which varies according to the type of technology used for treatment. Some schemes such as Kericho, Nyeri and Athi River appear to gain more than the costs of operation and maintenance, whereas others such as Mombasa are reported to be making large losses with little hope of becoming financially viable under current conditions. Few, if any, are yet financially viable in being able to recover the costs of operation and maintenance, depreciation and a contribution to reserves.

The sewer surcharge is normally set as a percentage of the water tariff (usually 50%) regardless of the actual cost of providing the services. At present, progressively less revenue is collected to pay for sewerage, as more people become dissatisfied with the water supply services in some municipalities. The viability of providing sewerage operations is very largely dependent on the good management of the water supply system and the extent to which water can be delivered to satisfied consumers who will pay their water bills (and therefore sewerage charges).

## 5.6 Summary of Problems and Constraints of Existing Sewerage Schemes

The population is growing at an alarming rate, exerting pressure on existing water and sewage infrastructure and the environment.

Most sewerage facilities have fallen into a serious state of disrepair. The need for rehabilitation and increased sewerage services is urgent to reduce health risks and environmental contamination. Major constraints/problems to the sustainable operation and maintenance of sewerage facilities are identified as follows:

(1) Insufficient operating revenue to support operation and maintenance

Low revenue contributes to inadequate budgets for operation and maintenance. Insufficient revenue is the principal cause for the serious state of disrepair in most sewerage systems. Low revenue is the result of: i) unaccounted for water due to unmetered consumption; ii) customers unwilling to pay because service levels are inadequate e.g. water rationing; iii) revenue billing and collection that is not well managed; iv) sewer surcharges that are collected by water undertakers but not remitted to sewerage operating authority; v) revenue collected for sewer services that are used to finance other municipal priorities; and vi) tariffs that are too low and do not represent the true cost of providing services.

(2) Facilities difficult to operate and maintain

There is no National standard for the planning and design of sewerage systems. Since most of he infrastructure is funded through donor agencies, foreign consultants carry out much of the planning and design. This has resulted in a wide variety of methods and designs often leading to the selection of inappropriate technology unsuitable for local conditions, difficult and expensive to operate and maintain.

(3) Insufficient water supply for sewer operations

The separation between the operation of sewerage and water services has lead to a serious lack of cooperation to planning and problem solving.
In several cases, conventional sewerage is provided in areas where individual water consumption is too low for proper operation resulting in blocking and in some cases complete failure.

In other cases, water supply systems that were once adequate have deteriorated to the point where water rationing is required. This also results in low wastewater flows and eventually sewage system failures.

(4) Lack of qualified personnel, and inadequate training and development

There is no data to quantify the magnitude of this problem or the reasons for a lack of qualified people. It is likely that there are several contributing factors: i) low pay for sewerage sector workers making it difficult to attract qualified people, ii) the negative stigma associated with sewage partly due to a lack of awareness and cultural acceptability and iii) inadequate education and training programmes.

(5) Inadequate tools, facilities and equipment

At the present time those responsible for sewage disposal are badly handicapped by a lack of transportation, poor office facilities, inadequate tools and equipment.

The situation is the direct result of inadequate operating revenue and can only be corrected by a concentrated effort to improve collection of revenue and subsequently increased spending for sewer operations.

(6) Inadequate preventive maintenance

There are two types of maintenance management: crisis and planned. In crisis management agencies perform repairs and maintenance primarily in response to emergencies. This is common in most systems encountered in Kenya because preventive maintenance is neglected. Crisis management is more costly in the long term because problems tend to get larger with time and eventually facilities must be replaced before their normal life expectancy.

(7) Ineffective control of industrial wastewater discharges

It is anticipated that in the future most industries will discharge their wastewater to public sewer systems instead of directly into the nation's waterways. These discharges may contain significant amounts of toxic pollutants and other substances that can affect the treatment systems and possibly interfere with its performance. Some pollutants may pass unchanged through the treatment process and into receiving streams. The pollutants may enter treatment plant sludge making its disposal difficult and re-use impossible.

If left uncontrolled, industrial pollution of water resources could lead to more costly water supply schemes (more treatment, clean source further away) and health problems with associated costs.

(8) Poor operation of sewerage works

Many treatment works and pumping stations are currently inoperative because mechanical and electrical components have failed or maintenance has been neglected for too long. Other systems are overloaded because the connected population has growth beyond the original design capacity. These two situations result in the disposal of sewage without adequate treatment and many operating problems

Most other treatment works fail to meet effluent standards because there is a lack of process monitoring and control due largely to the lack of procedures and trained operators.

# CHAPTER 6 WATER SUPPLY DEVELOPMENT STRATEGY

## 6.1 Development Target and Strategy

### 6.1.1 Development Objectives and Strategy

The 8th National Development Plan attempts to push industrial development in the coming period from 1997 to 2001 by achieving rapid and sustained economic growth. The Plan addresses that adequate and reliable supply of clean water is an essential requirement not only for industrial establishment but for all sectors of the economy. It also addresses an urgent need of review of NWMP with a view to many water supply projects currently suffering from serious financial, technical and managerial problems.

It further recommends the continued effort by MWR to implement a comprehensive plan for the rehabilitation and extension of existing water supply schemes with a view to ensuring sustainable water projects and the development of water resources by the various stakeholders.

Water is precious assets for all nationals. For their daily lives, safe and potable water supply is minimum requirements. Adequate supply also accelerates development of all fields of industry and commerce. This Study on water supply development plan will focus on the following development objectives:

(1) Improvement of Public Health

In the past decades, more emphasis was given to needs of quantity rather than quality in planning water supply schemes. According to the household surveys conducted in the current and previous studies by JICA, public health is in a crucial situation and many people are suffering from the water borne diseases. Provision of piped water was not effective as intended for improving public health in Kenya. The current study focuses on providing safe and potable water to all nationals by rehabilitation and development of new schemes. If all works proposed in the present report are successfully implemented, public health will be significantly improved. People will enjoy safe and clean water from their taps and water points nearby.

(2) Development of Industry and Commerce

Deferred augmentation of water supply schemes, despite their urgent needs, hindered the development of commerce and industry in the past. Water dependent industry such as agro-processing industry are in a crucial situation resulting from the lack of rational water resource management and control. Provision of water with sufficient quantity to all industry and commerce in a proper manner will enhance these activities in the country.

(3) Tourism Industry

In relation to the above, the most suffering industry may be tourism. This industry particularly in Coastal Province is adversely affected by chronic water shortage. If the planned schemes are successfully implemented, it will immediately solve the long-term pending issue by providing clean and safe water on continuous basis.

(4) Relief of Women and Children from Heavy Tasks

According to the Welfare Monitoring Survey II, more than 40% of population residing in Marsabit and Makueni districts are spending two hours or more fetching water. These tasks are usually done by women and children. If the communal water points and water pans are constructed in the vicinity of their residence, they will be immediately relieved from their heavy tasks.

### 6.1.2 Target Areas

Target areas of the current Study are 141 urban centres for urban water supply development and the remaining rural areas for rural water supply development. The rural water supply will be formulated on a basis of district and the number of districts is 50.

The 1989 Census identified 215 urban centres in the country as is discussed in Section 2.6. Some of these urban centres are small in population. From water supply engineering points of view, it might be allowed to cluster these centres into two in terms of population size: large urban centres, which have projected population more than 5,000 by the year 2010 and small centres with less population. These large centres are target areas for urban water supply scheme development.

The rural water supply schemes are those developed in sparsely populated areas, including small urban centres and the vast rural areas spread throughout the country. Therefore, areas other than the above 141 urban centres are target areas for rural water supply development.

The present report endeavours to discuss water supply planning on scheme basis as far as possible. As of 1996, thousands of small scale community based schemes have been constructed and in operation. Reliable technical and operational data are not available for such schemes. Accordingly, rural water supply development plan will be worked out on district basis.

### 6.1.3 Planning Horizon

All schemes under the Study in principle shall have a planning horizon year 2010. In the course of the Study, however, some may be justified more practical to defer their implementation beyond 2010.

### 6.1.4 Planning Target and Fundamental Concept

In planning water supply schemes in urban and rural areas, the following targets and concept are developed.

(1) Planning Target

NWMP, in line with the 1989 - 1993 Five Year National Development Plan then effective, adopted a target of providing safe and potable water within a reasonable distance to all the population by the year 2010. In the current review, more moderate targets are set up to formulate water supply development plan in Kenya as follows;

1) Target service coverage and population

It is assumed that the current 90% service coverage in urban centre will increase to 95% at the year 2010. In the rural area, the present 35% service coverage will increase to 70% at the year 2010. Major target population in rural areas are those who do not have any access to safe water and are spending many hours for collecting water. If they are successfully implemented, overall service coverage in the country will attain the 80% from the present 50%.

2) Target accounted-for-water (AFW) ratio

All water supply schemes shall have a certain level of accounted-for-water ratio (AFW), preferably over 70%. This target ratio will be achieved by each scheme by the year 2010.

(2) Fundamental Concepts

To ensure sustainable development of the schemes, the following fundamental concepts are worked out:

1) Maximum utilisation of the existing schemes

Many water supply schemes in operation are suffering from decreased production, far less than the design capacity originally intended. To achieve maximum utilisation of the treatment works constructed, it is proposed to implement rehabilitation works at the earliest stage of the project development.

2) Appropriate technology

Minimum use of mechanical and electrical equipment that requires special skills for operation and maintenance in planning water treatment and distribution. Gravity supplies are proposed, pumping being limited to areas where it requires.

3) Cost effectiveness

Through cost analyses of the proposed plans, the current Study seeks most cost effective solution to achieve the above target.

4) Universal metering

All individual and non-individual connections will be metered and water tariff will be levied on the basis of water consumption. In case of small scale water supply like community self-help schemes in rural areas, a flat rate tariff might be allowed although metering system is recommended. Water tariff applied, however, shall be high enough to balance costs required for routine operation and maintenance.

5) Safe and potable water

All schemes shall exercise chlorine dosage for disinfection to produce safe and potable water as a minimum requirement.

## 6.2 Population Projection

### 6.2.1 National Population

The framework of the projected population and the distribution by urban-rural area from 1990 to 2010 is summarised in the table below. Details are shown in **Table - 6.2.1.**

Summary of Population Projection, 1990 - 2010

(Unit: million)

| Classification | 1990 | 1990-1995 | 1995 | 1995-2000 | 2000 | 2000-2005 | 2005 | 2005-2010 | 2010 | 1990-2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Projected Population | Annual Average Growth Rate | Projected Population | Annual Average Growth Rate | Projected Population | Annual Average Growth Rate | Projected Population | Annual Average Growth Rate | Projected Population | Annual Average Growth Rate |
| Total Population | 23.7 | 3.0% | 27.52 | 2.5% | 31.18 | 2.1% | 34.55 | 1.6% | 37.40 | 2.3% |
| Urban Population | 4.07<br>(17.2%) | 5.2%<br>- | 5.28<br>(19.2%) | 7.1%<br>- | 7.44<br>(23.9%) | 6.1%<br>- | 10.02<br>(29.0%) | 2.8%<br>- | 11.50<br>(30.7%) | 5.3% |
| Rural Population | 19.63<br>(82.8%) | 2.5%<br>- | 22.24<br>(80.8%) | 1.3%<br>- | 23.74<br>(76.1%) | 0.7%<br>- | 24.53<br>(71.0%) | 1.1%<br>- | 25.90<br>(69.3%) | 1.4% |

Source: Kenyan Population Census 1989, Analytical Report Vol. VII, April 1996
The Eighth National Development Plan 1997 – 2001
Sessional Paper No. 1 of 1994 on Recovery and Sustainable Development to the Year 2010

The annual average growth rate of the total population will go down largely from 3.0% in the years of 1990 to 1995 to 1.6% in the years of 2005 to 2010, finally averaging 2.3% over the years of 1990 to 2010. The decline of the population was considered due to an increase trend of deaths by HIV/AIDS and decrease trend of fertility rates observed in the country.

