Water loss investigations in the distribution system of Dar es Salaam, Tanzania

by

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ABSTRACT

This study was carried out to investigate water losses in the distribution system of Dar es Salaam. The water supply in Dar es Salaam has not met water demand for the past eight years. Some areas of the distribution system have been under intermittent water supply and in other areas the supply is very unreliable, hence affecting production in industries and other important activities in hospitals, institutions and in domestic consumption.

The objective of this study was to establish which areas of the distribution system have biggest water losses, what is the percentage of unaccounted-for-water or water loss in the distribution system of Dar es Salaam and what are the key factors influencing water losses in the distribution system.

The water loss investigation methods used include the use of bulk flow meters to measure raw water inflow and plant outflow to check if there is more process water than the minimum required. In conveyance mains water loss investigations were done by direct measurement of leaks along the trunk mains and to supplement this study a comparison was made between plant outflow rate and inflow rate at every distribution reservoir. All known consumers along the trunk mains were documented and their average consumption per connection estimated using flow meters. The distribution reservoirs were investigated by carrying out a drop test and overflow test. The distribution network was investigated by minimum night flow (MNF) measurements in three pilot areas.

The study on water loss investigations in the distribution system of Dar es Salaam revealed that there is a high percentage of water loss or unaccounted-for-water averaging to 43 % of the total water production.

The reliability of these results was ascertained by a supplementary investigation whereby water put into the supply system was compared to water billed. The investigation revealed that only 51 % of total water produced was billed, and 49 % was unaccounted-for-water. Furthermore, studies done on plant design capacity utilization showed that 19 % of the plant capacity was not utilized and there was a high percentage of process water averaging to 15 %.

Rehabilitation and extension of water supply network as well as extension and building of new waterworks is required to augment the rising water demand of Dar es Salaam. Water losses in the distribution network should be cut down to an acceptable level by starting well planned water loss investigation and control programmes.

1 INTRODUCTION

Water loss investigations in distribution systems provide vital knowledge on the working condition of the network. The information obtained enhances the analysis of water loss problems. It assists in decision making, either in carrying out rehabilitation or both rehabilitation and extension of the water supply networks.

This study was intended to establish the quantity of unaccounted-for-water in the distribution system of Dar es Salaam. The causes of unaccounted-for-water were to be investigated. Measures to control water losses were to be recommended.

Water loss investigations and control in the distribution system are necessary for proper functioning of a water system. Measures to control water losses could decrease the costs of water treatment.

Water loss investigations have not been carried out recently in Dar es Salaam. A study on Dar es Salaam Property Survey was conducted in 1987 (Price Waterhouse Associates 1989).

The following definitions have been used in the study.

Total water loss or unaccounted-for-water is the difference between the total water production at the plants and the amount of water supplied to consumers.

Unaccounted-for-water is given by the following formula:

$$U = S - (M + a \times P) \qquad (1)$$

where
- U = unaccounted-for-water
- S = total water production at the plants
- M = total metered consumption
- a = unmetered per capita consumption
- P = population served

The unaccounted-for-water is expressed as percentage of the total water supplied (Bays 1984).

Unaccounted-for-water includes:

a) leakages from transmission main

b) leakages and overflows from service reservoirs

c) leakages from the distribution mains and service pipe connections

d) leakages and wastages on consumers' premises i.e. wastage from public and individual stand pipes, watering gardens from unmetered connections, illegal connections and under-recording of water supplied due to faulty meters

e) incorrect estimation of domestic per capita consumption i.e. unmetered domestic premises

f) inaccuracy of bulk supply meters or wrong estimation using installed capacity of the supply pumps

g) water used for fire fighting and street flushing which are not metered.

Leakage is the water lost or escaping through the leaks of pipeline, fittings, hydrants etc.

Wastage is the water, which after it has been put into the distribution system, is not effectively used by consumers; either water is allowed to overflow in water tanks, escapes in leaking stand pipes, or escapes in defective WC-cisterns.

Water accounted for is the water known to have been taken from a supply, distribution system and consumers' installation for any purpose which can be assessed in an accurate manner.

Acceptable water loss is the water used in processing in water treatment plants in sludge bleeding off and backwashing of filter beds. It also refers to loss occuring in the system which will be uneconomic to trace and repair.

2 WATER LOSSES IN DISTRIBUTION SYSTEMS

2.1 Sources of water losses

a) Metering losses:

These occur due to under-recording of water supplied from the source and after treatment because of faulty meters. The under-registration is caused by the failure of the meter to register low flows, especially at night when there are dripping taps, leaking ball valves etc.

b) Distribution losses:

Wastage of water from leakages and overflows from service reservoirs, from distribution mains, service connections and through valves and fittings.

c) Consumer wastage:

This consists of water wastage on consumer side of the meter. Like distribution losses, also consumer wastage can be estimated by minimum night flow (MNF) measurements on domestic premises during the night hours (e.g. 1.00 - 4.00 hours) because legitimate use of water at this time is considered minimal. The highest allowable MNF in domestic areas is 1.0 l/h per household (Giles, cited by Twort et al 1987).

d) Water taken through unauthorized connections must be detected by carrying out house to house survey to keep the losses to a minimum.

e) Other losses include incorrect estimation of domestic per capita consumption in unmetered system.

2.2 Factors affecting water losses

2.2.1 Pipe materials

Careful design and selection of pipe material is important for a proper functioning of a distribution system. The different pressures required in various parts of the system, the soil conditions, the aggressiveness of the water and the availability of pipe materials are necessary considerations to avoid fast deterioration of the pipes and consequently water losses in the system (Haymero 1988).

2.2.2 Corrosion

Internal deterioration of the pipes is caused by many factors, corrosiveness of the water, poor internal coating of the pipes etc. The corrosive action of the water should be checked at the water treatment plant.

External corrosion of pipes is mainly due to the electro-chemical reaction between the pipe and the environment where the pipe is laid. The existence of a potential difference between the two areas of a metal surface where electrons migrate from a metal of low potential (anode) to a region of high potential (cathode) increase the rate of external corrosion (Snoeyink and Jenkins 1980). For iron and steel pipes the best external and internal protection available is cold applied black bitumen or hot applied bitumen based coating.

The coatings are sprayed or brushed on the pipe surface. Coal tar can also be used. Iron and steel pipes can be protected using a polythene sheeting. Steel pipes can also be protected using cathodic protection methods.

2.2.3 Effects of pressure

Pressure to be maintained in a distribution network depends on the ground elevation, height of buildings and fire fighting requirements in the area.

It is not necessary to maintain very high pressure in the system. High pressure will increase water losses from leaks in the pipelines.

Areas with buildings not exceeding three storey height, 200 kPa at peak hour flow is considered sufficient. Areas with buildings of more than three stores high are provided with 300 kPa pressure. A distribution system in undulating areas is provided with static pressure of 800 kPa for smooth operation. However, in places where water is provided through stand pipes only, pressure of 100 kPa is sufficient and low pressure stand pipe taps can be used to avoid unnecessary loss of water (Twort et al 1987).

Unbalanced pressures in the network are undesirable. Low pressure in the system causes customer complaints. High water pressure may lead to pipe bursts and high leakage rate. Thus pressure variations in the network should be avoided wherever possible to minimize pressure surges which in many distribution systems are major causes of pipe bursts and high leakages.

Pressure surges in pipelines continue only for a short period of time but they cause very bad effects in pipelines including fluid compression, pipe wall straining etc. They become more destructive when the pressures in the pipelines are higher and can lead to pipe rupture and cause loss of water (Chadwick and Morfett 1986).

High water pressure affects leakage level in the distribution system. Reduction of pressure in the network will have three effects on leakages:

1) reduction of the rate of leakages

2) reduction of the rate of pipe bursts

3) helps in detecting a leaking network since small leaks will discharge more water during high pressure.

The rate of leakage reduction with pressure was investigated by Water Research Centre in England. Research was carried out by operating the distribution network at different pressures every night. The MNF measurements were taken using waste metering. When MNF figures were plotted against average zone night pressure for each night, a relationship was discovered revealing that for zones with maximum pressure of 500 kPa or below, MNF was directly proportional to the pressure. In zones with pressure between 500 - 1 500 kPa the relationship was plotted as an upward curve (Figure 1).

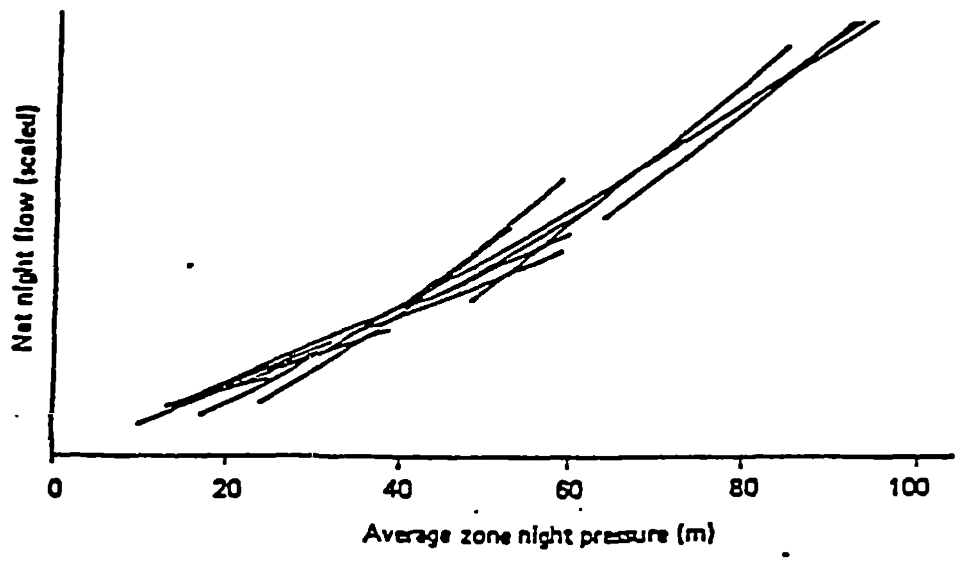

Figure 1. Graph of scaled net night flow and pressure relationship (Goodwin 1980).

For operational flexibility and to avoid excessive pressure in some areas of the distribution network, it is advisable to divide the system into different pressure zones. The different pressure zones are interconnected by pressure reducing valves or break pressure tanks. Break pressure tanks are preferred because they guarantee better protection to the pipelines in the lower distribution area and hence save the system from excessive leakage (Twort et al 1987).

The Dar es Salaam water distribution system is divided into two pressure zones: the lower pressure zone and the higher pressure zone. The lower pressure zone and the higher pressure zones get water from different water distribution reservoirs located at University Hill and Kimara respectively.

The Dar es Salaam water demand exceeded the supply of the water works since 1982. The water pressures in the network have been so low, that some areas of the distribution system have been under intermittent water supply for a long time. Therefore reduction of pressure in the distribution system of Dar es Salaam will not bring considerable benefits. In fact it will escalate the low distribution pressure problem. Results of pressure readings taken in the low pressure distribution zone are shown in Appendix 2.

