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WATER LEAKAGE IN ADDIS ABABA

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INTRODUCTION

A water leakage study was carried out in Ethiopia, between October 1980 and June 1982, by Associated Engineering Services Ltd (AESL) of Canada under a contract for consultancy services with the Addis Ababa Water and Sewerage Authority (AAWSA). Principal funding was by African Development Fund loan.

The objectives of the study were to evaluate losses due to leakage and billing errors and to make recommendations on the most cost-effective methods of minimizing these losses.

Addis Ababa,the capital city of Ethiopia, has a population of approximately 1.3 million. Average water production is 69,500 m^3/d, compared with a potential demand of about 95,000 m^3/d. A substantial water shortage therefore exists and there is great incentive to locate and reduce unaccounted-for water, which past records indicated to be in the order of 40% to 50% of water produced. Unaccounted-for water is defined here as the difference between the volume of treated water produced and the volume of water sold to customers.

The Addis Ababa distribution system is unusually complex for its size, having some 15 separate pressure zones,or subsystems. Serviced elevations range from 2730 m to 2220 m. The system comprises nearly 300 km of pipeline over 100mm diameter,18 service reservoirs and 17 pumping stations. There are currently 80,000 connections, all metered.

Implementation of the study was divided into four phases:appraisal, on-site investigation, final report and follow-up. Canadian staff included an engineer, assisted by up to two senior technicians. Ethiopian counterpart staff, supplied by AAWSA, included an engineer, two engineering aides, and up to eight technicians of various grades. Training of the counterpart staff was an important aspect of the work program.

The overall approach to the study was as follows:

(a) To assess and measure the various forms of unaccounted-for water.
(b) To assess the unit costs of water.
(c) To assess possible loss control programs.
(d) To assess the costs and select optimum programs to reduce losses.

The following sections describe the procedure and results under each of the above steps:

UNACCOUNTED-FOR WATER

Statistics

From updated AAWSA statistics of monthly water production it was apparent that unaccounted-for water had been declining considerably over the past few years, from 46.5% of production in 1975/76 to 30.3% of production in 1980/81. Some reasons for such a marked improvement were evident: there had been changes in management and organization, technician training and regrading, improved computer billing, and a program to replace older meters. In addition, the commencement of the leakage study had given management and technicians a greater awareness of the problem of losses, and a greater priority was being assigned to leakage repair work.

However, the records of treated water production were suspect, since the three main venturi meters had never been checked for accuracy.

Measurement of production

One of the primary tasks, therefore, was to accurately measure treated water production. This was done using pitometers, inserted through 25mm corporation stops installed in the pipelines by under-pressure tapping machine. It was found that all three meters were over-registering by up to 32.5%. Production had therefore been substantially overestimated and overall losses in 1980/81 were not 30.3% of production but actually only 22.0%. This value was considerably less than had been expected at the commencement of the study.

Forms of unaccounted-for water

The 22% of production unaccounted-for was considered under two main sub-headings, namely system losses, and metering and billing losses. Both categories of loss have different costs associated with them and require entirely separate measures to reduce them.

System losses consist of:

- supply main leakage,
- service reservoir leakage,
- pumping station leakage,
- distribution main leakage,
- service connection leakage, and
- unmetered use of water.

Metering and billing losses are due to:

- meter inaccuracy,
- incorrect sizing of meters,
- meter reading errors,
- incorrect assessment of consumption where meters are not working, and
- consumption through unauthorized connections.

The steps taken to estimate the contribution of each of these forms of loss to the overall total of unaccounted-for water are briefly described as follows:

Supply main leakage, from pipelines of 150mm diameter and over, was found to be relatively small. A survey was conducted,during the dry season, by a small team of technicians walking all supply main routes, inspecting the surface for signs of leakage and, where possible, sounding the main at regular intervals.

The main causes of loss were found to be leakage from air valves, washouts, and valve spindles, leaking joints, corrosion, and traffic damage. Loss reduction requires regular surveys, prompt repairs, improved security at valve chambers, improved access to pipe routes, regular maintenance and exercising of valves, and attention to pH control at the treatment plants.

Service reservoir leakage. A survey of reservoir leakage was carried out on only 14 out of 37 tanks in the system, limited firstly due to problems with valves (i.e.siezed or not closing tight), and secondly due to time constraints, since testing had to be carried out during the rainy season owing to supply difficulties. Leakage tests on reservoirs were carried out over 12 or 24 hours, with the tank full and all inlet and outlet valves shut tight. Where leakage was significant, as it was in 4 of the tanks tested, the tanks were drained, cleaned out, carefully inspected, and repairs made if possible. Problems found included cracked floor slabs and porous foundation concrete.