The total population of the country will reach at 37.5 million by the year 2010. Regarding the distribution by urban-rural area, urban population will have an annual average growth rate at

5.3% from 1990 to 2010 and reach at 11.5 million by the year 2010. The urban population will account for approximately 30% of the total population in 2010. On the other hand, by the year 2010, rural population will annually grow at a low rate of 1.4% on average and reach 25.9 million by the year 2010.

### 6.2.2 Urban Centre Population

Population for 215 urban centres identified in the National Population Census 1989 was projected up to the year 2010 by applying an average growth rate estimated from the population projection of the urban centres in NWMP. Population projection of the urban centres is presented in **Table - 6.2.2.**

The table below summarises the total number and population of the 215 urban centres by population classification for the planning period of 1995 to 2010.

Change of Urban Centres in Number and Population, 1995 – 2010

| Urban Centre Classification | 1995 | | | | 2000 | | | | 2005 | | | | 2010 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Nos. | % | Population | % | Nos. | % | Population | % | Nos. | % | Population | % | Nos. | % | Population | % |
| P>100,000 | 8 | 3.7 | 3,443,145 | 65.2 | 11 | 5.1 | 4,875,027 | 65.5 | 17 | 7.9 | 6,991,321 | 69.8 | 19 | 8.8 | 8,259,428 | 71.8 |
| 20,000<P<100,000 | 24 | 11.2 | 952,454 | 18.0 | 40 | 18.6 | 1,660,206 | 22.3 | 48 | 22.3 | 2,066,895 | 20.6 | 54 | 25.1 | 2,349,672 | 20.4 |
| 5,000<P<20,000 | 60 | 27.9 | 625,460 | 11.8 | 70 | 32.6 | 690,681 | 9.3 | 70 | 32.6 | 740,767 | 7.4 | 68 | 31.6 | 692,421 | 6.0 |
| 1,000<P<5,000 | 87 | 40.5 | 232,308 | 4.4 | 85 | 39.5 | 207,818 | 2.8 | 75 | 34.9 | 207,256 | 2.1 | 71 | 33.0 | 197,267 | 1.7 |
| P<1,000 | 36 | 16.7 | 26,833 | 0.5 | 9 | 4.2 | 6,267 | 0.1 | 5 | 2.3 | 3,964 | 0.0 | 3 | 1.4 | 2,212 | 0.0 |
| Total | 215 | 100.0 | 5,280,000 | 100.0 | 215 | 100.0 | 7,439,999 | 100.0 | 215 | 100.0 | 10,010,001 | 100.0 | 215 | 100.0 | 11,500,000 | 100.0 |

Source: The Aftercare Study Team

It is found that a total population of the urban centres less than 5,000 will go down slightly by the year 2010. Instead, for the urban centres more than 20,000, total population will grow significantly at 6.0% on an annual average. Then, total population of the urban centres between 5,000 and 20,000 will remain at almost the same level both in number and population.

## 6.3 Water Demand Projection

### 6.3.1 Approach to Water Demand Projection

All procedures and methodology applied in NWMP are considered appropriate except in the areas of industrial and livestock water demand projection which may require minor adjustment. Present review, therefore, will be mostly re-calculation based on the latest data available and/or reproduction from the existing reports on water supply development plans in several districts/towns. Working procedures for the water demand forecast is shown in **Figure - 6.3.1.**

In projecting water demand, all water schemes are grouped into three: "Urban Water Supply (UWS)", "Large Scale Rural Water Supply (LSRWS)*" and "Small Scale Rural Water Supply (SSRWS)", in accordance with the criteria set forth in the subsection 4.2.1.

* This includes Medium Scale Rural Water Supply

### 6.3.2 Residential Demand

(1) Population Served at 1995

The estimated water served population in 1995 is presented in **Table - 4.2.2**. Service coverage in Nairobi, Mombasa and Marsabit Districts exceeds 90%, while a number of districts, i.e., Kwale, Tana River, Kitui, Masaku, Nyambene, Thraka Nithi, Mwingi, Makueni, Mandera, Gusii, Siaya, Homa Bay, Migor, Nyamira, Kipsigis, Laikipia, Narok, Trans Nzoia, Bomet, Transmara, Elgeyo Marakwet and West Pokot endure low coverage, less than 50%. The severest situation is seen in Migori, Transmara and Kitui Districts. Coverage achieved in these districts are merely 20% or less.

Population serviced by schemes are estimated at 14.6 million in total, out of which 5.0 million are served by urban water supply schemes, and 9.6 millions by LSRWS and SSRWS. Non-served population is estimated at 12.0 millions.

(2) Population Served at 2010

The present study sets up target, 95% coverage at the urban centre and 70% at the rural areas at the year 2010. For Nairobi, Mombasa, and Marsabit where the present service coverage exceeds the target, the present ratio is set as target value.

The following three methods are generally applied to estimate served population by district and scheme.

1) In case the urban population is very small in comparison with the rural population, urban serviced population is first computed on assumption that it will reach target rate at 2010. The population served in rural areas are then adjusted to surpass the entire target rate, 80% by the year 2010.

2) When the urban water supply covers the fringe rural area of the urban centre, it is assumed that the 1995 population served will increase at the same growth rate of urban population up to the year 2010.

3) When the rural population is not large enough or almost similar size as urban population, target coverage ratio, 70% is assumed to rural area. Then urban population is adjusted to achieve goal at the respective district.

The results are summarised in **Table - 6.3.1**. Development of the water supply schemes will double the number of the serviced population from 14.5 millions in 1995 to 30.6 million in 2010. Based on these estimated population served, water demand projection is made.

(3) Unit Consumption Rate

The 1986 MWR Design Manual specifies that residential water demand shall be forecast reflecting income categories and service type (through individual connections, communal water points or share connections) of the customers. Unit consumption rate applied for customers with individual connections range from 75 lpcd to 250 lpcd for urban area and from 40 lpcd to 60 lpcd for rural area. These unit consumption rates, which have been utilised in numerous projects in the country, are comparable with the rates used elsewhere internationally and considered generally acceptable. However, they assume that:

1) All individual connections are metered.
2) Billing will take place on a monthly basis using a stepped tariff designed to constrain high water usage.
3) All water kiosks will be metered, and water paid for.
4) The consumption rates include an allowance for 20% losses.

Although most of the existing water supply systems in the country are not operated in compliance with these assumptions, the above rates are applied for all districts without exception in the present study. In view of the objectives of the water demand projection, this consideration may be allowed.

The only adjustment are the composition rates of land potentials in the rural areas. They are assumed as below. As for housing class in the urban area, the present study applies the same figures as those utilised in NWMP:

1) Rural Area

| Land Potential | SSRWS in ASAL | Others |
|---|---|---|
| High potential land | 5% | 60% |
| Middle potential land | 15% | 30% |
| Low potential land | 80% | 10% |

These values are assumed from the results of the previous studies (WRAP and the Study on Seven Town Projects in Eastern Province).

2) Urban Area (same as previous NWMP)

| Income Level | 1995 | 2010 |
|---|---|---|
| High class housing | 5% | 10% |
| Middle class housing | 70% | 75% |
| Low class housing | 25% | 15% |

The values above are utilised as far as reasonable. Rates for Nairobi are merely adjusted to obtain the 2010 water demand forecast made in the 1986 Long Term Development Plan, Third Nairobi Water Supply Project. Using the formula specified in the 1986

Design Manual, the estimated rates are 12%, 78%, and 10% for high, middle, and low class housing, respectively.

### 6.3.3 Non-residential Water Demand

(1) Livestock

Latest data on livestock population (1995) are available in DDP and the Welfare Monitoring Survey II. Livestock units are estimated for every district using data obtained from these sources. In districts where significant deviation are seen in these statistics, adjustment is made accordingly. In principle, the larger figures between the two are considered bases for the estimation. As data on composition of grade and indigenous cows are not available, it is assumed that grade cows account for 95% of all cows. This percentage is obtained from the values envisaged in the existing reports. Based on these statistics, livestock units were computed for each district in accordance with the following formula:

| | | |
|---|---|---|
| 1 grade cow | - | 1 livestock unit |
| 3 indigenous cows | - | 1 livestock unit |
| 15 sheep or goats | - | 1 livestock unit |

To compute livestock water demand in the year 2010 from the 1995 estimates, NWMP had applied slightly larger growth rate of the livestock population than those normally adopted in water development plans in the country. Accordingly, it was adjusted to 0.8% annual growth rate.

(2) Health and Schools

Data on health facilities and schools are also available in the reports on Welfare Monitoring Survey II and DDP. School enrolment rates significantly changes from district to district. The rates for arid and semi-arid districts are generally as low as 8%, while 20% is estimated for other districts. As the 1986 Design Manual proposes separate unit water consumption for boarding schools and day schools, it is necessary to look into composition of these types. Although no accurate data are available, most of the relevant project reports assume that boarding schools account for 7.5% of the total.

The unit consumption rates assumed in the 1986 Design Manual are applied in the current study. To estimate future water demand at the year 2010, 3% annual growth rate similar to population growth rate was assumed.

(3) Commercial and Industrial

These are insufficient data to forecast water demand for commercial and industrial activities. Because of this, NWMP had applied an average unit consumption rate of industry prevailing in Japan. Industrial water consumption, however, is heavily dependent on characteristics of the activities, process applied, scale, raw materials used, etc.

The present review, hence, proposes a more practical way of assumption, with a view to composition rate of both residential and commercial & industrial water demands.

Based on the scale of industrial and commercial activities, all districts are grouped into 5. Commercial and industrial water demand projection is made for each group as detailed in Supporting Report II.

It is assumed that the percentage of industrial and commercial water demand to residential in a district where industry and commerce is active is generally larger than that of a less active district. Based on this assumption, the composition ratio of water demands fells in these categories are determined, quoting from the existing reports such as: (i) NWCPC, Second Mombasa and Coastal Water Supply Project Distribution Network Improvement and Extension, Water Demand Study Volume 1 Draft Report June 1996, (ii) Kenya-Finland Western Water Supply Programme, Water Supply Development Plan, 1990-2005 for Western Province, Bungoma, Busia & Kakamega Districts, Volume I, 1993 and (iii) Third Nairobi Water Supply Project, Long Term Development Plan (Regional Studies) Volume II Draft Report. Districts or groups where data are not available are interpolated from these.

These percentages are applied merely to estimate the 1995 water demand. To forecast the 2010 water demand, the GDP growth rate (6.7% annual growth on average) set forth in the Sessional Paper No.2 of 1996 on Industrial Transformation to the Year 2020 is utilised.

### 6.3.4 Water Demand Estimates

Results of water demand forecast are summarised in **Table - 6.3.2** and **Table - 6.3.3.** These estimates are results of computation based on the 1986 Design Manual under an ideal situation (i.e., 80% AFW and standard unit consumption rates).

The 1995 and 2010 water demands estimated from the above procedures are summed up by district. Livestock water demand values except those in Nairobi and Mombasa are considered imperative to the water demand in the rural areas. Livestocks in Nairobi and Mombasa are regarded to constitute a part of the urban centre water demand.