Pressure control in the distribution system has some advantages:

- Unnecessary pressure variations should be avoided. High variations cause high pressure surge in pipelines, which may cause pipe bursts and high rate of leakage.

- Small reduction of pressure in high pressure zones can result in low water consumption. Careful study should be done whether pressure reduction in an area is useful.

- Pressure reduction in intermittent water supplies is not useful.

2.2.4 Other factors

Other factors affecting leakages include:

- type of ground soil where the pipeline is installed

- connection density; many connections in one pipeline and especially if the connections are not made properly high water losses may be occurring

- age of pipelines; rehabilitation of the distribution network should be well planned before the pipeline becomes very old, which could result in a great loss of water

- quality of the pipe fittings

- works done by a third party, e.g. sewerage, electricity etc.

- workmanship; e.g. transportation of pipes to working sites, pipe storage, pipe laying and jointing, etc.

2.3 Methods of water loss investigations and control

2.3.1 Passive leakage control

The leaks which become apparent are repaired. These include those which appear on the surface of the ground, leaks found due to customer complaints of low pressure or no flow and those which are discovered by water authority workers while doing other tasks.

2.3.2 Active leakage control

By this method the water authority makes efforts to survey and repair visible leaks. A water survey team walks along the mains inspecting possible leaking areas (e.g. areas seen flourishing with green grass during dry season indicate leaks), checking flows in drains etc.

2.3.3 Regular sounding

The method establishes the presence of leaks by their sound. Fittings on mains and service lines are sounded at predetermined frequency.

Equipment and tools include listening stick and electronic device like leak detectors, leak noise correlator etc.

2.3.4 District metering

Flow into network districts containing upto 500 connections is recorded by meters installed at points where flow into the districts is supplied through only one main. The meters are read at regular periods, for instance weekly or monthly. Any district indicating high water consumption should be surveyed and sounded to detect leaks (Twort et al 1987).

2.3.5 Waste metering

In this method, meters capable of recording low flow rates are installed permanently or temporarily in areas having 500 - 1 000 connections. The meters are read quarterly. If waste metering is indicating continuously high meter readings in a certain area, more specific minimum night flow measurements should be carried out in the area (Twort et al 1987).

2.3.6 Combined district and waste metering

District meters are used to check whether the unaccounted-for-water has increased while the waste meter records more precisely the location of leaking area. The leakage area is possible to locate because the distribution network has been reduced from a district of upto 5 000 connections to an area of 500 connections.

2.3.7 Pressure control

Pressure reduction can be applied in addition to the other methods of leakage control.

From basic fluid mechanics it is understood that leakages vary with the square root of pressure. It has been found out that leakages within a distribution system behave differently. A reduction in pressure causes a proportionate large reduction in leakage. This can be explained by the pipe or joint material flexing with higher pressures and widening the orifice size and hence increasing the volume of leakage. Thus during water loss investigations the relationship between pressure and leakage can be used to estimate the extent of unaccounted-for-water in an area. This is possible when the MNF and the average night pressure have been measured (Ridley 1976).

2.4 Water loss investigations in a distribution system

2.4.1 General

Planning for water loss investigations requires understanding of present and future water consumption of the system. Consumption can be determined by the water authority's records. The precise way is to make field measurements. This will eliminate errors in record keeping and meter reading.

The treatment plant output to the distribution reservoirs and from the reservoirs to the distribution network must be checked for accuracy. Bulk flow meter or pitometer may be used to measure pipe flow or drop of level in distribution reservoirs to measure flow to the distribution area.

Water demand varies from one district to another in a distribution system. To get a clear understanding of the variation, measurements should be made in each district isolated by control of valves. Flow into various districts is measured by pitometer, bulk flow meters, ultrasonic flow meters etc.

The magnitude and type of water demand (residential, industrial or commercial) can be determined and at the same time readings compared with residential, industrial and commercial meter readings.

From the investigations, an estimate of the consumption can be made in each district. Areas of different classes and different per capita consumption are measured. When all people are assumed to get adequate supply, a potential water demand of the district is obtained.

In practice, people may not get as much water as they need, thus there will be an unsatisfied demand. An equation between the supply and demand can be written (Twort et al 1987).

$$S_A = D_p + W_{dc} - D_u \pm M_e \qquad (2)$$

where S_A = actual supply
D = total potential demand
W_{dc} = distribution and consumer wastage
D_u = unsatisfied demand
M_e = metering error

When supply can meet all the demand in 24 hours, D_u can be dropped from the equation (2). The same applies to M_e if this has been appropriately estimated.

If supply is adequate and district metering or waste metering is practised more consumption than expected indicates unaccounted-for-water or loss of water in the district.

Proper operation of a water supply network requires system-wide water auditing from time to time. Such evaluations include meter testing, supply quantities, system pressure, pump head curves system inventory and updating of drawings etc. Auditing provides data on key parameters which are needed during the evaluation for system expansion, mains repair and replacement, meter repair and replacement. This will finally give data to reduce revenue loss through leaks.

Waste control of a water utility starts at the source of supply. The accuracy of bulk meters at the source must be checked from time to time. Bulk flow meters indicate the amount of water supplied to the system. The accuracy of all meters in the system is critical in tracing unaccounted-for-water. Bulk flow meter (domestic, commercial or industrial) should be checked, maintained and calibrated so that the amount of water supplied should be accurately recorded. If 5 % of the water used by consumers is not registered, there is a direct revenue loss of 5 % (Cori 1985).

Testing of water meters can be done using a pitometer connected through a tap in a straight portion of a main downstream or upstream of a flow meter. Bulk meters including those which serve large domestic, industrial and commercial consumers should be checked annually (Cori 1985).

2.4.2 Investigations on conveyance mains

Wherever there is flow, there is a drop in pressure. By measuring drops in pressure in fire hydrants or at special points along the main will give the trend of water consumption along the conveyance main. High pressure drops indicate high flow rate somewhere within the main (Franklin 1983).

The method commonly used to investigate water loss on conveyance main is to use a bypass meter or pressure gauge. All service connections are shut off from the main. Two valves on the main are selected and closed. Tapping on either side of the upstream valve is made for connecting a by-pass meter. If a pressure gauge is to be connected, only one tapping point between the valves is used.

When a main is put under flow or pressure test, the readings recorded on the meter or drop of the pressure gauge indicate leakages or illegal connections (Twort et al 1987).

This method does not locate specific leaks, but it identifies the probably leaking mains. Location of the leak can be identified by conventional methods of sounding, visual observations, use of modern equipment like leak noise correlator, thermal images, etc.

The leakage found in the flow test should be compared with the amount of leakage allowed in new mains. Leakage allowed in new mains varies from 5.5 to 23 l/km of pipeline in 24 hours (Steel and Terence 1988).

The American Water Works Association's specifications require that no pipe installation should be accepted until the leakage is less than that indicated by the formula (3).

$$L = (N \times D \times P) / C \qquad (3)$$

where L = allowable leakage (l/h)
N = number of joints in the pipeline tested
D = average test pressure during testing (kPa)
C = constant depending on units
= 326 (l/h, mm, kPa)

Pipeline testing length should not be more than 300 m. A test pressure of 50 % above the normal working pressure is recommended (Steel and Terence 1988).

2.4.3 Testing of reservoirs

Leakage testing of reservoirs is done by isolating the reservoirs from supply. The inlet, scour and outlet valves must be checked for drop tightness by sounding. Some reservoirs are constructed with provision of short removable sections of the mains on the outlet side of the valves. These sections can be removed and outflow measured.

The rate of leakage in reservoirs can be found by measuring the change in water level over a period of time (drop test). In most cases it is not practical to isolate the reservoir for longer periods, more precise measurements of the change in water level up to 1 mm in two to four days is required.

Leakages from service reservoirs do not represent large portion of the total losses. Gross leaks and overflow however occur and should always be checked. According to British Standard BS 5337 water level drop in a new reservoir should not exceed 1/1 000 of the average water depth of the full tank in seven days (Twort et al 1987).

Reservoirs are constructed with underdrains. These are constructed so that they could give an indication of location of leakage. If outflows from the underdrains are measured from time to time, a change from the normal flow should indicate leakage.

To find at what depth of the tank the possible leak is, the rate of leakage should be measured at full depth, half depth and at about 1.0 m above the floor. The outflow from the drains should be measured before and during the test and also after the test for each level to be tested.

If leakage is not located by use of different water levels, internal inspection of the reservoir after it has been emptied is done. The concrete walls should be observed when drying because a dark patch could show a poor area of concrete where leakage is taking place. The floor and wall joints should be examined. The jointing material should be inspected thoroughly. Most reservoir leakages come from these defects.

"Drop test" can also be used as a preliminary method to check the unaccounted-for-water or water loss situation in the distribution system. In an area where night consumption is not considerable, the fall of water level in the reservoir indicates the level of leakages in the system. A drastic drop of water level from the normal would indicate pipe burst somewhere along the rising main.

2.4.4 Investigations in distribution network

Water losses in the distribution network account for a high percentage as compared to those in conveyance mains etc. A study made in Tokyo Metropolitan Waterworks showed that more than 90 % of total leakages come from the distribution network (Sugawara 1985).

2.4.4.1 Minimum night flow measurements

Measurement of minimum night flows (MNF) needs careful planning and preparation. The preparatory work includes the following:

1) The distribution network map of the zone should be checked by field inspection and updated.

2) Location of a section/zone of the distribution system having about 1 000 connections.

3) Collection of consumer statistics of the area i.e. metered and unmetered house connections.

4) The boundary valves of the district or zone must be located, inspected and tested. The valves must be working properly to control inflow or outflow from the zone.

5) The zone should be tested for isolation from others by closing the boundary valves and feeding the zone through a single main.

6) The daily water consumption in the zone is measured by a flow meter or by reading individual meters in the zone to get the actual per capita consumption of zone.

   To assess total loss in the zone, a by-pass meter is temporarily installed or a waste meter is permanently installed around the valve to gauge the flows.

After all preparations are completed the minimum night flow measurements can start.

The control valve on the single supply main is closed. The total night flow passes through the waste meter. A meter which can measure low flow rates, generally a 15 mm or 25 mm displacement meter is preferred (Goodwin 1980).

The unaccounted-for-water in the zone can be calculated using formula (1).

Total unaccounted-for-water flow rate of 30-40 l/property/h indicates leakage problems and a leak detection check is advisable (Bays 1981).

The percentage of waste flow in a predominantly residential area can be calculated as (4):

$$\frac{\text{Unaccounted-for-water}}{\text{Average daily flow}} \times 100 \qquad (4)$$

Waste flow levels upto 10 % may be considered low. When the waste flow level is 20 - 50 %, it should be considered as excessive leakage and investigation should be started (Raman 1978).