Loss reduction requires replacement of faulty valves, thereby allowing all reservoirs to be tested, annual maintenance of valves and float valves, and periodic testing, cleaning and inspection every 5 years.

Pumping station leakage was limited to excessive pump gland leakage at a number of pumping stations. Regular pump maintenance would reduce these losses.

Distribution main and service connection leakage. Various surveys and investigations were undertaken to locate leakage in distribution mains and service connections, and to estimate the total volume of system leakage.

The main source of data was from leak detection areas set up in 15 representative sections of the system. The areas varied in size from 22 to more than 500 properties and were selected so that they could be isolated from the adjoining system, with total flow to each area metered. Several problems were encountered with these surveys, the most serious being the difficulty of isolating some areas. Distribution plans were often incomplete and in some areas daytime pressures were almost zero, thereby making it impossible to check for leakage or non-registering meters.

Other surveys consisted of inspections throughout the system of visible leakage and analysis of leak repair records.

The main causes of leakage were corrosion of small diameter steel pipe, insufficient laying depth and, in some areas, unnecessarily high service pressures. Reduction of leakage requires regular sounding surveys to locate leakage, prompt repairs, reduction in corrosiveness of the water, improvements in pipelaying practices, greater use of pvc and cement-lined ductile pipe, proper recording of leak repairs and planned replacement of old lines.

Unmetered use of water in Addis Ababa is essentially zero due to the fact that fire hydrants, public fountains and park supplies, which usually contribute to unmetered use, are all metered.

Losses due to meter inaccuracy. During the investigation phase study staff assisted with the reorganization and rehabilitation of the AAWSA meter repair shop, and carried out training in meter repairs and testing. Following this, records were kept of the accuracy of meters coming into the shop. Average accuracy was very close to 100%, indicating that meter inaccuracy did not contribute to unaccounted-for water.

Losses due to incorrect sizing of meters occur when meters are installed that are too large for a customer's water demand. It was found during surveys of large meters(over 25 mm) that as many as 55% may be oversized. The remedy lies in instituting a program of regular reassessment of large meter size, based on each customer's water usage.

Losses due to meter reading errors. Particularly with the older style clock-dial meters, reading errors are common in Addis Ababa. However, since there is no reason to suppose that under-readings are any more prevalent than over-readings it was considered that such errors would ultimately cancel out and have little effect on unaccounted-for water.

In common with meter inaccuracy, however, this problem does affect individual consumers and should therefore be tackled by a meter maintenance and replacement program and by continued training and supervision of meter readers.

Losses due to incorrect assessment of consumption. Whenever a meter is not read for any reason, or is stuck, consumption is in theory assessed as the average of several past month's consumption. From the results of surveys of meter condition, and from computer print-outs of monthly billings, it was evident that 10% of meters in the system are unreadable, for one reason or another, and it was also clear that many of these connections are consistently under-billed, or billed at zero consumption. The solution to this problem is again one of meter maintenance and repair, since if meters are working and legible, assessments will not be required.

Consumption through unauthorized connections is a problem which does exist in Addis Ababa but, according to surveys carried out, is of very minor proportions.

Summary of unaccounted-for water

Table 1 summarizes the losses under the various forms of unaccounted-for water described above.

Table 1

	Loss as % of production	
	Existing	Target value
System losses from:		
Supply mains	0.50	0.25
Service reservoirs	0.40	0.20
Pumping stations	0.10	0.05
Distribution mains	5.60	2.80
Service connections	8.40	4.20
Unmetered use	0	0
Total system losses	15.00%	7.50%
Metering/billing losses:		
Meter inaccuracy	0	0
Incorrect meter sizing	2.0	0.50
Meter reading errors	0	0
Assessment losses	4.50	1.50
Unauthorized connections	0.50	0.50
Total metering/billing losses	7.00%	2.50%
Total losses	22.00%	10.00%

UNIT COSTS OF WATER

The unit cost of system losses is the marginal cost of producing one additional unit volume of water. The unit cost is made up of firstly, operational costs for production and distribution and secondly, the value of deferring future demand-related water schemes. These were calculated, for Addis Ababa, as follows:

Unit operational cost:	Birr 0.090/m^3
Unit capital cost:	0.323/m^3
Total unit cost of leakage:	Birr 0.413/m^3

(The Ethiopian Birr is presently 3.00 to the £ Sterling).

For metering and billing losses, the unit cost of unbilled consumption is simply equal to the water tariff, which at present is Birr 0.5/m^3 (regular rate). A proposed new tariff would raise the average cost to Birr 0.87/m^3.