Water demand thus estimated is summarised in table below:

Water Demand Estimates

(Unit: 1,000m$^3$/day)

| Description | Water Demand in 1995 | | | | Water Demand in 2010 | | | |
|---|---|---|---|---|---|---|---|---|
| | UWS | LSRWS | SSRWS | Total | UWS | LSRWS | SSRWS | Total |
| 1. Residential (10$^3$ m$^3$/day) | 616.2 | 208.8 | 110.1 | 935.1 | 1,554.0 | 401.9 | 421.6 | 2,377.5 |
| 2. Non-residential (10$^3$ m$^3$/day) | | | | | | | | |
| Heath facilities | 4.6 | 5.0 | 6.4 | 16.0 | 8.9 | 7.1 | 9.4 | 25.4 |
| Schools | 37.2 | 41.2 | 56.9 | 135.3 | 59.6 | 48.6 | 68.0 | 176.2 |
| Industry & commerce | 142.5 | 26.8 | 31.8 | 201.1 | 383.4 | 60.8 | 55.5 | 499.7 |
| 3. Livestock (10$^3$ m$^3$/day) | 1.2 | 218.7 | 297.6 | 517.5 | 1.4 | 232.5 | 349.4 | 583.3 |
| Total | 801.7 | 500.4 | 502.8 | 1,805.0 | 2,007.3 | 750.9 | 903.9 | 3,662.0 |
| 4. Per Capita Consumption (lpcd) | 160.9 | 66.5 | 37.4 | 87.9 | 181.7 | 64.6 | 48.1 | 100.7 |

Source: The Aftercare Study Team

Estimated water demand, 1.8 million m$^3$/day in 1995, will increase to 3.7 million m$^3$/day in 2010 mainly due to the rapid population growth. Livestock, health, schools, industry and commerce water demand for the year 2010 estimated in the current study are similar to those in NWMP.

Overall consumption rate per capita increases from 88.8 lpcd in 1995 to 101.6 lpcd in 2010. These values are also similar to those estimated in NWMP.

## 6.4 Future Development Requirement

### 6.4.1 Water Balance between Forecast Water Demand and Water Supply

Production capacity of existing water supply facilities is estimated at 1.5 million m$^3$/day under the present conditions, whereas the overall safe water demand is forecast to be as large as 3.7 million/m$^3$ day in the year 2010. It is evident that there is serious need for development of new water supply projects, though magnitude of development needed may vary largely from one area to another.

MWR, NWCPC and other organisations concerned are now implementing and studying/designing in full strength a large number of urban and rural water supply projects in line with the national objectives as described in subsection 3.1.5. The water supply capability will be augmented to great extent upon completion of such projects. It also appears that such projects have been planned focusing on improvement of water supply condition of a particular area, while MWR aims at attaining water development management on a basis of district unit or catchment unit. To proceed further with the development plan it is absolutely necessary to assess the need for water supply augmentation under the condition that all the ongoing and planned/designed projects are completed.

As noted in subsection 1.2.2, it is set forth that the urban water supply and rural water supply development plans are to be elaborated on the basis of urban unit and district unit respectively. This is quite in line with the policy of MWR. Depending on the nature of available information, the results of water balance calculation will reveal the need for the development and timing and magnitude of the development required. In this Study, however, only the need and magnitude of development are ascertained, since the data available for the calculation are limited.

A flow chart of the water balance calculation is presented in **Figure - 6.4.1**. As noted in section 6.3.1 the water supply schemes are grouped into UWS, LSRWS, SSRWS. In this Study, however, water supply for livestock is dealt with separately, since its water quality is not of potable nature. To facilitate the planning of future water supply projects, the water balance calculation was worked out along with the following four successive steps:

(1) Step 1: Under the existing condition

The 2010 water demand is compared to the production capacity of the existing facilities, which is estimated as mentioned in the subsection 4.2.4 of this report. A water deficit (1) occurs if the demand exceeds the production capacity.

(2) Step 2: Step 1 + with completion of the ongoing projects

The resultant water deficit (1), if any, is the compared to the water supply capacity of the ongoing projects in the area concerned.

The existing data such as the MWR Status Report and the NWCPC Status Report do not always indicate the water supply capacity of the ongoing project but design population. In such case the water supply capacity is estimated based on the design population and assumed per capita water consumption (75 lpcd for rural water supply scheme and 125 lpcd for urban water supply scheme).

A water deficit (2) occurs if the on-going projects capacity falls short of the water deficit (1). There is no need to development a new project if the resultant is vice versa.

(3) Step 3: Step 2 + with completion of the planned/designed project

In the same manner as Step 2, the water deficit (2) is again compared to the water supply capacity of the planned/designed projects in the area concerned. The deficit, if any, is defined as water deficit (3).

The water supply capacity of the planned/designed projects is given by the MWR Status Report and the NWCPC Status Report.

(4) Step 4: Step 3 + with completion of the proposed rehabilitation works of existing facilities

MWR has been placing great emphasis on rehabilitation of existing facilities to restore them to their original functions. The Study Team quite agrees with this approach and recommends to implement as promptly as possible as discussed in Section 6.5.

It is evident that the rehabilitation works will result in augmentation of production capacity, which is taking into consideration under Step 4. The eventual water deficit (4) must be covered by development of new projects.

In the process of the above calculation, roof catchment supply is assumed to be adaptable to SSWRS only and to be constant throughout the planning horizon.

**Tables - 6.4.1, 6.4.2** and **6.4.3** present the water balance calculation for the UWS, LSRWS and SSRWS respectively. It should, however, be noted that the water supply for the livestock is not included in the water demand and it will be planned separately. The table below presents the results of the water balance calculation.

Summary of Water Balance Study

| Year | Objective Water Supply System | Number of Urban Areas/ Districts Subject to Water Deficit | | | | Amount of Water Shortage ($10^3$ $m^3$/day) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Step 1 | Step 2 | Step 3 | Step 4 | Step 1 | Step 2 | Step 3 | Step 4 |
| 2010 | UWS | 133 | 121 | 111 | 109 | 1,313.6 | 1,253.6 | 1,152.6 | 1,111.6 |
| | LSRWS | 36 | 15 | 11 | 9 | 233.4 | 65.7 | 42.3 | 35.9 |
| | SSRWS | 46 | 42 | 34 | 34 | 355.0 | 324.9 | 292.0 | 292.0 |
| | Total | | | | | 1,902.0 | 1,644.2 | 1,486.9 | 1,439.5 |

Source: The Aftercare Study Team

The following conclusions are made from the water balance study:

1) If the present water supply conditions continue, great amount of water deficit will occur in 2010, 1.31 million $m^3$/day in UWS, 0.23 million $m^3$/day in LSRWS, and 0.36 million $m^3$/day in SSRWS.

2) The ongoing and planned/designed projects play a predominant role in the long-term water supply development plan. Upon completion of these projects, out of 141 urban centres, 30 centres will be ensured with full supply as required, and in LSRWS and SSRWS, 39 and 22 districts, respectively, will not require any development of new water supply projects (see **Figures - 6.4.2, 6.4.4**, and **6.4.6**). In other words, in such urban centres and districts, there is possibility to defer the implementation of the ongoing and planned/designed projects beyond the year 2010 as the case may be.

3) The rehabilitation works also contributes to mitigate the water deficit. Upon completion 109 UWS will suffer from water shortage and, in terms of LSRWS and SSRWS, only 9 and 28 districts, respectively, will fall short of water supply (see **Figures - 6.4.3, 6.4.5**, and **6.4.7**).

4) The eventual water deficit is 1,112 x $10^3$ $m^3$/day in UWS, 36 x $10^3$ $m^3$/day in LSRWS and 292 x $10^3$ $m^3$/day in SSRWS. These deficit shall be met by means of development of new water supply projects.

**Table - 6.4.4** shows the water balance for livestock water supply in the respective districts. The present water supply capacity for this is also estimated as explained in subsection 4.2.3.

Supporting Report IV provides more detailed process and methodology adopted in the water balance calculation.

### 6.4.2 Water Resources Development Plan for UWS, LSRWS and SSRWS

In Nairobi and Mombasa urban centres, organisations concerned have been implementing water supply improvement projects with assistance of international funding agency and donor countries. Those two urban centres are, therefore, discarded from further study.

Under the present conditions, the surface water of rivers and groundwater are the main source for water supply and, as analysed in Sections 2.5 and 2.6, these resources still remain almost untapped, though their availability is widely different from area to area. In view of the natures of water consumption and supply system in the contemplated water supply areas and availability of water resources, the following development concepts are introduced to water resources development planning:

(1) UWS

The surface waters of the rivers are the predominant source of the raw water for the large urban centres, and accordingly are given first order of development. As much as the unregulated runoff of the river is available, a run-of-river intake method is considered to be best suited. When the unregulated runoff of the river is insufficient to meet the water deficit, such a large scale dam with seasonal flow regulating capacity or inter-basin transfer scheme as identified by NWNP will be considered.

Depending on the magnitude of the water deficit, groundwater, particularly boreholes will be proposed in place of the surface waters as it is available in the vicinity of the urban area concerned and is more economical than surface water.

(2) LSRWS

The same development concepts for urban water supply schemes are basically adaptable for LSRWS. However, the groundwater development will be given first order of development when the objective area is located in ASAL.

(3) SSRWS

The groundwater development will be considered as promising predominant sources for the SSRWS. It is evident that there are no perennial surface water resources available in the ASAL as reported in the Section 2.4 of this report. In general for small community water supply, construction of boreholes or dug wells are more advantageous than surface water because of lower initial investment and operation and maintenance cost.

**Tables - 6.4.5, 6.4.6,** and **6.4.7** show the proposed water resources development plans for the UWS, LSRWS, and SSRWS, respectively. More detailed reporting for the water resources development is presented in Supporting Report IV. The summary of the water resources development plan is as follows:

Proposed Water Resources Development

| Type of Water Supply System | Number of Urban Centres/ Districts by Water Resources | | | Water Resource Development ($10^3$ $m^3$/day) | | | | |
|---|---|---|---|---|---|---|---|---|
| | Surface Water | Ground water | Surface & Ground water | Surface Water | Ground water | Surface & Groundwater | | Total |
| | | | | | | Surface | Ground | |
| UWS | 89 | 15 | 5 | 1,046 | 42 | 20 | 4 | 1,112 |
| LSRWS | 8 | 1 | 0 | 35 | 1 | 0 | 0 | 36 |
| SSRWS | 1 | 21 | 27 | 7 | 101 | 128 | 60 | 292 |
| Total | | | | 1,088 | 144 | 148 | 60 | 1,440 |

Source: The Aftercare Study Team

Groundwater will be exploited by means of dug wells and boreholes. A large water deficit is expected to occur in some urban centres and such centres are located in the areas where the groundwater and surface water resources are not much available. Therefore, for these urban centres, as identified in NWMP, it is proposed to develop a large dam and an inter-basin transfer scheme as shown in **Table - 6.4.8.**

### 6.4.3 Water Resources for Livestock

It is not an absolute requirement to feed the livestock with potable quality water. It is simply assumed that all the water deficit will be secured by means of construction of small dam/water pans. The proposed development is discussed in Chapter 8.

## 6.5 Water Supply System Development Method

### 6.5.1 Basic Framework

All targets set up in the preceding sub-sections are possible to achieve, if necessary actions are properly taken in a short period of 10 years.

The production capacity of the existing treatment works is only 50% of the estimated water demand forecasted for 2010. Various measures to meet water demand may include rehabilitating the existing treatment works to restore capacity, quickly implementing the ongoing and proposed expansion projects, and to strengthen weak capacity of water undertakers in the field of operation, maintenance, management and financing.

1) Structural Measures

   i) Rehabilitation works of existing water supply projects
   ii) Completion of ongoing projects
   iii) Implementation of planned/designed projects
   iv) Implementation of newly proposed projects

2) Non-structural measures

   i) Leakage control programme
   ii) Functional metering system
   iii) Institutional and legislative improvement

### 6.5.2 Approach to Rehabilitation of Existing Water Supply Projects

Many existing UWS and LSRWS in operation are facing serious operational and financial problems. They are, for one reason or another, producing less water than the production capacity originally designed. As reported in Chapter 4 more than half of the schemes have operational hours less than 16. If they are normally operated on continuous basis, water production would increase by 20% - 30% of the present production in the whole country. The situation of the LSRWS is worse than UWS. This percentage comes to 40 %. This means water supply conditions could be significantly improved by normalising operational aspects of each scheme, particularly LSRWS.