Minimum night flow has less effect in estimating leakages in intermittent water supply. The method used to assess leakages in such situation is to close stop corks or taps in all house service lines and the recorded flow in the bypass meter indicates the waste of water in the zone. The percentage of leakage is expressed as the ratio of flow in the system with stop corks closed to the average daily flow. Leakage of 5 - 7 % is considered normal and leakage level of 10 - 20 % is unsatisfactory (Raman 1978).

In full metered water supplies where all connections are metered and metering system is accurate, the unaccounted-for-water is the difference between the total metered input to the system and the total measured by consumer meters. The consumer wastage and leakage in this case are under the responsibility of consumers because the wastages are measured in consumer meters.

Generally unaccounted-for-water will include under-registration of consumer meters. Small domestic meters tend to under-record consumption when aging. When meters are upto five years old, they under-record consumption by at least 2 % and when more than five years old under-registration is at least 3 % (Twort et al 1987).

2.4.5 Frequency of water loss investigations

After the water loss investigations have been completed, all leaking lines identified and leaks located and repaired, the analysis should not be stopped. The water loss investigation programme should not be a once-and-for-all operation. There should be a well planned schedule of water loss investigations. It has been shown in some water

authorities where water loss investigation programmes are implemented, leakage could be decreased to 50 % or more. However, the system will inevitably deteriorate again (Hammerser and Bachmann 1984).

If water loss investigation programme is carried out frequently in different districts, information on the frequencies in which the district should be inspected is obtained; sources and causes of leakage can be ascertained. A phased programme enables a water utility to give priority and survey the suspected portion of the network and hence a continuous leakage control programme can be established.

3 WATER LOSS INVESTIGATIONS IN DAR ES SALAAM WATER DISTRIBUTION SYSTEM

3.1 General description of the study area

The Dar es Salaam water distribution network is about 400 km long. The network was constructed between 1950-1976. Materials used are cast iron, ductile iron, PVC, steel, reinforced concrete and asbestos cement. Figure 2 shows the main lines of the water distribution network.

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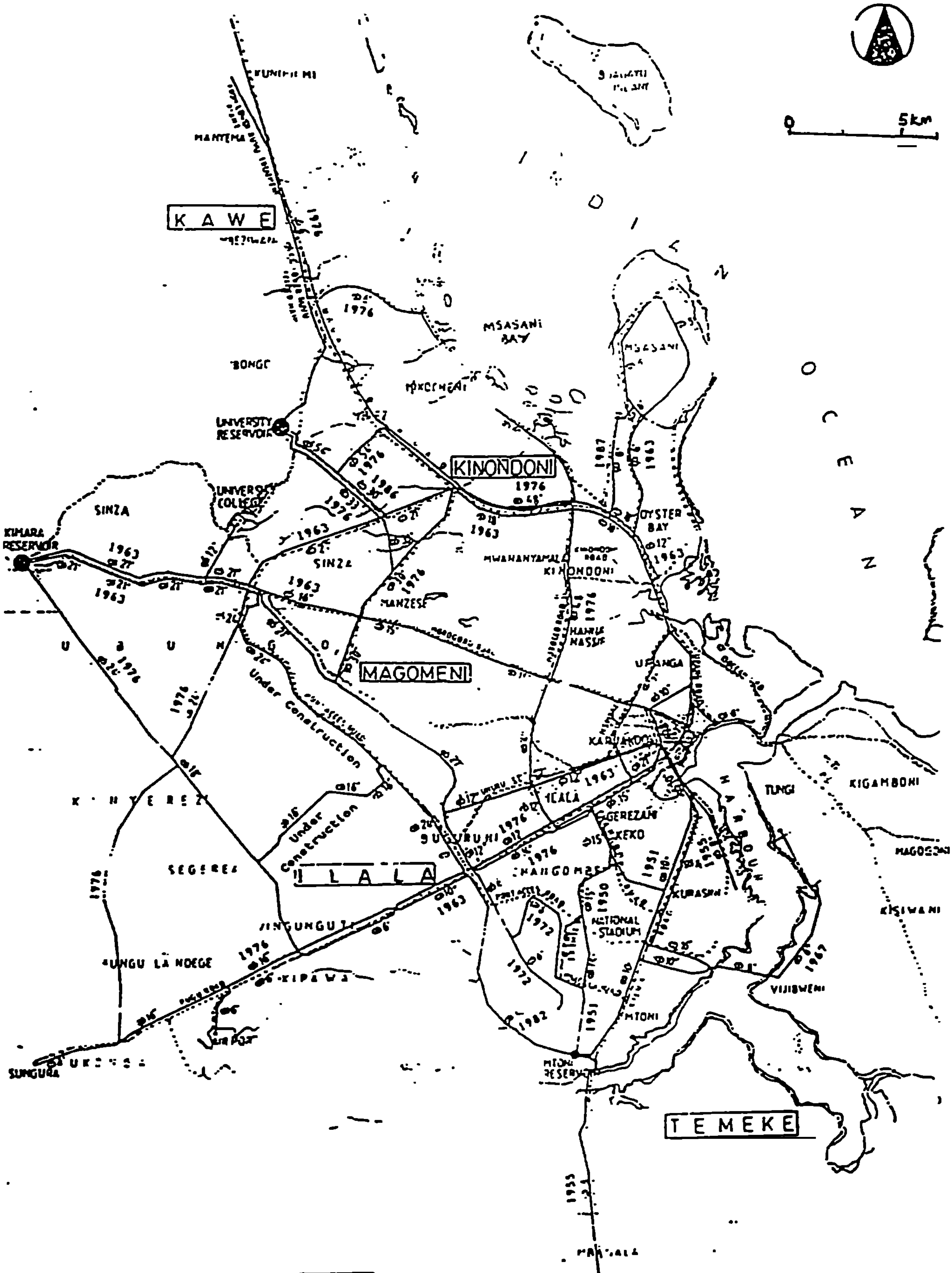

Figure 2. Dar es Salaam water distribution network.

Three water treatment plants are feeding the distribution system: Lower Ruvu, Upper Ruvu and Mtoni (Figure 3). The Lower Ruvu and Upper Ruvu plants with capacities of 18 000 m^3/d and 81 000 m^3/d respectively take the raw water from Ruvu river about 60 km west of Dar es Salaam. Mtoni water tretment plant with capacity of 9 000 m^3/d takes the raw water from Kizinga river about 4 km south-east of Dar es Salaam. Table 2 shows the dates of construction of the treatment plants.

The Upper Ruvu transmission main has two parallel lines each 60 km long, the first with diameter of 500 - 600 mm, and the second 520 - 750 mm.

The Lower Ruvu transmission main is 50 km long with diameter of 1 350 mm. Mtoni water treatment plant is pumping directly to the distribution network.

The Dar es Salaam water demand exceeded the capacity of the water works since 1982. Expansion of the networks was continued without due consideration of the supply capacity available. No extensions or construction of new water works were done in time to meet the rising water demand.

The population of Dar es Salaam is 1 360 000 (Tanzania Census 1987). The number of properties connected to water supply network by June 1989 was 50 000, assuming that each property connected consists of eight water consumers. Thus 35 % of Dar es Salaam population have piped water connections. The percentage of population connected to water supply is doubtful.

Dar es Salaam water distribution network has very few control valves, e.g. pressure regulating valves, non return valves, air valves etc. During high flows there is low pressure in the higher elevated areas of the network and during low flows there is very high pressure in the low elevated areas of the network.

Water supply and distribution systems should be planned and designed for a certain design period, assuming that at the end of the design period the water demand of the supply area may equal or exceed the the capacity of the system. When this occurs, new facilities or expansion of the system should be implemented. In Dar es Salaam, an expansion to the water supply system or new water treatment plants should have been in operation already by 1976 to provide the additional capacity to satisfy the increased water demand.

There is lack of systematic action programme for network development and leakage control in Dar es Salaam. The network expansion has not been in line with plant extensions; the distribution system has been extended without due consideration of the amount of water supplied by the water works. This has resulted in intermittent water supplies in some areas of the distribution system.

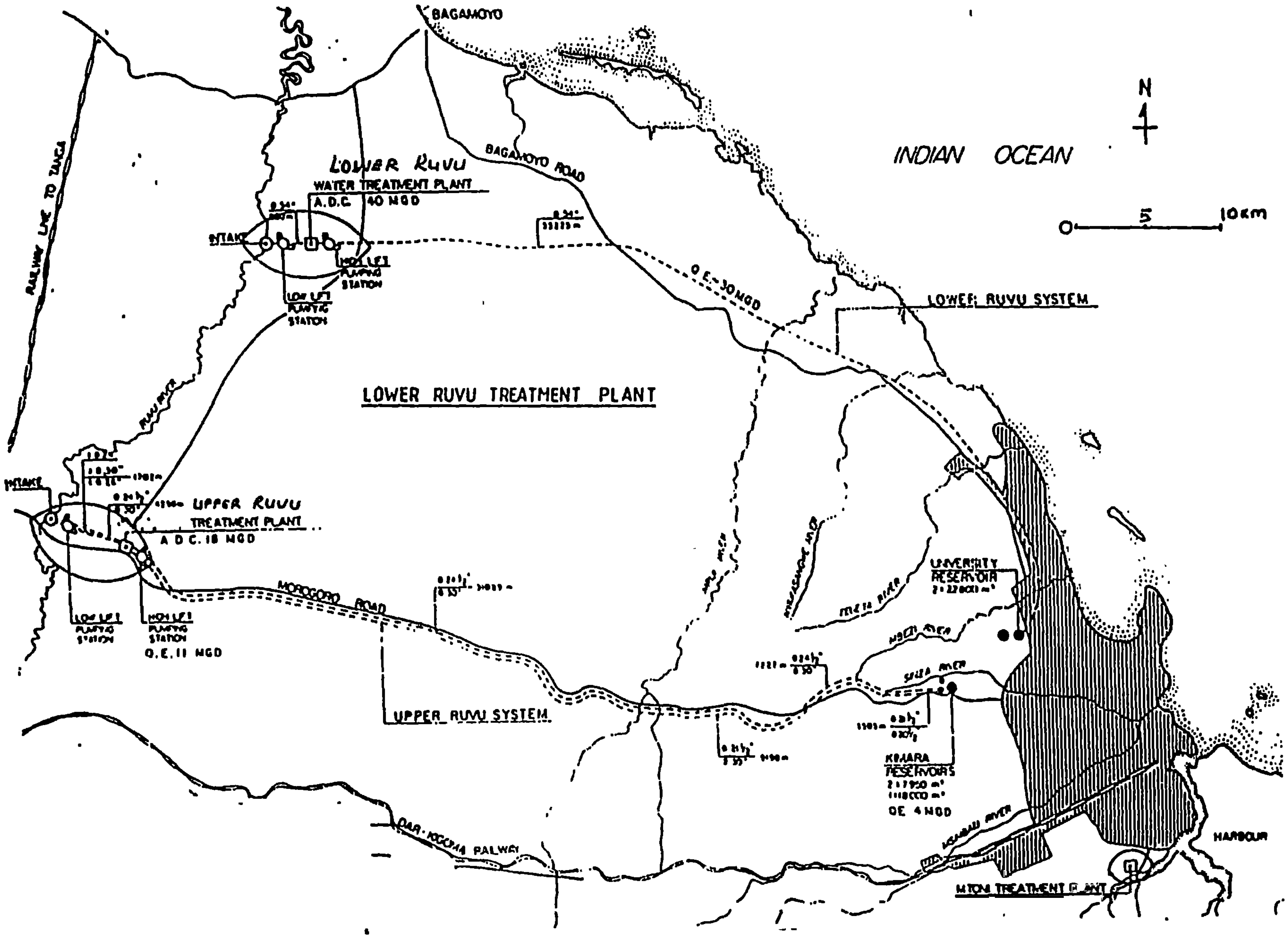

Figure 3. Water treatment plants and their location.