The study, in "Seven Town Water Supply Development Projects in Eastern Province" suggests that households who are levied on flat rate are utilising five times as more water as normally metered customers. If this is applicable to other urban schemes, introduction of universal metering system to all schemes would drastically improve the present water supply conditions resulting in increase of water sales and revenue.

Situation of RWS is worse than UWS. Rehabilitation and rationalisation is considered most urgent and effective especially for LSRWS. The existing SSRWS are usually managed and operated by communities. Under the circumstances, most preferred way is periodical support and guidance by the DWOs and the local authorities concerned that lead to sound management.

Rehabilitation and rationalisation are prerequisites for sustainable development of all water supply schemes. The approach to the rehabilitation works are set out as described below:

(1) General Scope of Rehabilitation Works

Major problems that existing water supply schemes are currently facing are: (i) obsolete and malfunctioning facilities left without repair and maintenance, (ii) a large amount of the leakage at the pipeline reticulation, (iii) wasteful water usage by customers, and (iv) a low efficiency of revenue collection.

Proposed scope of rehabilitation work is based on Water Supply Sector Survey and similar surveys by MWR. Careful review of each scheme (approximately 300 schemes surveyed in total, although not sufficient to cover all schemes) is made for screening. The scope of the rehabilitation thus identified, however, is not necessarily effective to rationalise entire system to a satisfactory level of accounted-for-water ratio (AFW ratio over 70%). Proposed scope for rationalisation, therefore, includes: (i) installation of master and zonal meters and (ii) repair/installation of chemical dosing equipment, (iii) construction of storage facilities, (iv) leakage control activities, and (v) establishment of metering system, and (vi) public campaign on needs of safe water, metering system, hygienic water use, etc.

(2) Methodology

Work items (iv), (v), and (vi) regarded as non-structural measures will be done under "operation and management improvement plan". Careful attention, however, shall be paid to scheduling of whole tasks that interrelate with each other.

If sufficient funds are available, urgent rehabilitation shall be initiated for all schemes in the country. If not, higher priority may be given to such schemes that accountability or accounted-for water ratio are less than 50%.

### 6.5.3 Approach to Ongoing and Planned/Designed Water Supply Projects

As stated in Section 3.1 of this report, in the country, there are many ongoing projects. And some of them are stalled due mainly to a shortage of financial resources or technically improper design, but reliable information on their background and technical assessment are not available. Completion of these ongoing/stalled projects (under construction and design) affects significantly development needs. The estimated water shortage in 2010 could be cut in half if all of these projects are successfully implemented. It is, however, a hard task to evaluate and justify feasibility of the stalled projects. Leaving the task for future study, the Study Team tentatively assumes that all these ongoing projects will be completed and put in operation by the year 2010.

To incorporate these projects in the current Study, the Team attempted to follow the design frame established by the government organisations without any particular amendment. In case significant contradictions were found in the design values, adjustment or update were accordingly made.

### 6.5.4 Approach to Newly Proposed Water Supply Projects

(1) UWS

Water supply planning shall reflect local conditions such as geography, water resource availability, climate, social and economical situation, living conditions, and demographic features which varying widely from area to area over the country.

The present Study found its basis on the WMR 1986 Design Manuals as many past studies and projects did. Since the current Study reviews the previous National Water Master Plan, some information are not necessarily available in this report. In case needs arise, it is recommended to refer to the previous NWMP or the Design Manuals.

Fundamental concepts (see section 6.1.4) are to establish reliable water supply by supplying safe and potable water. To achieve this ultimate target within the time frame up to 2010, the Study emphasises the following aspects:

1) Continuous supply with a minimum pressure head of 10m: To this end, appropriate design and operation manuals shall be prepared and mobilisation of operational staff through training is indispensable.

2) Disinfection as minimum requirement for all schemes to meet the MWR Water Quality Standard: Water supply is one of the utilities to protect public heath and improve living conditions. Although performance largely depends on skills of operators, superintendents or technicians concerned, all schemes shall have chemical facilities for disinfection.

3) Measures for increasing cost recovery through a number of initiatives including reduction of unaccounted-for -water and the universal application of metering: This may not function unless public opinion reach a consensus for their introduction. Public campaign tailored for this purpose is of vital importance.

4) Gravity supplies to reduce recurrent cost and pumping being limited to areas where it is essential: To achieve this, engineering design shall be based on appropriate technology.

(2) RWS

For the SSRWS, mainly water points with some pipe works are supply sources to the residential and non-residential water supply excluding livestock. To the contrary, the LSRWS may have pipe reticulation consisting of trunk, secondary, and tertiary mains for distribution and transmission. Individual connection is a major type of service connection for LSRWS. At the peripheral supply areas, schemes may have water points to serve the surrounding rural population. The following planning concepts, accordingly, are for constructing new SSRWS.

1) Supply basically from water points with minor piping works to supply water to major institution such as schools and hospitals.

2) Disinfection is a minimum requirement for all schemes to meet MWR Water Quality Guidelines.

3) Installation of a master meter to increase cost recovery, and the application of universal metering, especially at large consumers as a minimum requirement.

4) Gravity supplies to reduce recurrent costs and pumping being limited to areas where it is essential.

5) Community based organisation and management in line with the decentralisation policy set up by the Government.

In addition to the above engineering approach, the following social issues of RWS are considered important for successful implementation.

1) Cultural issues: Nomads dependent on livestocks move seasonally from place to place. Provision of water points may cause socio-cultural problems among the people, if not appropriately located.

2) Assessment of public needs for water: People's needs for water will be assessed carefully. Where water supply is planned to be constructed by other undertakers, water point construction is not recommended.

3) Formation of water user committee: To ensure sustainability of the developed water supply scheme, a water user committee responsible for operation and management of the scheme will be organised within the community concerned.

4) Public involvement and participation: To increase opportunities of the public involvement to the schemes, it is more preferable to ask the community to provide work forces during construction.

5) Investment costs to be borne by the beneficiaries: Beneficiaries shall meet part of investment costs.

6) Women's involvement in the stage of design, construction and operation: Women play an important role in handling water in their daily lives and should therefore be involved in all stages of the scheme development.

7) Hygiene and health education: It is of vital importance to instruct people the needs for safe and potable water, sanitation, water borne diseases related to public hygiene and health through seminar, meetings, movies, etc.

### 6.5.5 Approach to Livestock Water Supply

Apart from potable water supply for domestic water use, water points for livestocks will be designed at strategic points of the study area. Abundant surface water is available in the coastal and western areas and in eastern slope of Mt. Kenya, while the perennial flow is very rare in the arid and semi-arid areas. The following concepts are used in identifying needs of and planning the livestock water points.

1) Earth pans or small dam are most practical methods to supply water to livestock.

2) In selecting potential areas for construction of the livestock water supply, ASAL areas shall have a priority.

3) Storage capacity of the pans shall be determined in view of the loss due to seepage and evaporation. It is tentatively assumed that the pan shall have a active storage capacity of 50,000 $m^3$.

4) Earth pans shall be accessible both for livestocks and human-beings. Each pan shall be separated into two basins so that livestocks can easily access to one without polluting the other. Dug well will be constructed in the vicinity of the pans for domestic use and will be equipped with hand pump.

## 6.6 Improvement Plan of Operation and Maintenance System for Water Supply

### 6.6.1 Establishment of Functional Metering System

Metering is a basic tool for effective management of water supply schemes. Without metering, water production and consumption cannot be measured. Accordingly, a tariff will have no base for billing. Flat rate tariff is not an optimal solution. People tends to use water without any restriction. If a functional metering system is established, people suffering from chronical water shortage may significantly benefit from vast amount of water saved from improved customers' attitude. Eventually water sales and revenue will increase, generating funds for better management and operation of the schemes.

Keeping in mind the vulnerable nature of the metering system which can be easily vandalised by the customers, all schemes shall endeavour to keep and pursue a desirable level of water supply services in terms of quantity and quality, and a close relationship with the customers in their routine operation and management.

At national level, MWR will be a key player in cooperation and consultation with NWCPC, MOLA, taking actions for administrative procedures, legislative set-up and national campaign programme. Thus MWR will be responsible for creating circumstances so that every water scheme can easily shift and adopt the metering system. To manage and support these activities, the Government should carry out the following:

1) Mobilise meter readers from existing staff through KEWI courses for the training of trainers, and local training programmes;

2) Mobilise accountants for requisite bookkeeping and accounting at District level;

3) Mobilise technicians from existing staff for meter calibration and repair through KEWI courses for the training of trainers, and local training programmes;

4) Assist DWOs to set-up or refurbish meter repair shops with the necessary equipment;

5) Conduct public awareness campaigns for the introduction of the metering system, directly and through the media.

At district level, DWOs, Municipalities, Regional offices of NWCPC shall play a important role in driving all water schemes into introduction of the metering system.

### 6.6.2 Leakage Control

As described in the foregoing chapters, many waterworks are suffering from a large quantity of water losses particularly at their transmission, distribution and service pipelines. In these waterworks, leakage and wastage control are considered effective not only to reduce water losses but to save precious water resources. With a view to the limited water supply sources in the country, MWO shall work out a National Programme for leakage and wastage control, that consists of crash and routine sub-programmes. To materialise this programme, the MWR shall take the following actions:

1) Establish a short course at KEWI for active leakage control (detection and repair);

2) Mobilise technicians from existing staff through KEWI courses for the training of trainers, and through local training programmes;

3) Assist DWOs to acquire and install bulk meters at the outlet of each treatment works and storage reservoir, and subsidiary meters to isolate sub-areas of each system;

4) Assist DWOs to set up or refurbish the necessary detection and repair facilities and equipment;

5) Assist DWOs to prepare the necessary work programmes to cover detection and repair in the distribution network where the majority of leakages occur.

Along with the implementation of the above programmes, agencies such as DWOs, municipalities and NWCPC regional offices shall intensively undertake necessary measures for the wastage control under overall supervision of MWR.

### 6.6.3 Staff Training

The training needs of the above programmes should be reviewed against the latest Action Plan for the Kenya Water Institute (KEWI) to see if they can be accommodated within the planned implementation schedule (see Chapter 12). If not, the KEWI's resources should be further strengthened in both range of courses and capacity to accommodate larger numbers of trainees. The subjects for which training is required will include the following:

1) Meter reading,
2) Meter repair and calibration,
3) Billing and revenue collection,
4) Bookkeeping and accounting, with special reference to the billing and collection system,
5) Leakage control and the reduction of UFW,
6) Supervisory courses for the above,
7) Water and sewage treatment for operators and supervision, and
8) Personal computing using spreadsheet and database software.

### 6.6.4 Customer Registration

The measures mentioned above would not be effective if many consumers exist unregistered. To complement the above programme, unregistered consumers should be traced in the course of the metering system development. Since the consumers are usually reluctant to be registered and metered, the MWR should take the following measures to accelerate this:

1) public campaign on needs of functional metering system, referring to inequity between metered and unregistered consumers,
2) rescue people from any duties arising from nonregistration, and
3) two step approach by scheduling periods separately for voluntary and compulsory registration.

### 6.6.5 Chemical Water Treatment

Many waterworks are not dosing water with chemicals due to financial constraints and a lack of quest for better quality of water. To produce safe and potable water, chemicals must be acquired, stored and added to process. Failure to follow this absolute priority will not be tolerated in the interest of public health. To this end, MWR or other related agencies shall take the following actions:

1) periodical water sampling and laboratory testing by district or provincial water offices,

2) technical guidance to all waterworks for producing potable water and protecting water sources from possible contamination, and

3) provide them with necessary equipment and chemical agents required for minimum level of water testing (pH, turbidity, chlorine residuals, etc.).

### 6.6.6 Technical Assistance at Districts

The above programme of work will need significant improvement in the practice and management of District activities. This will apply to operation and maintenance of water supply systems as well as to regulatory tasks, such as control of water abstraction, pollution and water quality. It is recommended that externally sourced expert engineers should be assigned to groups of MWR Districts including NWCPC schemes and municipality schemes. They will assist in upgrading service delivery and regulation and to help implement the above programmes.

### 6.6.7 Water Tankers at Provincial Offices

The Household Survey indicates that during the dry season, more than 50% of the households do not have access to water, getting water merely once a week. This is particularly serious in ASAL areas. Life of many vulnerable people and livestock is reportedly jeopardised due to water scarcity. It is recommended that two or more water tankers should be procured at each Provincial Office to alleviate this hardship.

# CHAPTER 7 SEWERAGE DEVELOPMENT STRATEGY

## 7.1 Development Target and Objectives

### 7.1.1 Development Objectives

Sewage, whether domestic or industrial must no longer be disposed of indiscriminately. Controlled disposal of domestic sewage and industrial wastewater is the only solution for safeguarding water resources and public health in Kenya.

The planning horizon for the Study is the year 2010. The objectives of the Study related to be sewerage are:

1) To provide a sewerage development plan with priorities for implementation, and
2) To provide a strategy for the sustainable operation and maintenance of sewerage systems

Clearly, actions to resolve the identified constraints must be taken to ensure that operating authorities have the management capacity to properly operate and maintain sewerage. Otherwise continued development will not be sustainable.

### 7.1.2 Target Areas

Planning in the Study is done for 40 urban centres shown in **Figure - 3.1.1**. Of the proposed 40 urban centres 30 already have sewerage systems. The other 10 are urban centres with a population greater than 20,000 where the need for improving sanitation conditions has been identified by MOLA.

## 7.2 Strategy for Sewerage and Sanitation Development

### 7.2.1 Service Standards

As preceding chapters have indicated, urban centres in Kenya have well developed water supply systems serving a high percentage of the population (>90%). In comparison, sewerage remains poorly developed serving only 28% of the population living in urban centres while almost 50% rely on pit latrines. The environmental and health implications of inadequate sanitation have been further aggravated by rapid rural urban migration and a poorly maintained and failing sewerage infrastructure.

It is not a requirement of the Study to undertake a comprehensive review of on-site sanitation facilities or prepare plans for development of on-site sanitation. However, by the year 2010 more than 7 million people living in urban centres will depend on pit latrines for basic sanitation. Providing sewerage in only part of a community will have little benefit if the health of the residents and the water resources is threatened by the unsanitary practices of neighbouring communities that do not have sewerage.

The technical feasibility of alternative sanitation systems in Kenya depends heavily on water supply services in the area, on population densities, on soil permeability, and hydrogeological conditions. These conditions vary widely from one urban centre to the another and are very site specific. Conventional sewerage schemes are an excellent form of sanitation for those who can afford them and have sufficient water. There are many other less costly options which, like sewerage, can provide a high standard of health, environmental protection and user convenience. Alternatives to conventional sewerage will play an important role in the improvement of sanitation conditions in Kenya's urban centres. Technically acceptable sanitation solutions are ventilated improved pit latrines, pour flush toilets, small bore sewers, septic tanks, public toilets and conventional sewers. A qualitative comparison of various sanitation alternatives is provided in Supporting Report III.

More research including pilot installations will be required to determine which of the non-conventional sewer options (e.g. small bore sewers) are technically acceptable and economically feasible. Problems of user acceptance and maintenance are likely in the initial stages and will require appropriate support programmes to inform the public.

Based on a review of current practice and experience in other developing countries, conventional sewerage is usually cost effective in urban zones where:

1) The population density is greater than 120 persons per hectare, and
2) Water is supplied to individual residences in sufficient quantity to procedure wastewater flows greater than 75 lpcd.

In other cases properly constructed on-site sanitation systems should be used. If conditions are not suitable for on-site sanitation (plot size, soil conditions) and conventional sewers are not affordable than lower cost options such as small bore sewers must be considered. On-site sanitation systems can be upgraded over time to complement improvements in water supply services. **Figure – 7.2.1** illustrates the typical upgrading sequence and the various service standards of water supply that can be accommodated by alternative sanitation technologies.

The above service standards are recommended as guidelines for future sewerage development but should be re-evaluated again when preparing urban water and sewerage master plans to reflect specific conditions encountered in each urban centre.

### 7.2.2 Proposed Development Strategy

Based on a review of existing conditions and discussions with MWR and MOLA the following development strategy for urban sewerage is proposed:

1) Existing infrastructure should, where economically feasible, be rehabilitated before investing in new works. This approach will in most cases be more cost effective and result in more immediate benefits such as improved treatment levels.

2) Residences with water connections should have conventional sewer connections if they are located in already sewered areas.

3) Residences with water connections in presently unsewered areas should have connections to conventional sewers, or small bore sewers or septic tanks by the year 2010. The final decision on which technology to use cannot be made at this study stage and should be based on an economic evaluation of options using local conditions.

4) Residences which today have a water connection but which cannot be served by a conventional or small bore sewer connection should during the planning period improve their sanitation by upgrading their existing cesspits or septic tanks. In later years they should be connected to the extended sewer network.

5) Residences that do not have a water connection today but will be supplied with one by 2010 should, for the immediate future, be served by pour flush toilets with sludge soak-aways if they do not install flushing toilets. They should use new cesspits or septic tanks if they do install internal flush toilets. The choice between cesspits or septic tanks depends on whether enough land is available for the more efficient and cost effective septic tanks.

6) Those who are unable to afford the sanitation system that must accompany a water connection will have to rely on standpipes for their water supply. Such residents will principally use either VIP latrines or pour-flush toilets for sanitation. The choice between VIP latrines and pour-flush toilets should be left to the individual householder.

The implementation and monitoring of on-site facilities in urban centres must be formalised to make them more effective. Formalising on-site sanitation will require:

1) Setting standards for construction of pit latrines, septic tanks and soak-away pits,
2) Regulating construction through the issuing of permits and follow-up inspections,
3) Regulating maintenance intervals of septic tanks and cesspits through mandatory collection,
4) Providing facilities for disposal of septage, and
5) Regulating municipal and private sludge collection services through licensing and manifest system to ensure proper disposal.

Further study and assistance will be required to determine the appropriate institutional arrangements, and implementation plan. It is proposed that the MWR play a leadership role in coordinating the provision o planning and inspection service with other key actors such as the ministry of local authorities and local public health departments.

## 7.3 Future Demand for Sewerage Services

It is impossible to identify exactly how many people live in conditions where no-site sanitation is unsuitable because each urban centre is different. A detailed survey within each urban centre would be required to identify specific needs for sewerage versus on-site sanitation. According to a 1973 WHO report, it was estimated that approximately 95% of the urban population by the year 2000 would be in a situation where on-site sanitation was no longer suitable. This ratio is rather high and could not be achieved by 2010.

If a large number of residents in an urban community do not have adequate sewage disposal the health of water resources and of other residents who do have sewerage can be adversely affected. Therefor, it is assumed that some improvement over existing conditions is required.

In Mombasa a recent water supply and sanitation study determined that only 50% of the population could afford to pay for conventional sewerage. This seems likely to be the case in most urban centres. Therefore, 50% is assumed to represent maximum economically feasible level of sewerage development for full cost recovery. Working with 50% as a starting point, sewerage development is planned for 40 urban centres.

The level of investment required to achieve the 50% target in all urban centres is larger than the forecasted investment funding, therefore, a lower target is required. More moderate service targets are selected on the basis of population size as shown in the following table. These individual targets translate into serving 38% of the total urban population by the year 2010. This 10% improvement is substantial considering the urban population is expected to double over the period. The corresponding investment requirements are considered achievable if donor support is provided at historical levels. This large increase, driven by rapid population growth, will require a considerable effort in sewerage development activity.

Proposed Sewer Connection Ratio

| Population in Urban Centre | Proportion of Population Connected to Sewer |
|---|---|
| P > 300,000 | 50% |
| 300,000 > P > 100,000 | 40% |
| 100,000 > P > 20,000 | 25% |
| P < 20,000 | 15% |

In some cases where urban centres already have a higher service ratio than those proposed the strategy will be to continue sewerage development just keeping pace with population growth, to maintain the existing service ratio.

The target service ratio proposed for selected urban centres is shown in **Table - 7.3.1** and the overall targets achieved for urban cities classified by population size is shown in **Table - 7.3.2.**

## 7.4 Forecast Sewage and Septage Quantities

The amount of wastewater produced by the consumption of water and the amount of solids produced by various on-site sanitation systems are estimated to provide an assessment of the sewage treatment and septage disposal facilities required in the future.

The production of sludge from stabilisation ponds is not significant in quantities therefore no estimates are made. There is no requirement for specialised sludge treatment at this time and none is anticipated in the future. The practice of sludge drying beds and land application is quite adequate and requires no special planning at this stage.

### 7.4.1 Dry Weather Sewage Flow

The components of dry weather flow and the assumptions used for estimating wastewater flows are summarised in **Figure - 7.4.1**. The usual method of estimating flows is on the basis of land use data and per unit water consumption. Land use data does not exist for most urban centres making the use of recommended per unit consumption and wastewater generation factors impractical without a comprehensive land use survey for each urban centre.

Since land use data is unavailable, wastewater flows adopted for planning are estimated by establishing average contributions from domestic users and adding a percentage for commercial, institutional and industrial wastewater flows.

A review of data from previous master planning studies carried out in six urban centres indicates that on average the total sewage flow is composed of domestic sewage (60%), commercial/institutional sewage (20%) and industrial wastewater (20%). The average domestic wastewater flow is approximately 93 litres per capita daily. Therefore, using the above percentages the total sewage flow (including residential, commercial, institutional and industrial) is 155 litres per capita daily.

The total base sewage flow is multiplied by a factor of 1.2 to allow for the significant contribution of water from extraneous sources such as groundwater infiltration and surface water inflow that occurs even during dry weather periods. The total dry weather flow assumed for planning purposes is 186 lpcd.

The total volumes of sewage generated by existing and future populations in the selected urban centres are estimated based on the selected target service ratios and the assumed contribution from various sources as discussed above. The volumes are compared to existing treatment plant capacities to determine the need to develop sewerage infrastructure to service the target population. Calculations are shown in **Table - 7.4.1**. In 2010, approximately 4.4 million people of 40 urban centres and a number of industries will produce an estimated 750,000 $m^3$/day of wastewater requiring a total incremental treatment capacity of 510,000 $m^3$/day.

### 7.4.2 Septage

The method for calculating the volumes of septage is shown in **Figure - 7.4.2.** The total volumes of septage generated by on-site facilities in 40 urban centres are estimated based on target service ratios. The volumes are used to demonstrate the need for septage disposal equipment and facilities.

Two methods are used to calculate the volume of septage. An average of the two results is taken for planning purposes.

Due to the poor design of septic tanks, soak-away pits are also sludge receptacles and, therefore, need to be evacuated. The volume of liquid from the average soak-away is added to the volume of septage to obtain the total volume of liquid waste that must be handled at treatment facilities in urban centres.

The amount of septage waste generated from on-site systems in the year 2010 is presented in **Table - 7.4.2.**

## 7.5 Planning Criteria

### 7.5.1 General Wastewater Management Process

A flow diagram presented in **Figure - 7.5.1** provides an overview of the liquid and septage waste management processes from source to disposal. The figure also provides a summary of the number of people contributing to the process, the strength of the waste, and the method of disposal assumed in forecasting facilities required.