3.2 Water demand, production and consumption in Dar es Salaam

The present average water demand of Dar es Salaam is 360 000 m^3/d and the total design capacity of the three water treatment plant is 270 000 m^3/d. Water production was meeting water demand up to 1982 when demand exceeded production (Figure 4 and Table 1).

Table 1. Dar es Salaam population and water demand forecasts upto year 2000.

Parameter	Unit	Year			
		1989	1990	1995	2000
Population	10^3	1360	1555	2170	3030
Water demand	10^3 m^3/d	360	405	540	725
Plant design capacity	10^3 m^3/d	270	270	270	270
Water production	10^3 m^3/d	230	240	240	240
Shortage of water supply	10^3 m^3/d	130	160	295	480

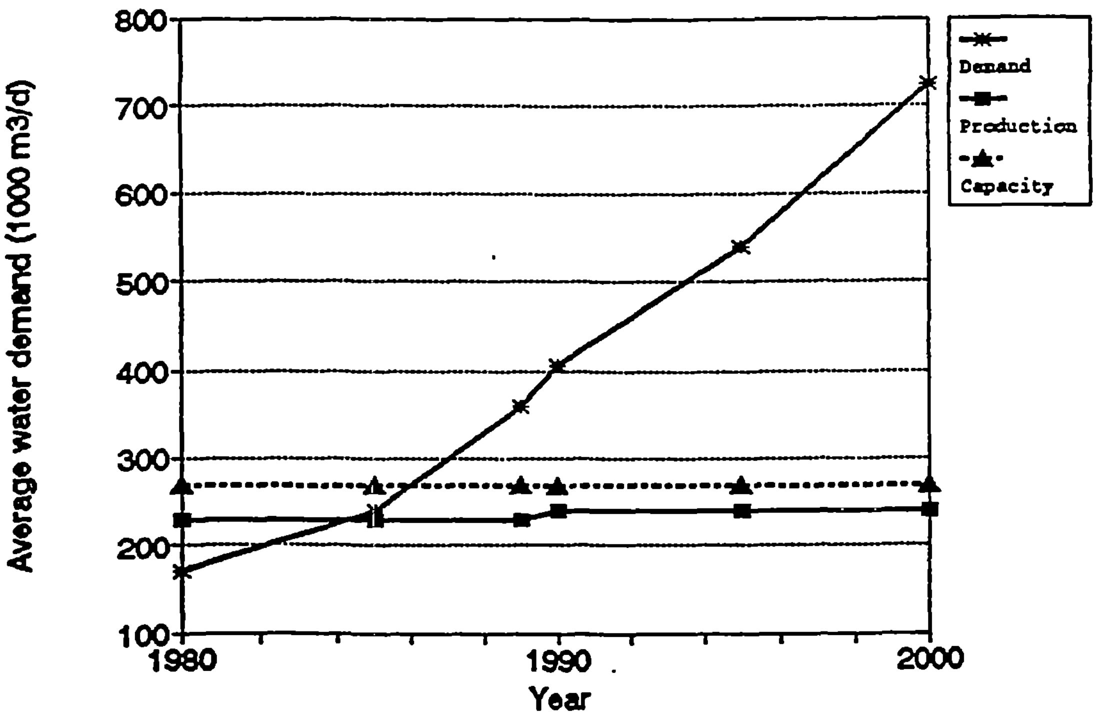

Figure 4. Water demand, actual water production and water treatment plant capacity.

The shortage of water supply as shown on Table 1 and Figure 4 has resulted from :

- lack of expansion of the existing water treatment plants since 1976

- no addition of new water sources to the existing water system despite of the rapid expansion of Dar es Salaam population

- old age of the water distribution system whose useful life is normally assumed to be 15 - 20 years.

The above situation has led to the loss of supply capacity and supply not meeting water demand of Dar es Salaam.

Some areas of the distribution system, particularly in the outer fringe of the city are without proper water distribution network. The area can have only one main in the vicinity, hence a few people could afford the cost of installing long service lines. Such areas contribute to the high level of unaccounted-for-water in many ways:

- Individual stand pipes serve as free public kiosks for the whole area while the owner pays an average bill per month to the water authority.

- The owner vends the water, hence denying revenue to the authority.

- Water is wasted in irrigating small farms and gardens using treated water.

- Vandalism on conveyance main exists when desperate people search for water in areas without distribution network.

Figure 5 shows how it should be considered during the life time of the working of a water supply system in timing of the extension or expansion of the water works to take care of the expanding of daily water demand as compared to the reduction of water works supply capacity.

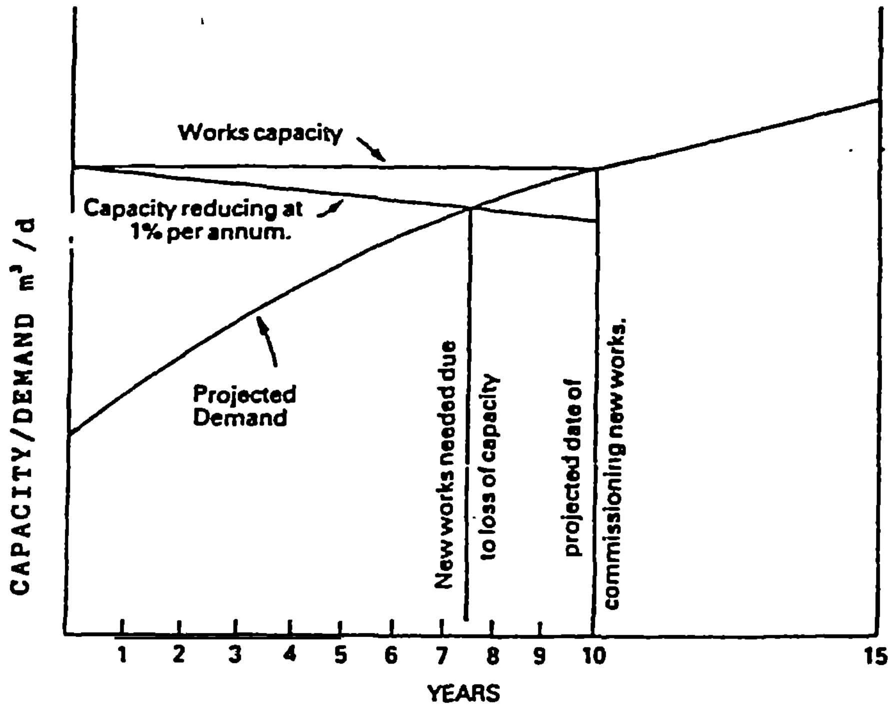

Figure 5. Timing of construction of new waterworks.

Table 2. Water treatment plant capacity and actual water production (in November 1989).

Water treatment plant	Design capacity 1000 m^3/d	Water production 1000 m^3/d	Year of construction	Remarks
Lower Ruvu	180	171	1976	Conveyance main = 50 km
Upper Ruvu	81	44	1954	Conveyance main = 60 km
Mtoni	9	4	1952	Pumps directly to the network
Total	270	219		

<u>Comparison between water production and billed water consumption in Dar es Salaam</u>

During the study, records on raw water pumped and treated water produced were studied. Records on three water treatment plants were analyzed. Records at Upper Ruvu plant were based on the designed capacity of pumps. At Mtoni and Lower Ruvu plants there are bulk flow meters which give the actual water production.

All bulk flow meters were checked for accuracy using an ultrasonic flow meter. The difference of bulk flow meters and ultrasonic flow meter indicated 2 % error. This was considered small and readings on bulk flow meter were assumed correct.

The records available on billed consumption and consumers served seem to be inaccurate. Some of the zones do not have records. Table 3 and Figure 6 show produced and billed water amounts in 1988 - 1989.

In 1988 the plants produced 91 million m^3 of water and 41 million m^3 was billed. The billed water amount is 45 % of the total water production at the three water treatment plants. In 1989 water production was 95 million m^3 and only 48 million m^3 was billed, which is only 51 %.

From the above general comparison, it can be observed that 55 % and 49 % are unaccounted-for-water percentages for 1988 and 1989 respectively. This is a high percentage of water loss. The difference between water pumped into the distribution system and water billed gives an indication of how much water is unaccounted for. It gives evidence of:

- inadequacies of metering
- incorrect billing procedures
- inefficient use of the water sources and mismanagement of the water distribution system. In a water distribution system which is efficiently managed, the water bills must generate enough revenue which should be equal or more than the fixed and variable costs.

Table 3 shows the detailed billed consumption records in 1988 - 1989.

Table 3. Water production and billed consumption in Dar es Salaam 1988 - 1989.

	1988			1989		
Treatment plant	Raw water	Treated water	Billed water	Raw water	Treated water	Billed water
	1000 m^3/a			1000 m^3/a		
Mtoni	2500	2031		1217	961	
U/Ruvu	25677	20407		25020	21180	
L/Ruvu	73200	68600		76400	72700	
Total	101377	91033	41000	102637	94641	43000