### 7.5.2 Sewage Collection

Most urban centres have implemented separated systems and it is advisable to continue this practice. However, design practice allows for the acceptance of some very limited storm water termed "inflow"; therefore, the wastewater forecasts provided for this study assume a 20% allowance above the normal flow of sewage for inflow during dry weather.

For developing costs in this Study, it has been necessary to make several general planning assumptions about conditions of sewage in urban centres such as:

1) The target population lives in conditions that make waterborne sewerage the only technical and economically viable option for sanitation and wastewater disposal,
2) All sewers will be partially separated and will flow by gravity. The use of pumping stations will be avoided if at all possible by judicious selection of treatment sites and layout of trunk sewers with respect to topography, and
3) Existing trunk sewers have sufficient capacity to serve larger population. Most large diameter trunk sewers need to be cleaned to restore hydraulic capacity.

Actual conditions will vary widely from one urban centre to the next and a site specific assessment of technical options will be required at the master planning or feasibility study stage.

### 7.5.3 Wastewater Treatment

Future treatment processes must be capable of removing inorganic material and stabilising the organic portion of the wastewater to produce an effluent that meets the standard. They must also produce sludge that can be disposed of safely with a minimum of nuisance. A qualitative comparison of various treatment alternatives is provided in Supporting Report III.

Where land is a readily available, stabilisation ponds are generally the most suitable method of treatment providing three major advantages:

(1) Removal of excreted pathogens at a much lower cost than any other form of treatment,
(2) Good removal efficiencies for BOD and low sludge production, and
(3) Minimum operating and maintenance requirements.

In urban centres where land availability is small, it is generally more cost-effective to provide aerated lagoons where receiving streams do not require tertiary treatment

For the purposes of preparing a sewerage development plan under the Study, it is assumed that waste stabilisation ponds will be constructed in all urban centres where sewerage treatment works are required. The final selection of treatment method will depend on site-specific conditions and should be evaluated in future feasibility studies based on a detailed assessment of technical, economic, and environmental criteria for each urban centre.

The use of a primary facultative pond will probably not provide the desired level of treatment in most urban centres. For strong wastes (>400 mg/l) which is usually the case in Kenya, the use of anaerobic ponds as a pre-treatment unit ahead of the facultative pond is advantageous since it reduces the organic loading of the facultative pond and thus minimises the land requirements of the whole pond system. For planning purposes it is, therefore, assumed that the design should consist of at least two anaerobic ponds followed by secondary facultative ponds and two or more maturation ponds to reduce fecal coliform counts.

### 7.5.4 Septage and Sludge Disposal

It is assumed that specially constructed anaerobic ponds added in front of the normal treatment process will provide treatment of septic liquid wastes. These ponds, depending on their depth and operating characteristics will need to be de-sludged approximately every five years. The facultative ponds and maturation ponds will need de-sludging every 15 years and will not contribute a significant amount of sludge if grit removal facilities are provided and well maintained.

For urban centres where sewage treatment works already exists or are proposed, facilities for the treatment of liquid waste should consist of specially designed anaerobic treatment ponds dedicated to the pre-treatment of septic waste.

There are generally two methods for the disposal of sludge at treatment facilities: (a) discharge to sludge drying beds or, (b) discharge to dewatering and digesting facilities.

For disposal of sludge from anaerobic and facultative ponds the current practice of using sludge drying beds is simple, low cost and effective. The only condition is that the sludge must be stored and dried for over 12 months in order to ensure that the material is pathogen-free.

### 7.5.5 Wastewater Strength and Effluent Criteria

The strength of influent raw sewage to the treatment works depends not only on domestic per capita contributions but also on the load contributed by industry which tends to increase BOD and the amount of "clean" groundwater and surface water that enters the sewer which tends to decrease sewage strength. The average BOD obtained from sampling is 480 mg/ℓ. A value normally used in design around Kenya is 500 mg/ℓ and is assumed a safe value for planning purposes.

The National standard for discharge to a receiving stream specifies two main effluent parameters that must be considered in the design of sewage treatment works:

(1) $BOD_5$ not to exceed 20 mg/ℓ, and
(2) Fecal coliform not to exceed 5,000 MPN per 100 mℓ

A review of literature on the performance of waste stabilisation ponds in East Africa and the results of sampling during the Study would seem to indicate that a $BOD_5$ of 20 mg/ℓ is achievable, if the sample is filtered to remove algae.

Where discharge is into a river or watercourse that is likely to be used for domestic purposes downstream, a value of 1,000 MPN per 100 mℓ is appropriate. This value is easily achievable with maturation ponds as shown by the results of samples taken at several facilities during the Aftercare Study.

For the purposes of preparing a sewerage development plan, the Aftercare Study assumes the following revised standards for the main effluent parameters:

1) $BOD_5$ not to exceed 20 mg/ℓ (*when filtered to remove algae*)
2) Fecal coliforms not to exceed 1,000 MPN per 100 mℓ

## 7.6 Improvement Plan of Operation and Maintenance System for Sewerage

Very little information on the management and organisation of operations and maintenance was available to the aftercare study team. Local authorities should be structured to perform and monitor operation and maintenance, administer budgets, record and retain system information, enforce sewer by-laws, plan for repairs and future system growth. Few of the local authorities surveyed can meet these requirements. It is, therefore, proposed to strengthen operation and maintenance capacity as follows:

### 7.6.1 Increase of Operating Revenue

Development projects will not succeed if policies are not in place to generate the revenues required to sustain the services provided. The ultimate goal of every service provider should be to establish a commercially viable organisation with a long-term view to privatisation.

Since operating revenue for sewerage is based on water consumption it is imperative that recommended improvements for water supply systems be implemented. These are:

1) Improving levels of service water supply
2) Reducing UFW
3) Improving metering
4) Improving customer billing and collection systems
5) Establishing tariffs aimed at cost recovery

### 7.6.2 Improvement of Staff Training and Hire Qualified Personnel

The determination of staff requirements and skills requires a detailed working knowledge of the collection and treatment system and includes variables such as: level of service expected and funded, age of system and materials used, travel distances, type of treatment process among as well as many other variables. No single formula can be sued to determine the staffing needs of a particular system.

It is recommended that the following actions be undertaken within each operating authority under the combined supervision of MOLA:

1) a detailed review of organisational structures, staff establishment and qualifications needed,
2) a detailed audit of personnel already in post, their qualifications and experience against their job descriptions,
3) identification of: vacancies, training needs for existing staff, non-performing surplus staff, and
4) development of a programme of: recruitment, training, or transfers to other more suitable positions

The training needs for various operating authorities must be reviewed against the latest Action Plan for KEWI to see if they can be accommodated within the planned implementation schedule. If not, KEWI's resources should be further strengthened in both scope and capacity to accommodate larger numbers of trainees from the sewerage sector.

Local authorities will need to budget sufficient funds to increase the level of training and competence of its employees. MOLA may have to subsidise training from its own budget until operating authorities can generate sufficient revenue.

The following training needs are anticipated for collection systems and treatment plant workers:

1) Sewer inspection and condition assessment
2) Sewer repair and maintenance
3) Inspection of house connections
4) Mechanical maintenance; valves, screens, pumps
5) Electrical maintenance; motors, controls, electronics
6) Preventive maintenance management techniques
7) Operation and maintenance of waste stabilisation ponds
8) Operation of aerated lagoons and other advanced biological treatment processes
9) Biology and chemistry for treatment plant operators
10) Process monitoring and control techniques
11) Laboratory skills
12) By-law enforcement
13) Inspection of industrial wastewater processes

### 7.6.3 Procurement of Required Facilities, Equipment and Tools

Proper facilities, equipment and tools are essential to collection and treatment operation and maintenance. Without them, even the best-trained and motivated staff will be ineffective.

It is recommended that the following actions be undertaken within each operating authority under the combined supervision of MOLA:

1) Review maintenance facilities needs (equipment yard, office space, materials and spare parts storage)
2) Review and prepare an inventory of existing tools and equipment to identify what is required
3) Assess what equipment, vehicles, and tools are needed for maintenance
4) Rank items required in order of priority, obtain prices, and identify costs in future operating budgets
5) Obtain funding to construct required facilities and purchase required tools and equipment. Proceed with purchasing on an annual basis in order of priority based on level of funding available
6) Account for the cost of depreciation and identify equipment and tool replacement costs in annual operating budget

### 7.6.4 Establishment of Preventive Maintenance and Standard Operating Procedures

When equipment and manpower needs have been determined, the next step is to plan how these resources should be used.

Crisis management tends to be more expensive because the size of the problem tends to grow with time. Preventive maintenance on the other hand includes regular inspection and scheduling routine maintenance before problems occur for the purpose of extending equipment life, reducing maintenance costs, and increasing reliability. Sewerage infrastructure represents a large investment and should be protected and cared for. A preventive maintenance programme is one of the best ways to keep the system in operation and in good condition.

In the short-term it is recommended that the following actions be undertaken:

1) Prepare a detailed sewer inventory identifying pipe size, material and location
2) Prepare topographic survey along sewer lines and a house connection survey
3) Prepare utility maps
4) Inspect all trunk sewers and manholes complete with an assessment of condition and rehabilitation needs (this will require contract services for closed circuit television)
5) Assemble an inventory of all mechanical and electrical equipment and prepare a manual with manufacturers operating and maintenance instructions, and replacement parts list
6) Prepare a maintenance schedule for all M&E equipment
7) Prepare a maintenance schedule for regular inspection and cleaning of trunk sewers
8) Prepare a monthly and weekly manpower scheduling procedure
9) Design and implement a work order system to track all maintenance activities including corrective and emergency repairs
10) Write standard operating procedures for process control, equipment operation and maintenance, laboratory procedures, and data recording

In the long-term it is recommended that preventive maintenance programmes be developed within each operating authority. This will require significant effort but is considered a very necessary requirement to establish sustainable operation of sewerage schemes. Successful implementation will require full time assistance and support from externally sourced engineers and experienced maintenance programme managers.

### 7.6.5 Implementation of Industrial Wastewater Pre-treatment Programme

Industrial effluent laws are in place but enforcement is very weak because there is a lack of money, manpower, and equipment to implement a comprehensive programme at the local level.

Typically, pre-treatment programmes should be implemented at the local authority level where the sewerage operator is responsible for inspecting and monitoring industries connected to its sewer system to ensure compliance with local sewer by-laws.

Implementation of a pre-treatment programme at the local level usually includes the following elements:

1) Development of an inventory of industrial discharges to the public sewer system,
2) Adoption of an industrial pre-treatment by-law,
3) Purchase of monitoring and laboratory equipment,
4) Sampling and analysis of industrial effluents to ensure compliance, and
5) Establishment of administrative procedures to obtain compliance with regulations.

# CHAPTER 8 URBAN WATER SUPPLY DEVELOPMENT PLAN

## 8.1 Rehabilitation Works of Existing Facilities

Chapter 6 proposes urgent rehabilitation for all urban and rural water supply schemes, based on review of the 1996 questionnaire survey on needs of rehabilitation at 300 water supply schemes carried out countrywide by MWR and a similar survey by the JICA Study Team. Major work items for rehabilitation include repair/construction of boreholes, repair/installation of raw water and distribution mains, treatment facilities, and repair of malfunctioning equipment. The scope tentatively proposed shall be subject to further studies and analyses in a feasibility study or detailed design stage.

In addition, both preventive and corrective measures are proposed as a part of rehabilitation to decrease water losses at distribution networks and rationalise system operations. The proposed scope of work for rehabilitation is reiterated with technical particulars in the paragraphs which follow:

(1) Repair/replacement of broken/timeworn/malfunctioning pipe works, valves, gates, gauges and meters which are all indispensable for normal operation.

Due to absence of proper maintenance, some waterworks are obliged to reduce their production. Minor repair of the damaged equipment may result in producing more water, resulting in improvement of the water supply conditions. Scope and scale of the rehabilitation work were evaluated for each water scheme based on engineering practices generally applied.

(2) Installation of chemical dosing equipment

It is one of the sector objectives that all schemes except those for livestock shall supply potable water. To this end, installation of chemical dosing equipment at every waterworks is considered essential. In this context, one full set of chlorine dosage equipment with necessary appurtenances is assumed to be installed.

(3) Installation or repair/replacement of master and zonal meters

Master and zonal meter installation is a first step to reduce water losses from the pipe networks. In the longer run, all subscribers shall be supplied through metered connections. It is assumed that two sets of master meters are installed at inlet and outlet of treatment works. Diameter of these meters are consistent with the raw water and distribution mains already installed.

(4) Construction of additional service reservoirs

Service reservoirs/elevated tanks constructed within the supply area often have insufficient capacity for storage to offset peak demand during daytime. During night time when water demand drops to a minimum level, produced water are stored in the reservoirs. Without a proper size of storage reservoirs, this mechanism will not function. Worse, plant operators tends to shorten its night time operation. To overcome this issue, it is urgently required to resume continuous operation by adding sufficient capacity reservoirs, which is considered most cost effective to increase water production. Required storage capacity is estimated from balance between the existing and the recommended storage (24 hours storage).

(5) Miscellaneous works

Substantial parts of mechanical equipment in many waterworks outstrip their lives and/or are not in operation and function. It is necessary to repair/replace such equipment to restore the system to its original function.

## 8.2 Preliminary Design

For UWS, the surface water resources will be the predominant source of raw water supply, though the groundwater resources will also be required to be developed in ASAL and other minor urban centres. General flow of water process is prepared for the surface water as shown in **Figure - 8.2.1** and for the groundwater as shown in **Figure - 8.2.2**.

(1) Water Source Facilities

1) Large dam and inter-basin transfer system

Such source facilities as large dam and inter-basin diversion systems require extensive field survey and technical feasibility study in a further stage. Fortunately, NWMP provides general features and preliminary cost estimate for such and they are quoted in this study.

2) Run-of-river intake

The intake will be located at right angles to direction of flow with inlet velocities of less than 0.1 m/s, at a level well above the river bed level. The coarse screen will be installed so that the floatage garbage should not carry into treatment facilities.

Raw water main uses uPVC and its length is assumed to be 1 km for small and medium scale schemes, and 5 km for large scale schemes. Flow velocity is assumed to be 1 m/s.

3) Borehole with powered pump

Reference is made to the subsection 2.4.2 of this report, which evaluates the present operation and maintenance status of existing boreholes. The contemplated urban areas are supplied with electric power by KPLC, and therefore electric powered pump is adaptable.

(2) Water Treatment Facilities

The treatment of surface water is assumed to be by conventional coagulation, flocculation and rapid sand filtration as follows.

1) Coagulation and flocculation

Coagulation and flocculation are simple hydraulic mixing and flocculation. Chemicals for coagulation will basically be alum and soda ash which are widely used in Kenya.

2) Sedimentation

For convenience of operation and maintenance, a conventional horizontal flow sedimentation basin is used. Retention time is set at 4 hrs and surface load in basin is assumed at 1.0 $m^3/m^2/hr$.

3) Rapid sand filtration

Conventional rapid sand filters are used. Filtration rate is proposed at 120 m/day. The filter sand is washed by the backflow.

4) Disinfection

The chlorine disinfection is most widely adopted in water treatment in Kenya. Sanitary safety is secured by the reaction time of generally 30 minutes. Disinfection will be by use of chloride of lime or hydrochloride solution, using gravity drip feeds.

(3) Storage Reservoir/Tank

Storage capacity was assumed to correspond to one day average water demand for small scale schemes and 12 hours for medium and large scale schemes.

(4) Distribution

Gravity flow distribution is assumed and uPVC pipes are proposed.

Rough salient features of the newly proposed projects are summarised in **Table - 8.2.1.**

## 8.3 Preliminary Construction Cost Estimate

### 8.3.1 General Conditions

The proposed long term development plan comprises: (a) rehabilitation works of existing projects, (b) the ongoing projects by the Government, (c) the planned/designed projects by the

Government, (d) newly proposed projects, (e) leakage control programme, and (f) metering campaign. Of these, the required investment for categories (b) and (c) are available from the MWR Status Report and the NWCPC Status Report. For installation of individual meter, according to the prevailing regulation, the customer is responsible for cost of installation. Under the Study, therefore, the preliminary cost estimate is attempted for the rest of the categories. The method of cost estimate is reported in detail in supporting Report II.

(1) Price Level and Exchange Rate

Unit cost of materials and equipment is estimated at the price level prevailing in February 1998. An exchange rate, US$1.00 = Kshs 61.1 = Japanese Yen 124.7 (as of 10 February 1998) is applied in estimating unit cost of imported materials and equipment. Materials and equipment locally available are based on market price, the latest quoted price or results of the recent studies carried out in the country.

(2) Construction Cost

The construction cost comprises:

1) Direct construction cost

It is estimated for the respective major structure depending on features of the works.

2) Land acquisition and compensation

It is assumed to be 5% of the direct construction cost.

3) Engineering services for design and supervision

It is assumed to be 10% of the direct construction cost.

4) Administration cost of the executing agency

It is assumed to be 15% of the direct construction cost.

5) Contingency

It is assumed to be 10% of the sum of Items 1) through 4).

### 8.3.2 Rehabilitation Cost of Existing Facilities

The direct construction cost of the rehabilitation works is estimated for the respective item as follows:

(1) Flow Meter

It is estimated based or a price quotation from manufactures and include an allowance of 30% of the procurement cost (CIF, Site) to allow erection, installation, and other associated works.

(2) Chlorination Equipment

It is estimated by means of the same method as above.

(3) Storage Tank

It is estimated by applying unit construction cost: Kshs 3,137/$m^3$.

(4) Associated Works

The rehabilitation works will involve various civil, electrical, mechanical and other miscellaneous works, apart from the above major works. It is estimated by applying unit rate of Kshs 4,257/$m^3$ of water produced.

The summary of estimated rehabilitation cost is presented in **Table - 8.3.1.**

### 8.3.3 Construction Cost of O-ngoing and Planned/Designed Projects

The MWR Status Report and NWCPC Status Report provide the construction cost of the on-going and planned/designed projects under their administration. In this report those estimated costs are directly applied in order to estimate the total investment required to achieve the long-term water supply plan of the respective urban centre. The costs are shown in **Table - 8.3.1.**

Note, the construction cost of the ongoing projects shows the investment required to complete the remaining works.

### 8.3.4 Construction Cost of Newly Proposed Projects

The direct construction cost of the main structures is estimated as mentioned below:

(1) Source Works

1) Large dam and inter-basin transfer system

Their construction cost is obtained from NWMP allowing price escalation for the period form 1992 to 1997.

2) Run-of-river intake

It is estimated based on the following equation.

$$Cri = US\$740{,}000 \times Qi^{3/4}$$

where,

Cri : Cost of run-of-river intake

Qi : Intake rate, $m^3/s$

A constant of US$740,000 is referred to the feasibility study of the Seven Towns Water Supply Project.

3) Borehole with powered pump

The construction cost of this source work is basically divided into (a) construction cost of borehole, (b) procurement and install of borehole pump with instrument, and (c) construction cost of electric power supply. They are estimated based on prevailing local market costs.

(2) Raw Water Main

It is derived from a cost curve (cost vs. design intake rate) which is presented in Supporting Report II. Unit construction costs for raw water mains (uPVC pipes) are estimated from the local contractors. Estimated unit costs vs. diameter are plotted on a cost curve.

(3) Treatment Works

It is estimated based on from a cost curve (cost vs. production capacity), which is presented in Supporting Report II.

(4) Storage Facilities

It is estimated based on a cost curve (cost vs. storage capacity), which is presented in Supporting Report II.

(5) Distribution Pipe Network

It is roughly estimated by applying a unit rate of Kshs 14,420/$m^3$ of water distributed. The rate is derived from average of water supply projects in Japan.

**Table - 8.3.1** presents the summary of the preliminary construction cost for the newly proposed urban water supply projects. Detailed estimate is presented in Supporting Report II.

### 8.3.5 Total Construction Cost

It is the sum of construction costs of the rehabilitation works, the ongoing projects, the planned/designed projects and the newly proposed projects to achieve the long-term urban water supply plan. The estimated investment requirement is US$ 1,322.2 million as broken down below:

Total Construction Cost for Urban Water Supply Development Plan

| Type of Project | Number of Projects | Amount (US$$10^3$) |
|---|---|---|
| Rehabilitation of Existing Projects | 120 | 44,400 |
| On-going Projects | 21 | 7,400 |
| Planned/Designed Projects | 21 | 27,400 |
| Newly Proposed Projects | 108 | 1,243,000 |
| Total | 270 | 1,322,200 |

Source: The Aftercare Study Team

The rehabilitation works, ongoing and planned/designed projects are mostly under jurisdiction of MWR and NWCPC. These organisations concerned will share the investment accordingly. It is supposed that MWR and NWCPC will continue to play predominant role for implementation of the newly proposed projects, though responsible executing agency will definitely be determined in the subsequent study stage. As the case may be, local authority or MOLA will participate in some urban areas.

## 8.4 Annual Operation and Maintenance Cost

### 8.4.1 Water Supply Facilities

The annual operation and maintenance cost is estimated for all the projects included in the long-term development plan in order to facilitate the project evaluation.

The cost comprises all expenditures which are required to keep a system in operation and good condition after it is placed on line. They include expense for annual maintenance and repair costs, operation costs (ex., salary, power, fuels, chemicals) and miscellaneous costs. Detailed estimate is presented in Supporting Report II.

(1) Cost for Fixed Asset Costs

The costs for civil works, pipelines and electrical/mechanical works are conservatively assumed to be 1%, 1%, and 5% of the initial construction costs, respectively.

(2) Salary Cost

According to the 1986 Design Manual, the minimum staff requirement of the treatment works is 13. In addition, there must be adequate number of meter readers, administrative staff, supporting staff, etc. The required total staff is, therefore, estimated as a function of total population served with water as reported in Supporting Report II.

(3) Chemical Cost

The unit rate is assumed to be Kshs 0.7/m$^3$ of water produced for chlorine and Kshs 1.3/m$^3$ for alum.

(4) Electric Power Charge

The electric power requirement varies largely from one scheme to another, characterised mainly by water treatment process and water intake and transmission. It is, therefore, very difficult to assess the electric power charge for each scheme under the present study. So, power cost was calculated in case of borehole, pump station of dam site, back wash pump for filtration and some office maintenance expenditure of illumination etc.

The estimated annual operation and maintenance costs is as shown in **Table - 8.4.1.**

### 8.4.2 Leakage Reduction Programme

It is hardly possible to estimate the cost for this programme because the actual situation varies greatly from one urban centre to the another. Especially in Kenya, this programme is recommended to be implemented as one of the national water supply sector programme comprehensively, without regard to urban water supply and rural water supply projects.

Referring to the actual annual expenditure of typical Japanese municipal water supply and taking into account of a difference in price levels between Kenya and Japan, it was roughly estimated at Kshs 3/m$^3$ of water produced.

### 8.4.3 Summary of Annual Cost

The annual operation and maintenance cost is summarised in the table below:

Annual Costs for Urban Water Supply

| Type of Project | Amount (US$ $10^3$) |
|---|---|
| Ongoing Projects | 1,676 |
| Planned/Designed Projects | 14,895 |
| Newly Proposed Projects | 14,235 |
| Leakage Reduction Programme | 5,705 |
| Total | 36,511 |

Source: The Aftercare Study Team

The annual operation and maintenance cost will be shared by the water undertakers concerned.