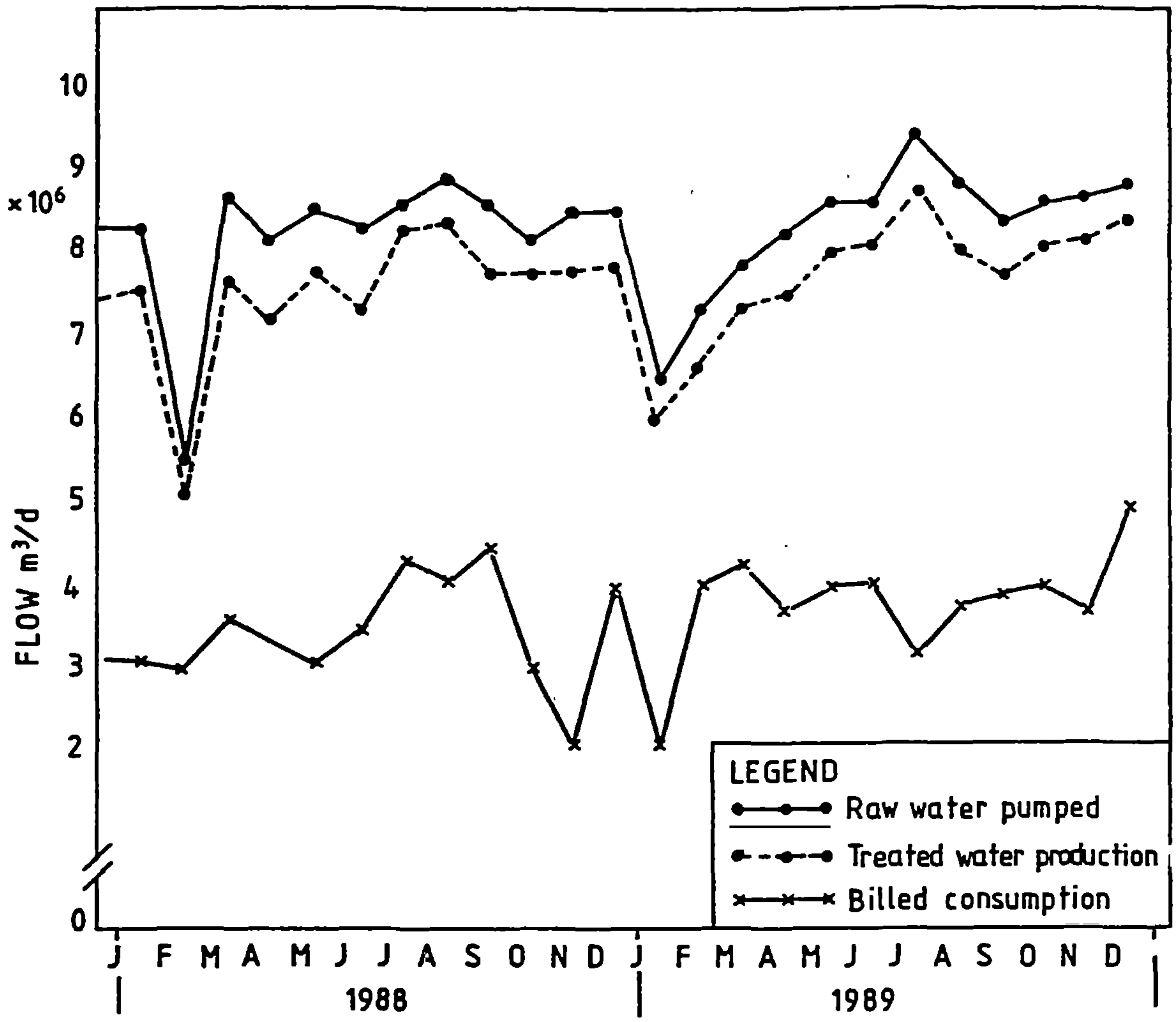

Figure 6. Water production and billed consumption in 1988 -89.

3.3 Methodology of the investigations

3.3.1 General

The following methods were used to investigate water losses in Dar es Salaam water distribution system:

1) Water treatment plants: bulk flow meters were used to measure the inflow and outflow to determine leakages, wastage and process water.

   - The accuracy of flow meters was checked by using an ultrasonic flow meter.

   - Questionnnaire forms were used to check the frequency of backwashing and sludge bleeding of the sedimentation tanks.

2) Conveyance mains: Water loss investigations were carried out by direct measurement of leaks or flows along the trunk mains. To supplement the study, a comparison was made between the outflow rate from the treatment plants and inflow rate at every distribution reservoir. All known consumers along the trunk mains were documented. The amount of water was estimated using flow meters installed and read for three months to get the average consumption per connection per day.

3) Distribution reservoir: A drop test and overflow flow test were carried out. It was possible to carry out drop test and overflow test in one reservoir at Mtoni water treatment plant. Isolation of Kimara and University Hill reservoirs was not possible due to high water demand of Dar es Salaam.

The procedure of the drop test used to investigate water loss in reservoir was:

- to fill the reservoir to 3/4 capacity
- to isolate the reservoir from the distribution system by shutting off inlet and outlet valves
- to check the valves for tightness using ultrasonic flow meter
- to take water levels at hourly interval with respect to a fixed point in the reservoir.

The procedure for overflow test:

The best way to conduct an overflow test would have been to install a flow meter at the end of the overflow discharge pipe. However, this was not possible due to shortage of time and connection fittings for bulk flow meters. Hence, the procedure adopted during the study to check whether overflow occurs or not was to block temporarily the overflow discharge pipe with loose (easy to remove) material. The overflow was observed for six days.

4) Distribution network: Water loss investigations in the distribution network were done by conducting minimum night flow (MNF) measurements.

The following representative pilot areas were selected: Sinza block A, Sinza block B/E, Mbagara area and Msasani Peninsular area (Figures 7, 8 and 9).

The following procedure was followed during the investigations:

- Valves, hydrants and mains were identified and the existing drawings updated.
- Boundary valves and bulk flow meters were inspected and checked for tightness.

- When all preparations for the MNF measurement were completed the minimum night flow test was conducted between 1.00 a.m and 5.00 a.m. The midnight time was chosen because at this time genuine water consumption is considered nil or minimum.

The test included the closing of the boundary valves. The flow to the area was allowed through one main where a bulk flow meter was installed.

When flow in the area was stabilized, flow into the area was recorded to measure losses.

3.3.2 Minimum night flow measurements in pilot areas

The objective of district metering study was to identify loss of water which may be due to leakage, wastage or illegal use of water in the distribution network and to assess its magnitude.

The major aim of water loss investigations is the interpretation of minimum night flow records. Where the MNF is small compared to the average or maximum daily flow, the losses will be small. If the MNF is large, there is possibility of excessive losses. When the aim is to locate the sources of leakage, further night should be carried out in each section of the zone. Sections with high records of MNF should be sounded by either sound rods, leak noise correlator or by careful visual observation to locate leaks.

During the study four pilot areas, Sinza block A, Sinza block B/E, Mbagara area and Msasani Peninsula were selected so that it could be easier to isolate the network using boundary valves. During the MNF measurements, flow into the area was let through one main with the district meter.

3.3.2.1 Description of the selected pilot areas

<u>Sinza area, Block A:</u>

Medium density area consisting of medium to large single family houses. All premises have water connections and septic tank drainage. There are guest houses, restaurants and garages. (Figure 7).

<u>Sinza area, Block B/E:</u>

A medium density area. Consists of medium to large single family houses. All premises have water connections and septic tank drainage. There are medium size hotels, restaurants and guest houses. (Figure 8).

Mbagara area:

This zone consists of a high density area and a new industrial area which is in the initial stage of development. Most of the industrial plots have not yet been connected to water mains. Consumption in this zone has been assumed to be purely domestic. About 30 % of the premises have backyard stand pipes, mostly charged on average basis. A few houses have showers and flush toilets. There is one private secondary school mission centre, primary school, guest houses and a restaurant. (Figure 9).

Msasani Peninsula area:

This is a low density high class residential area. All premises have water connection and some houses are connected to the sewer system. There are large single family houses with gardens and also a few blocks of flats. There are primary schools, hotels and shopping centre. It was not possible to carry out MNF measurements in this area due to many boundary valves being non-operative. Secondly during the water loss investigations the area was affected by excessively low pressure, hence MNF measurements could not give meaningful results.

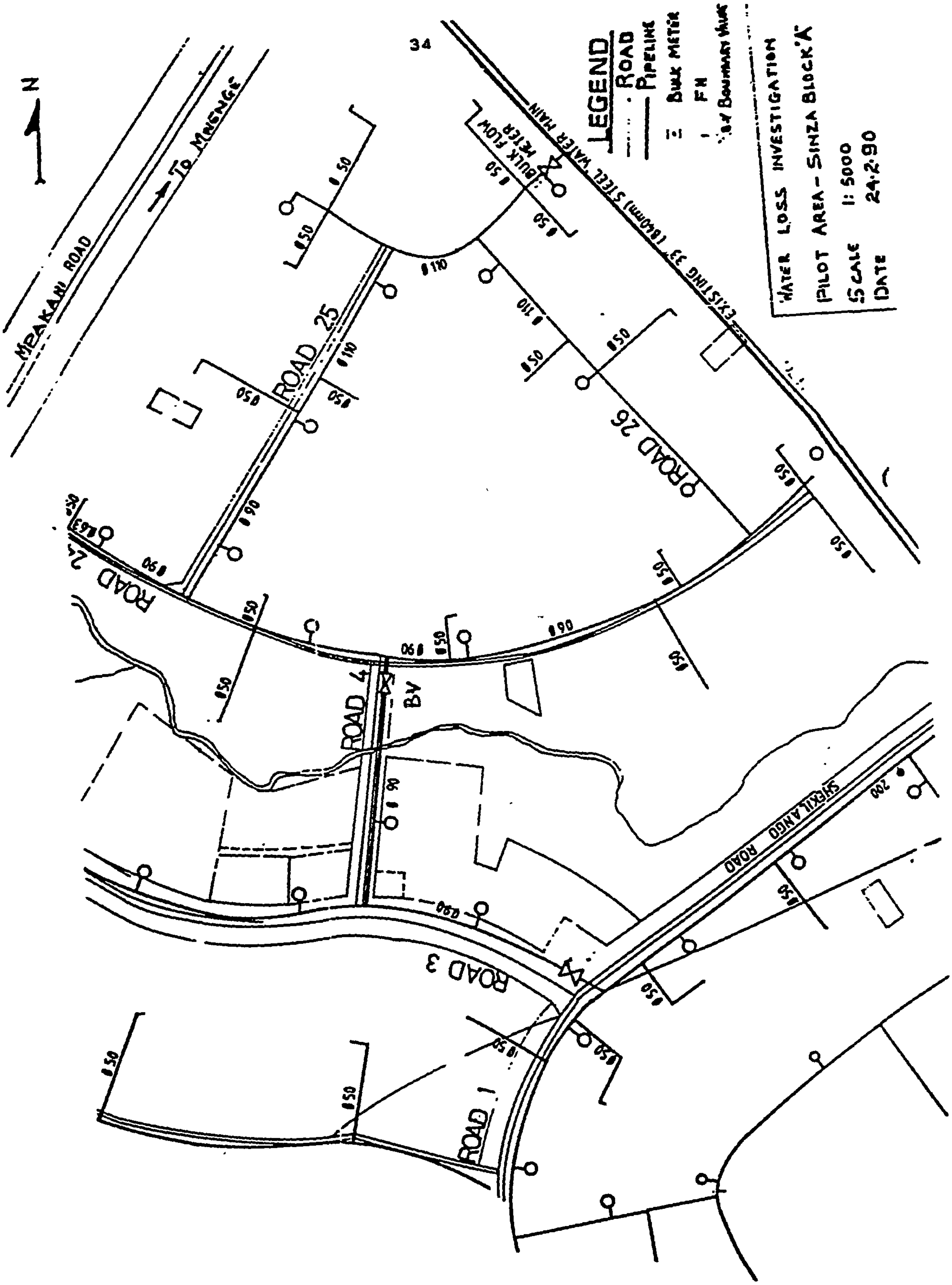

Figure 7. Network map of Sinza Block A pilot area.