The leakage reduction programme is expected to be launched as a nation-wide campaign under coordination of every water undertaker.

## 8.5 Construction Period

The construction period of the project depends on the scope and natures of works, physical and natural conditions prevailing over the project area, method of construction, etc. The proposed urban urban water supply development plan is highly diversified in terms of source development (large scale dam, run-of-river intake, borehole) and status (ongoing, planned, designed). Taking such factors into consideration, construction method and construction period are worked out at a preliminary level.

### (1) Mode of Construction

It is assumed that all the projects proposed will be implemented by contractors, which will be procured through competitive biddings.

### (2) Feasibility Study, Detailed Design, and Financial Arrangement

For the proposed rehabilitation and newly proposed projects, it is absolutely necessary to do the feasibility study and detailed engineering design. The period required is assumed to be two years.

### (3) Pre-construction Procedures

This will cover prequalification tender, tender, and contract award and will be required for the proposed rehabilitation work, planned/designed projects, and newly proposed projects. This period is assumed to extend one year.

### (4) Construction Period

Depending on status and nature of the projects, construction period will be divergent. The assumed construction period is shown in the table below:

Assumed Construction Period

| Type of Project | Assumed Construction Period (Year) |
|---|---|
| Rehabilitation Works | 1 |
| Ongoing Project | |
| - Present progress less than 30% | 2 |
| - Present progress more than 30% | 1 |
| Planned/Designed and Newly Proposed Projects | 1 |
| - Project with borehole | 1 |
| - Project with run-of-river intake | 2 |
| - Project with a large dam | 4 |
| - Project with inter-basin transfer | 4 |

# CHAPTER 9 RURAL AND LIVESTOCK WATER SUPPLY DEVELOPMENT PLANS

## 9.1 Rehabilitation Works of Existing Facilities

As with the urban water supply schemes, it is proposed to rehabilitate the existing rural water supply facilities so that the quantity of water production can be restored to the originally designed level and water quality can be secured to the standard levels. Characterised by types of rural water supply projects, two different approaches are deployed.

(1) LSRWS

The LSRWS is quite identical to the urban water supply projects in terms of structural components, water resources, water supply capacity, and water served population. So, the concluded that scope of the rehabilitation works will be the same as that of the urban water supply project.

(2) SSRWS

As reported in subsection 3.1.3, there are 848 water supply systems in the country as of 1994 which are actually operated by communities, self-help mode, and NGOs. These could be classified into SSRWS and it is supposed that such systems have been increased.

It is hardly possible to systematically identify the present operation and maintenance status. In general routine and periodical maintenance and repair are supposed to be executed by means of participation of inhabitants, assistance of NGOs, and harambee, and therefore no public investment would be required.

## 9.2 On-going, Planned and Designed Projects

As with the urban water supply projects, it is not necessary to complete all the ongoing and planned/designed projects during the planning horizon, according to the water balance analysis. Therefore, screening was attempted to select the projects to be integrated into the long term rural water supply plan from the long list of ongoing and planned/designed projects. The selected projects are listed in **Table - 9.2.1.**

There are 556 ongoing water supply projects and 130 planned/designed projects, which form an integral part of future rural water.

MWR and NWCPC have all the relevant documents for their projects, and such projects will be implemented accordingly.

## 9.3 Newly Proposed Project

### 9.3.1 Design Criteria

In principle, the same design criteria as stated in subsection 8.3.1 will be adaptable even for the rural water supply project. It is, however, necessary to take cognisance of the following particulars.

1) It is assumed that protected dug well and/or boreholes are the major water sources. All facilities will be designed to protect from completely against possible pollution by human beings and livestocks.

2) Hand pumps installation at dug wells may be applicable for schemes that require water production less than 10 $m^3$/day.

3) Balancing tanks, where deemed necessary, will have a capacity of one-day water demand.

4) Roof catchment is considered as one of supply sources to meet institutional water demand including health facilities, churches, and schools located especially in the sparse rural areas.

### 9.3.2 Preliminary Design

Basically, newly developed LSRWS will have the same features as those of the UWS. On the other hand, the SSRWS will be small in terms of water served population and water supply quantity and similar to such existing SSRWS as being managed by community/self-help system.

One of the objectives of the Study is to ascertain at preliminary level the amount of investment required to achieve the long-term development plan for rural water supply. It is, howeve, hardly possible to locate the site of RWS, since each district is very large and its population scatters over a wide area. Therefore, the required investment can be rationally estimated by applying water supply scheme models. It is presumed that the number of served population, source facilities and distribution mode will govern significantly the investment amount. With those factors in mind, the following prototype models were developed.

Typical Water Supply Models

| Model Name | Water Supply Capacity | Target Population | Source Facilities | Distribution Type |
|---|---|---|---|---|
| SS-1 | 4 $m^3$/day | 200 | Dug well with hand pump | Point supply |
| SS-2 | 10 $m^3$/day | 500 | Same as above | Same as above |
| LS-1 | 600 $m^3$/day | 5,000 | Borehole with chlorination | Point and piped supply |
| | | | Surface water with full treatment | |
| LS-2 | 2,500 $m^3$/day | 20,000 | Same as above | Same as above |

Source: The Aftercare Study Team

As reported in Section 6.4, water resources development plan has been worked out for districts which face shortage of water supply even after completion of the rehabilitation works and the ongoing and planned/designed projects. On the basis of new water development requirement (water deficit) and water supply models presented above, water supply projects to be newly planned/developed are formulated for every districts.

(1) LSRWS

Either LS-1 or LS-2 or combination of both models will be applicable. The surface water use model will be deployed where perennial water is available in the river.

(2) SSRWS

Either SS-1 or SS-2 or combination of both modes will be applicable.

**Table - 9.2.1** presents a long list of the newly proposed projects in the respective district.

## 9.4 Livestock Water Supply Facilities

It is planned that the livestock water supply will depend on water pans and/or small dams. Storage capacity is assumed to be 50,000 $m^3$ per unit, according to NWMP. Climatic characteristics over the country are very diversified as reported in Section 2.2. ASAL areas are subjected to a relatively long dry period of 5-6 months as shown in **Figure - 2.2.1** and there are two rainy periods in a year. It is supposed the rain water and/or seasonal flow are available during the rainy period so that water storage is only required for the rest of the year.

**Table - 9.4.1** shows the number of small dams/water pans proposed for the respective district. It is assessed that 597 small dams/water pans are required to meet the long term livestock water demand in total.

## 9.5 Preliminary Construction Cost Estimate

### 9.5.1 Rural Water Supply Projects

The construction cost estimate was attained under the same general conditions as set forth in the subsection 8.4.1.

(1) Ongoing and Planned/Designed Projects

The construction cost of the respective project is quoted from the MWR Status Report and the NWCPC Status Report.

(2) Rehabilitation Works Cost

The rehabilitation works are proposed only for LSRWS. Its cost estimate followed the same method as for UWS.

(3) Newly Proposed Project

The construction cost is at first estimated for the respective typical model. The method of estimate is almost identical to that of the urban water supply project, and is reported in detail in Supporting Report II. Unit construction cost of the respective models is summarised below:

Unit Construction Cost of Model Project

| Model | Construction Cost (1,000 US$) |
|---|---|
| SS-1 | 1,980 |
| SS-2 | 1,980 |
| LS-1 | 1,566 |
| LS-2 | 2,801 |

Source: The Aftercare Study Team

The construction cost of SSRWS is estimated on the basis of the additional water development requirement and application method of the prototype model,

**Tables - 9.5.1** and **9.5.2** present the construction cost of the rural water supply projects for the respective district. The investment requirement to achieve the long term rural water supply plan is estimated as summarised below.

Estimated Investment Requirement for Rural Water Supply Plan

| Type of Project | Number of Projects | | | Construction Cost (US$ $10^3$) | | |
|---|---|---|---|---|---|---|
| | LSRWS | SSRWS | Total | LSRWS | SSRWS | Total |
| Rehabilitation of Existing Projects | 295 | 0 | 295 | 95,100 | 0 | 95,100 |
| On-going Projects | 239 | 313 | 552 | 54,200 | 13,500 | 67,700 |
| Planned/Designed Projects | 25 | 192 | 217 | 3,700 | 5,000 | 8,800 |
| Newly Proposed Projects | 52 | 51,131 | 51,183 | 84,100 | 101,200 | 185,400 |
| Total | 611 | 51,636 | 52,247 | 237,100 | 119,700 | 357,000 |

Source: The Aftercare Study Team

As the same as the urban water supply, the above investment will be borne by the water undertakers, though further continuous assistance by NGOs are expected especially in realisation of SSRWS.

### 9.5.2 Livestock Water Supply Projects

According to MWR's data, average construction cost of small dam/water pan is US$0.61/m$^3$ of active storage capacity, resulting in initial construction cost US$30,500 per small dam or water pan (50,000 m$^3$ x US$0.61).

**Table - 9.5.3** also shows the summary of the construction cost for the respective district. The total construction cost is estimated at US$ 18.2 million for the entire works.

## 9.6 Annual Operation and Maintenance Cost

### 9.6.1 Rural Water Supply Projects

The annual operation and maintenance cost of the rural water supply project is estimated basically by the same method as that adopted for the urban water supply projects.

**Tables - 9.5.1** and **9.5.2** shows the annual operation and maintenance cost by the type of projects and district. The summary of the annual cost is presented below:

Annual Costs for Rural Water Supply

| Type of Project | Amount (US$10$^3$) | | |
|---|---|---|---|
| | LSRWS | SSRWS | Total |
| Ongoing Projects | 13,183 | 746 | 13,929 |
| Planned/Designed Projects | 415 | 617 | 1,032 |
| Newly Proposed Projects | 1,120 | 757 | 1,877 |
| Leakage Reduction Programme | 8,029 | - | 8,029 |
| Total | 22,747 | 2,120 | 24,867 |

Source: The Aftercare Study Team

This annual cost will be dealt with in the same manner as the urban water supply.

### 9.6.2 Livestock Water Supply Projects

The proposed small dams/pans will be located in a relatively remote area and of earthfill structure. They are almost free from operation and maintenance; therefore, the minimum cost, one percent of the initial cost is allowed as annual operation and maintenance cost.

## 9.7 Construction Period

### 9.7.1 Rural Water Supply Projects

Each SSRWS is actually very minor in scope of work, so construction can be completed within one year period, without regard to the fact that there is a great number of such SSRWS in the district concerned. Normally it is common practice from the donor's view point that the rural water supply project will be implemented on a basis of district unit, as experienced in the Kajiado, South Nyanza and Kakamega districts. Accordingly it is assumed that rural water supply plan will implemented on a basis of district unit. On the other hand LSRWS will normally require the same construction period as that of UWS.

Assumed Construction Period

| Type of Project | Construction Period (Year) | |
|---|---|---|
| | LSRWS | SSRWS |
| Rehabilitation Works | 1 | - |
| Ongoing Project | | |
| - Present progress less than 30% | 2 | 2 |
| - Present progress more than 30% | 1 | 1 |
| Planned/Designed and Newly Proposed Projects | | |
| - Project with borehole | 1 | 3 |
| - Project with run-of-river intake | 2 | |
| - Project with large pond | 2 | (for entire district without regard to type of project) |

Source: The Aftercare Study Team

### 9.7.2 Livestock Water Supply Projects

Actually, MWR in many cases has been mobilising its own resources for construction of small dams/water pans. Major work is earth moving/excavation, and it does not require complicated concrete and/or mechanical installation. As such it is assumed a three-month period for construction of each structure.