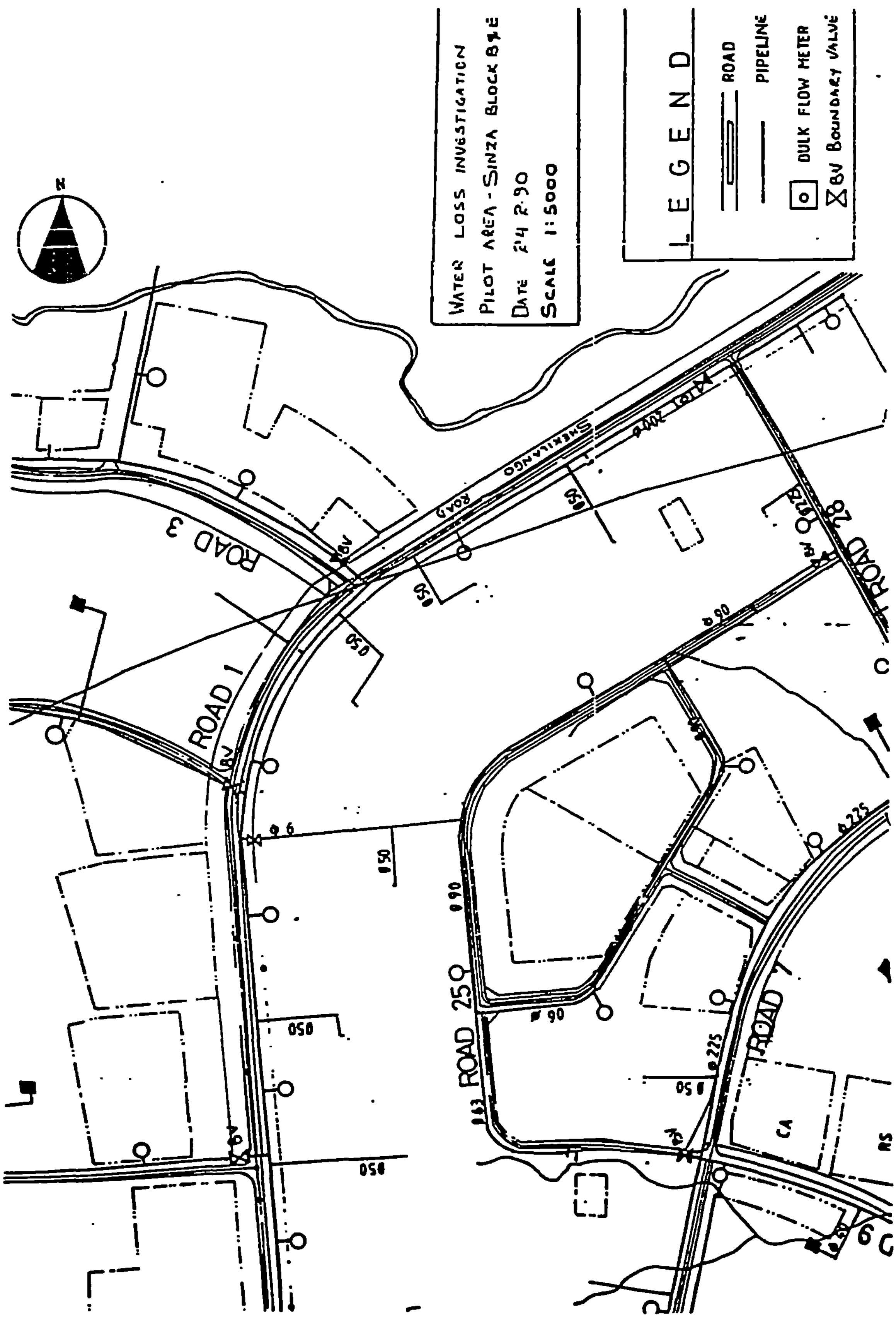

Figure 8. Network map of Sinza Block B/E pilot area.

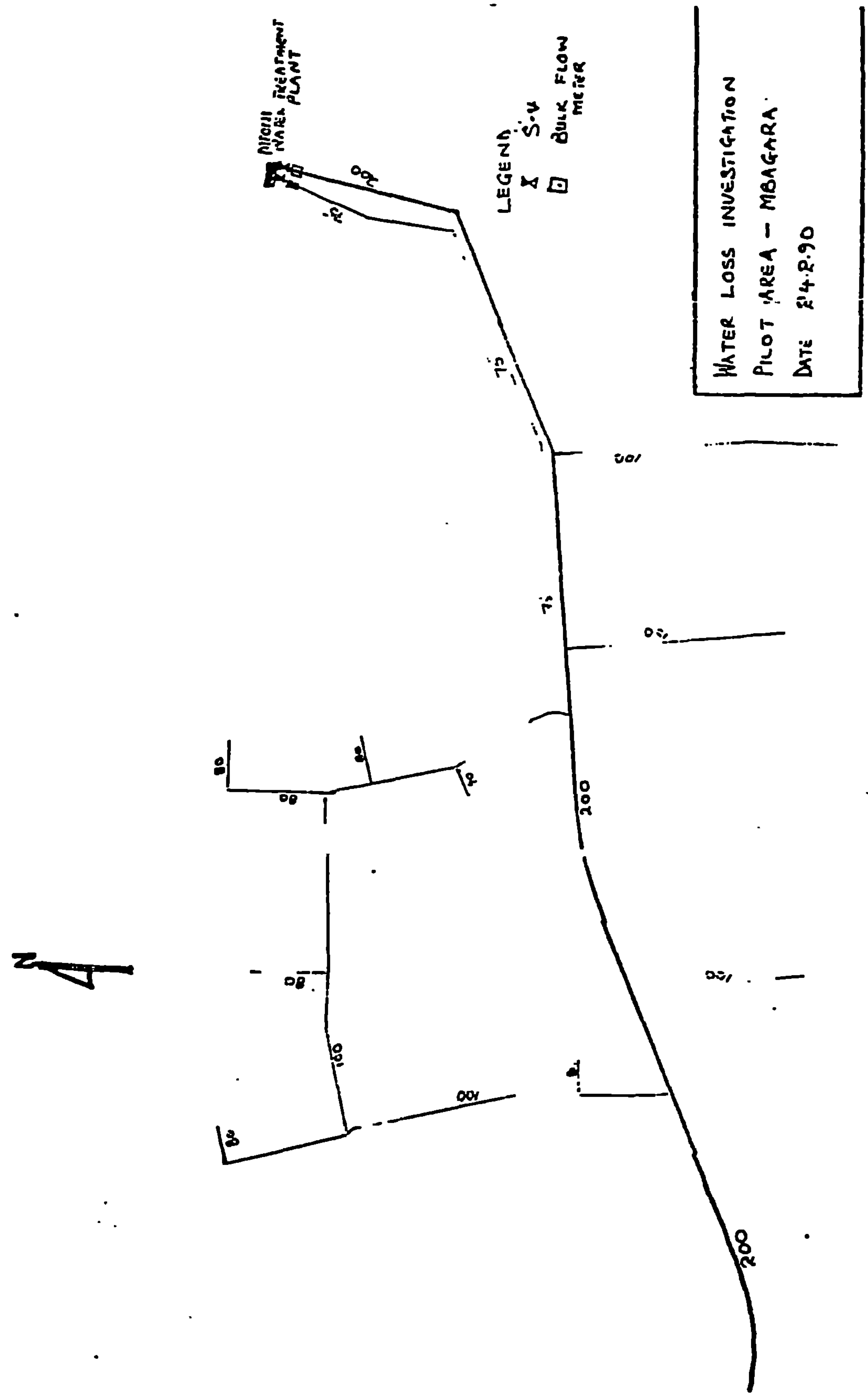

Figure 9. Network map of Mbagara pilot area.

3.4 Analysis of data and test results

3.4.1 Water treatment plants

The objective of water loss investigations at the water treatment plants was to find out if there is water wastage due to overflow in sand filters, leakages at the water treatment plant, under-utilization of design capacity of the water source and the treatment plants.

The use of excessive process water in filter backwashing and sludge bleeding of the sedimentation tanks were also investigated.

At Mtoni waterworks, investigations started from the intake works to the water treatment plant. Table 4 shows that design capacity utilization of the plant for the last five years averages to 66 % and total water loss due to leakage, process/wastage etc. is 13 - 19 %.

Table 4. Raw and treated water production at Mtoni water treatment plant in 1985-89 (design capacity 9 000 m^3/d).

Year	Raw water m^3/d	Pumped treated water m^3/d	Treated water/ design capacity %	Design capacity utili-zation %	Process water m^3/d	Water losses of raw water %
1985	4860	4250	47	54	610	13
1986	4390	3610	40	49	780	18
1987	6760	5920	65	75	940	14
1988	7000	5670	63	75	1330	19
1989	6530	5270	59	73	1260	19

At Upper Ruvu water treatment plant, analysis of water production data (Table 5) shows that design capacity utilization is 70 - 95 % and total water loss due to leakage and process water is 6 - 22 %.

Table 5. Raw and treated water production at Upper Ruvu water treatment plant in 1985-1989 (designed capacity 81 000 m^3/d).

Year	Raw water 1000 m^3/d	Pumped treated water 1000 m^3/d	Treated water/ design capacity %	Design capacity utili- zation %	Process water 1000 m^3/d	Water losses of raw water %
1985	65	61	75	80	4	6
1986	77	60	74	95	17	22
1987	57	53	65	70	4	7
1988	66	68	72	81	8	12
1989	70	60	74	86	10	14

The analysis of water production statistics for Lower Ruvu plant (Table 6) revealed that total loss due to leakage, process water etc. is 6 % and capacity utilization is 106 %.

Table 6. Raw and treated water production at Lower Ruvu water treatment plant in 1985-1989 (designed capacity 180 000 m^3/d).

Year	Raw water 1000 m^3/d	Pumped treated water 1000 m^3/d	Treated water/ design capacity %	Design capacity utili- zation %	Process water 1000 m^3/d	Water losses of raw water %
1985	167	157	87	92	10	6
1986	180	168	93	100	12	7
1987	200	191	106	110	9	5
1988	200	191	106	110	9	5
1989	213	202	112	118	11	5

In the three water treatment plants investigated, the pumped treated water is less than the raw water processed. The difference has resulted from water being used in backwashing of filters and desludging of the sedimentation tanks.

For a properly functioning and well operated water treatment plant process water is 5 % (Associated Engineering Services 1977). According to Tables 4, 5 and 6, Mtoni and Upper Ruvu plants use more water for backwashing and desludging.

Table 7 shows a summary of plant design capacity utilization and process water for the three water treatment plants of Dar es Salaam. On an average 19 % of the plant design capacity is not utilized and there is a high percentage of process water averaging to 15 %.

[redacted]

Table 7. Plant capacity utilization and process water in 1989.

Water treatment plant	Plant design capacity m^3/d	Pumped treated water m^3/d	Plant design capacity utilization %	Process water %
Mtoni	9000	5270	58	20
U/Ruvu	81000	60000	74	19
L/Ruvu	180000	202000	112	6
Total	270000	267270	81	15

3.4.2 Conveyance mains

The common method used to investigate water losses in conveyance mains is to install a by-pass flow meter. In this method two valves on the main to be investigated are selected and closed. A by-pass meter is installed on the upstream valve. Readings registered on the meter show leakage or wastage of water along the main.

It was not possible in this study to isolate conveyance mains, to isolate the valves and make tappings to connect the by-pass flow meter due to high water demand in Dar es Salaam.

The method used to investigate losses in conveyance mains was direct measurement of flow rates in known outlets from the conveyance mains. By comparing outflow from the treatment plants and the inflow at every distribution reservoir, the water loss in every conveyance main was found. Table 7 shows flow rate of known outlets along the conveyance main from Lower Ruvu to University Hill reservoirs.

Table 7. Summary of measured flow rates of known consumers along the conveyance main between Lower Ruvu and University Hill reservoirs.

Outlet size mm	Average flow rate 1/s	Number of outlets	Total flow rate 1/s
250	8.0	1	8
150	3.7	9	33
100	3.0	11	33
75	2.3	7	16
50	1.5	13	20
40	1.0	8	8
25	0.8	130	104
Total	20.3	179	222

Known consumption along the conveyance main from Lower Ruvu to University Hill reservoirs is 19 000 m^3/d. Table 8 shows the comparison of plant outflow and inflow at the University Hill distribution reservoir. The Lower Ruvu to University Hill reservoir conveyance main is 50 km long and made of reinforced concrete with 1 350 mm diameter. The Lower Ruvu conveyance main was provided with special outlets or offtakes at predetermined location to avoid haphazard water connections which could weaken the main and lead to water losses.

Table 8. Daily plant outflow and inflow at University Hill reservoirs (known consumption along the main is 19 000 m^3/d).

Date	Plant outflow 1000 m^3/d	Reservoir inflow 1000 m^3/d	Unaccounted-for-water 1000 m^3/d
03.12.89	167	147	1
04.12.89	189	168	2
05.12.89	191	171	1
06.12.89	191	168	4
07.12.89	190	166	5
08.12.89	192	167	6
09.12.89	191	164	8
09.12.89	192	167	6
10.12.89	192	167	6
Average	190	165	6

The results of the analysis show that 80 $m^3/d/km$ or 2 % of flow pumped into the main is unaccounted-for-water consumption.

Table 9. Summary of flowrates of known consumers along the conveyance main between Upper Ruvu and Kimara reservoirs.

Outlet size mm	Average flowrate l/s	Total no. of outlets	Total flow l/s
300	9	1	9
250	6	2	12
200	3	6	18
150	4	1	4
75	1	55	55
63	2	4	8
50	0.4	104	42
38	0.1	140	14
25	0.8	51	41
Total	26	364	203

Known consumption along the main is 18 000 m^3/d.

The conveyance main from Upper Ruvu to Kimara reservoirs is 60 km long. The conveyance main consists of two steel pipes with 750 mm and 600 mm diameters.

Table 10 shows a comparison of Upper Ruvu plant outflow and reservoir inflow at Kimara.

There are no bulk flow meters at Upper Ruvu treatment plant, therefore the water production records are based on design capacity of pumps and efficiency of pumps, assumed as 75 %.

Table 10. Outflow at Upper Ruvu plant and inflow at Kimara reservoir (known consumption along the main is 18 000 m^3/d).

Date	Plant outflow 1000 m^3/d	Reservoir inflow 1000 m^3/d	Unaccounted-for-water 1000 m^3/d
16.12.89	44	6	20
17.12.89	44	2	24
18.12.89	44	2	24
23.12.89	44	6	20
24.12.89	44	2	24
Average	44	4	22

The analysis indicates that 367 $m^3/d/km$ of flow pumped into the mains is unaccounted-for-water. This is 50 % of the water pumped into the conveyance main.

The reasons for the high percentage of unaccounted-for-water may be:

- long conveyance main passing through an agricultural land where consumers use too much treated water for irrigation

- unknown or illegal connections along the main line.

3.4.3 Distribution network

3.4.3.1 Results of minimum night flow measurements

In countries where water loss detection metering is practised, the criterium used in the interpretation of MNF results is to consider the ratio of MNF to the peak hour flow. In purely domestic areas a ratio of MNF to peak hour flow 1:12 is considered reasonable. In commercial/ industrial areas a ratio of 1:15 is acceptable (Associated Engineering Services 1977). Another criterium is to consider MNF in excess of 4.5 l/h per connection or l/h/km of main. The criterium used in this study is the ratio of MNF to peak hour flow.

Table 11 shows the results of MNF measurements in pilot areas.

Table 11. Summary of MNF measurements in pilot areas.

Pilot area	Bulk meter size mm	Length of main km	Peak hour flow m^3d	MNF m^3/h	MNF/Peak hour flow Acc. ratio	MNF/Peak hour flow Test ratio	U.F.W %
Sinza Bl.A	150	4	56	21	1:12	1:3	60
Sinza Bl.B/E	200	6	188	69	1:12	1:3	60
Mbagara A.	150	18	205	52	1:12	1:4	42

The ratio of MNF to peak hour flow calculated in the pilot areas is as shown above. In Mbagara area 1250 m^3/d or 42 % of flow pumped to the area is unaccounted-for-water. The ratio of MNF to peak hour flow is 1:4. This ratio is too high as compared to the acceptable ratio of 1:12. Water is pumped to Mbaraga area for 24 h/d. Since there are no storage reservoirs or factories working for 24 hours, the water pumped during the night is wasted through the leaking pipes and taps left open during the night. It is advised to sound the mains to locate the leaks. In Mbagara area where water is pumped to the distribution system without storage, it is advisable to install pumps with frequency converters which will adjust the flow to the demand in the area.

In Sinza Block A pilot area, MNF observed is 21 m^3/h or 504 m^3/d. The average daily flow in the area is 750 m^3/d. Hence 60 % of flow pumped into the area is unaccounted-for-water. The ratio of MNF to peak hour flow is 1:3. For Sinza Block B/E pilot area, the measured MNF was 69 m^3/h or 1 650 m^3/d and the ratio of MNF to peak hour flow is also 1:3. In both Sinza pilot areas the night flow is high. Tables 12, 13 and 14 show MNF results in Sinza A, Sinza B/E and Mbagara pilot areas respectively. Table 15 shows the summary of water loss investigations indicating the percentage of unaccounted-for-water in each pilot area.

Table 12. Results of MNF measurements in Sinza A pilot area.

Date	Time h	Consumption m^3/h	Remarks
02.01.90	22.00		
	23.00	26	Average daily flow
	24.00	33	= 750 m^3/d
	01.00	21	
	02.00	27	Peak hour flow
	03.00	28	= 56 m^3/h
	04.00	27	
	05.00	30	

[illegible]

Table 13. Results of MNF measurements in Sinza B/E pilot area.

Date	Time h	Consumption m^3/h	Remarks
02.01.90	22.00		
	23.00	106	Average daily flow
	24.00	115	= 2500 m^3/d
	01.00	69	
	02.00	103	Peak hour flow
	03.00	97	= 188 m^3/h
	04.00	91	
	05.00	115	

Table 14. Results of MNF measurements in Mbagara pilot area.

Date	Time h	Consumption m^3/h	Remarks
06.11.89	22.00	174	
	23.00	94	Average daily flow
	24.00	201	= 3500 m^3/d
	01.00	93	
	02.00	102	Peak hour flow
	03.00	125	= 205 m^3/h
	04.00	52	
	05.00	100	

Table 15. Summary of water loss investigation results.

Type/area of investigation	Unaccounted-for-water %
Upper Ruvu conv. main	50
Lower Ruvu conv. main	2
Sinza A pilot area (MNF)	60
Sinza B/E pilot area (MNF)	60
Mbagara pilot area (MNF)	42
Average	43

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The unsatisfactory water supply situation in Dar es Salaam can not be blamed on high percentage of unaccounted-for-water alone. There are many other factors influencing the deterioration of water supply services in Dar es Salaam.

The average water demand of Dar es Salaam is at present about 360 000 m^3/d. The existing water treatment plants' design capacity is 270 000 m^3/d and actual present water production is 230 000 m^3/d. Even with the full utilization of the existing water works capacity, there is a deficiency of 90 000 m^3/d. This alone could be the cause of low flows and intermittent water supply in most areas of the distribution system. Other factors, like poor maintenance of pumps, frequent power failures, lack of standby units, low utilization of the water treatment plant capacity, may contribute to the deterioration of water supply services in Dar es Salaam.

In this study water loss investigations were carried out in three pilot areas of distribution network, two conveyance mains and one distribution reservoir. The research in the distribution system showed that the system had 43 % unaccounted-for-water. In Mbagara pilot area the unaccounted-for-water was 42 %, while Sinza A and Sinza B/E pilot areas had 60 % unaccounted-for-water. Lower Ruvu to University and Upper Ruvu to Kimara conveyance mains had unaccounted-for-water equal to 2 % and 50 % respectively.

These high percentages of unaccounted-for-water are believed to be influenced by other factors, like genuine water use in filling of storage tanks, filling water containers e.g. water drums for water storage especially in areas affected by low pressure during the daytime.

Large component of unaccounted-for-water could be due to leaking individual stand pipes, leaking network and wastage in individual and public stand pipes left open as the result of low flows during the daytime.

When total water produced was compared to total water billed, the records revealed that 49 % of the total water produced was unaccounted for water.

Furthermore, water used as process water in sedimentation tanks and filters is high compared to other well operated water treatment plants in other countries. The three water treatment plant use 15 % of water produced as process water while for a well operated water treatment plant 5 % is considered satisfactory.

The deteriorating water supply situation in Dar es Salaam is also contributed by not effectively utilizing the design capacity of the existing water treatment plants. Only 81 % of the water treatment plant capacity is utilized.

The 43 % of unaccounted-for-water is a high percentage of water losses especially when considering that the existing water production is 64 % of the total water demand of Dar es Salaam. Thus it is important to start a well planned water loss investigation and control programme in Dar es Salaam, whereby methods like MNF measurement in the network and direct measurement of leaks in conveyance main could cut down the 43 % of unaccounted-for-water to an acceptable level of 10-15 %.

The total actual water consumption in Dar es Salaam is not known because not all water connections are metered; therefore total water consumption has to be estimated from per capita consumption.

The metered connections are 4 683 compared to 43 158 which are billed on average basis. Thus the high percentage of unaccounted-for-water is believed to be due to the low estimation of the average per capita water consumption. The average daily consumption per connection estimated by the water authority is 0.5 m^3/d. This figure is used by the water authority as the basis for average billing for those connections which are not metered. An average family or connection in Dar es Salaam consists of 6 water consumers, hence under-estimation of the per capita consumption per connection could give low total water consumption on connection/property billed on average basis; hence giving unrealistically high percentage of unaccounted-for-water.

4.2 Recommendations

1) The unsatisfactory water supply situation in Dar es Salaam has developed due to various technical and managemental problems. Planning, financing and execution of major water projects has been under the responsibility of the Ministry of Water. The Urban Water Supply Department was responsible for the extension of pipelines and service connections. This trend continued even after the establishment of National Urban Water Authority (NUWA). Hence the expansion of the network was continued without proper consideration of the water works supply capacity.

   The two bodies which have worked without proper coordination have contributed to the unsatisfactory water services in Dar es Salaam. It is necessary to reorganize so that one body is solely responsible for the water supply activities, including planning, organizing, designing, financing and executing the water supply systems in Dar es Salaam. Let the Ministry of Water be the policy maker and NUWA the executing body.

2) The Dar es Salaam water distribution system lacks proper information and management system. The necessary data needed for planning and designing for execution of water supply systems are not readily available; for example daily data on joining consumers, network

data etc. are not available at the NUWA Dar es Salaam branch office. The operation department should be well equipped with e.g. personal computers, trained staff, working tools and equipment e.g. pipe locators, leak noise correlator, pressure recorders etc. All necessary data from the NUWA sub-branches should be stored and ready for use whenever they are needed.

3) To improve the water supply situation in Dar es Salaam the following should be initiated:

   a) Rehabilitation of the existing water treatment plants to restore the reduced design capacity.

   b) Expansion or extension of the existing water works to meet the rising average water demand which now stands at 360 000 m^3/d.

   c) Rehabilitation of the aging water distribution network to avoid water losses through pipe leaks.

   d) NUWA Dar es Salaam branch should start a well organized water loss investigation and control programme to cut down water losses to an acceptable level.

4) MNF measurements in networks, direct measurement of flow rate of leaks in conveyance mains and "drop test" and overflow test in distribution reservoir are suitable methods in the distribution system Dar es Salaam.

   Other methods are doubtful, for example water loss investigations in conveyance mains could not be done by isolation of a main, to install a by-pass meter. Either there exists only one rising main or even if there are two conveyance mains, the water demand is so high that isolating a main could cause unnecessary high inconvenience to consumers. The same applies to water loss investigations in the distribution network. Use of hose pipe connections to fire hydrants could not be used in Dar es Salaam because the fire hydrants are so widely spaced.

   The water loss investigation research has revealed that 43 % of the water produced is unaccounted-for-water. Therefore further research is required to locate the worst leaking areas and causes of deterioration so that repair or rehabilitation could be initiated or protective measures taken.

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APPENDIX 1

CONSUMPTION BASED ON METERED AND AVERAGE BILLING

ZONE	TYPE OF CONSUMER	1988 ACCOUNT BILLED			1989 ACCOUNT BILLED		
		METERED 1000 m^3/a	AVERAGE 1000 m^3/a	TOTAL BILLED CONSUMPTION 1000 m^3/a	METERED 1000 m^3/a	AVERAGE 1000 m^3/a	TOTAL BILLED CONSUMPTION 1000 m^3/a
A-F	1	55	3200	3255	77	2882	2909
	2	15	540	555	0	343	343
	3	35	455	490	33	838	871
	4	0	410	410	1	820	821
G-K	1	65	3930	3995	56	3702	3758
	2	75	870	945	99	1420	1520
	3	7	260	267	120	576	696
	4	554	514	1068	186	2043	2229
L-F	1	450	5052	5502	777	4034	5411
	2	122	22510	2373	59	2092	2151
	3	7	1271	1278	171	2221	2392
	4	3	2660	2663	472	2909	4381
Q-W	1	1773	10958	12731	976	13012	13988
	2	456	2720	3176	120	2354	2474
	3	374	516	890	1340	954	2294
	4	346	938	1284	196	1408	1604
TOTAL		4337	36545	40882	4683	43158	47841

APPENDIX 1 .... CONT ....

NOTE: TYPE OF CONSUMERS:

1. Domestic
2. Institutional consumers, training instituted, hospitals, governmental offices, etc.
3. Commercial consumers, hotels, restaurants, shops, etc.
4. Industrila consumers.

ZONES: A-F, G-K, L-F, Q-W indicte areas where different types of consumers are located.

**APPENDIX 2: Dar es Salaam water distribution network
Lower Zone Pressure gauges and flowmeters list
(17 August 1989)**

A. PRESSURE GAUGES LIST (LODIGIAN S.p.A. 1980)

DISTRIBUTION ZONE	NUMBER	CLOSEST NODE	PIPELINE (MM)	DIAMETER INCH (mm)	MATERIAL	NOMINAL PRESSURE
IL	1	30e	30e - 72b	150	C.I.	5
IL	2	157	157 - 155	400	D.I.	10
IL	3	193	193 - Distr.	150	C.I.	5
IL	4	159	159 - 157	400	D.I.	5
IL	5	30b	30b - 30	200	C.I.	5
IL	6	194	194 - 179	375	C.I.	10
IL	7	141	141 - 131	150	C.I.	10
IL	8	34	34 - 26	550	STEEL	5
IL	9	30c	30c - 30d	150	C.I.	2
IL	10	157	157 - 161	150	C.I.	5
IL	11	179b	179b - 143	200	C.I.	5
IL	12	183	183 - 191	200	PVC	5
IL	13	179	179 - 178	400	D.I.	10
IL	14	192	192 - 74	300	C.I.	5
IL	15	74	74 - 192	300	C.I.	10
IL	16	163	166 - 163	200	C.I.	2
IL	17	172	172 - Distr.	200	C.I.	2
IL	18	191	191 - 179b	250	C.I.	5
IL	19	143	143 - 179b	200	C.I.	5
IL	20	30	26 - 30	300	D.I.	5
IL	21	37b	37b - 190	300	C.I.	10
IL	22	190	190 - 191	250	C.I.	10
MM	3	811	811 - 4	750	D.I.	5
MM	4	17	14 - 17	750	CONCRETE	10
MM	5	66	66 - 68	375	C.I.	5
MM	6	53	53 - 70	375	STEEL	10
MM	7	24	24 - 22	375	C.I.	10
MM	8	10	10 - 811	825	STEEL	5
MM	9	22	22 - 23	375	C.I.	10
MM	12	117	117 - 115	375	C.I.	5
MM	13	71	71 - 74	525	STEEL	5
MM	14	72b	72b - 30e	150	C.I.	2
MM	15	111b	111b - 72b	150	PVC	2

B. FLOWMETERS LIST

KW	1	12	12 - 811	1350	STEEL	5
MM	2	811	4 - 811	750	STEEL	5
KW	3	811	6 - 811	1350	STEEL	5
KN	4	14	14 - 15	450	C.I.	5
MM	5	53	53 - 70	525	STEEL	5

N.B. KW = Kawe KN = Kinondoni TK = Temeke IL = Ilala MM = Magomeni

APPENDIX 2 .... CONT ....

A. PRESSURE GAUGES LIST

DISTRIBUTION ZONE	NUMBER	CLOSEST NODE	PIPELINE (MM)	DIAMETER INCH (mm)	MATERIAL	NOMINAL PRESSURE
KW	1	17t	17t - distr.	150	PVC	2
KW	2	252	17t - 252	100	PVC	2
KW	3	12	12 - 14	1350	STEEL	2
KW	4	252b	12b - 252b	100	PVC	2
KW	5	14	14 - 16	450	STEEL	10
KW	6	811	811 - 6	1350	STEEL	5
KN	1	150	150 - 154	300	C.I.	5
KN	2	147	147 - 15	450	STEEL	5
KN	3	151	151 - 150	200	C.I.	5
KN	4	155	155 - 154	300	C.I.	5
KN	5	250a	250 - 250a	200	C.I.	10
KN	6	209	209 - 219	150	C.I.	2
KN	7	219	219 - 209	150	C.I.	2
KN	8	208	208 - 204	200	C.I.	2
KN	9	151C	151C - 151a	200	C.I.	5
KN	10	148	148 - 204	250	C.I.	5
KN	11	151C	151C - 202a	150	C.I.	2
KN	12	252a	252a - 151c	150	C.I.	2
KN	13	15b	156 - 15b	150	C.I.	2
KN	14	250b	250b - 15b	100	C.I.	2
KN	15	15	15 - 14	450	STEEL	10
TK	1	33	33 - 83	350	D.I.	5
TK	2	29	29 - 26	250	C.I.	5
TK	3	26	26 - 30	300	D.I.	10
TK	4	103	103 - 26b	375	C.I.	10
TK	5	26b	84a - 26b	150	C.I.	5
TK	6	83	83 - 89	350	D.I.	5
TK	7	99	99 - 103	250	D.I.	5
TK	8	121	121 - 103	200	D.I.	5
TK	9	86	86 - 89	200	C.I.	2
TK	10	97	97 - 199	250	C.I.	10
TK	11	97	97 - 99	375	C.I.	10
TK	12	94	94 - 91	350	STEEL	2
TK	13	202	202 - 203	250	C.I.	5
TK	14	129	129 - 127	200	C.I.	5
TK	16	84	84 - 84a	150	C.I.	2
TK	17	26a	26a - 29	250	D.I.	5

N.B.

KW = Kawe
KN = Kinondoni
TK = Temeke
IL = Ilala
MM = Magomeni

APPENDIX 3

LEAKS DETECTED AND REPAIRED IN DAR ES SALAAM WATER DISTRIBUTION SYSTEM IN 1989 *

NUWA SUB-BRANCH	JANUARY DET	JANUARY REP	FEBRUARY DET	FEBRUARY REP	MARCH DET	MARCH REP	APRIL DET	APRIL REP	MAY DET	MAY REP
KINONDONI	46	37	26	21	14	14	29	26	19	18
KAWE	31	22	142	143	27	20	32	31	39	36
MAGOMENI	106	80	56	40	66	32	83	55	79	77
TANDALE	58	55	49	49	54	76	46	44	64	55
ILALA	280	246	318	320	312	338	312	348	321	358
TOTAL	621	440	591	572	473	480	502	504	522	544

NUWA SUB-BRANCH	JUNE DET	JUNE REP	JULY DET	JULY REP	AUGUST DET	AUGUST REP	SEPTET DET	SEPTET REP	OCTOBER DET	OCTOBER REP	NOVEMBER DET	NOVEMBER REP	DECEMBER DET	DECEMBER REP
KINONDONI	37	36	28	27	48	42	17	20	10	9	14	12	13	13
KAWE	28	31	37	33	42	36	43	31	15	19	39	31	25	24
MAGOMENI	94	81	107	110	111	85	85	44	78	64	58	27	54	19
TANDALE	82	64	70	76	66	65	54		37	33	35	53	40	37
ILALA	353	374	312	359	393	448	322	333	298	347	339	372	196	206
TOTAL	571	586	544	605	660	676	521	432	444	472	489	495	320	298

NOTE:

DET = DETECTED
REP = REPAIRED

* Leaks detected by Leakage Survey team