LOSS CONTROL PROGRAMS

Following the assessments of unaccounted-for water and unit costs, it was then necessary to establish what loss control programs are called for and estimate what effect they would have on reducing losses. Two programs are required, a leakage control program to tackle system leakage, and a separate program to tackle metering and billing losses.

Leakage control

There are various established methods of leakage control which have been adequately described in the literature (see Bibliography) and may be summarized as follows:

Regular or intensive sounding surveys, involving systematic sounding and inspection, by special crews of technicians, of all mains, valves, hydrants, consumer services and meters. The method is flexible and effort may be intensified or reduced as the need of a particular area requires. Instruments are required to locate pipelines so that they can be closely followed, and leak detection is based on electronic or mechanical amplification of the noise of the leak.

District or subsystem metering, consists of metering flows into districts, usually of 2000 to 5000 properties. By reading district meters weekly or monthly it is possible to note any increases in flow which may be due to leakage, and to intensify the sounding surveys in those districts. In Addis Ababa the system is conveniently divided into 15 sub-systems which form a very suitable basis for district metering.

A number of subsystem meters already existed in the system and during the study considerable effort was put into repairing meters, installing new ones and isolating subsystems in order to upgrade the level of subsystem metering. A monthly meter reading program was commenced and by the end of the study some useful statistics were being produced on the monthly supplies to all subsystems. It was also possible, using the monthly computer billing statistics, to compare total supply with total consumption in each subsystem, thereby obtaining a monthly record of unaccounted-for water, by subsystem.

Waste metering involves the division of the city into a number of small metered areas, consisting of from 1000 to 3000 properties, which can be isolated from the adjoining distribution, with flow into the areas measured by a recording waste meter. This technique is not suitable for use in Addis Ababa at the present time owing to the extreme difficulty of isolating areas to be fed through one meter. Other disadvantages are the necessity for extensive night work and the high cost of

providing meter installations for each waste meter area.

Summary of leakage control programs considered

(a) Regular sounding: comprising a small central loss control data and advisory section, with annual surveys of all consumer connections and main pipelines conducted by crews from the AAWSA small and large lines sections. (Estimated leakage reduction from 15% to 12.5% over 3-year period).

(b) Intensive sounding:as program (a) but with 6 monthly surveys. (Estimated leakage reduction from 15% to 10% over 3-year period).

(c) Intensive sounding and subsystem metering: comprising a larger loss control data and advisory section,with surveys as program(b) combined with a full subsystem metering and efficiency assessment program. (Estimated leakage reduction from 15% to 7.5% over 3-year period).

Meter maintenance program

Since unaccounted-for water due to metering and billing losses is largely due to inadequate meter maintenance, a program is required which involves increased staffing and effort, directed towards recalling and replacing old and defective meters. Assistance and support would be required from the loss control section. In the program, costs are included for replacement meters and spare parts, and for regular computer listings of meters requiring servicing. Costs of operating the meter shop would continue as before and are therefore not included. It is estimated that the program could reduce billing losses from 7.0% to 2.5% over a 3-year period.

SELECTION OF OPTIMUM PROGRAM

The costs of the various leakage control programs are given in Table 2, together with an estimate of the longer term annual water savings.

Table 2

Program	Annual cost (Birr)	Annual water saved (m^3)	Unit cost of water saved (Birr/m^3)
(a)	101,000	634,000	0.159
(b)	154,000	1,269,000	0.121
(c)	182,000	1,903,000	0.096

It may be seen that the greatest benefit (or saving in leakage costs) is obtained by the implementation of program (c)--intensive sounding and subsystem metering. The unit cost of water saved must be compared with the unit cost of leakage of Birr 0.413/m^3 to illustrate the benefits of the programs.

The important effect of the capital cost portion of the unit cost of leakage can be seen by the fact that on the basis of operational costs alone, none of the programs would be worthwhile economically.

Costs and benefits associated with the proposed meter maintenance program are as follows:

Annual cost:	Birr 293,000
Annual increased billings:	1,142,000/m^3
Unit cost of increased billing:	Birr0.257/m^3

This unit cost must be compared with the water tariff of Birr 0.50/m^3 (average) to illustrate the benefit of this program.

It was therefore concluded that the introduction of both the leakage control program (c) and the meter maintenance program is fully justified on economic grounds, and would result in reduction of losses to the target values shown in Table 1. In addition, there are numerous other benefits which would accrue from the successful implementation of the programs such as improved public relations, knowledge of the water system and distribution operation, and reduced disruption of utilities and damage to roads from leakage.

In future, if the recommended programs are carried out successfully, it should be possible to reduce unaccounted-for water in Addis Ababa to a level of 10% of production. A major portion of the losses remaining would be leakage, undetectable by normal methods.

The study Final Report included recommendations regarding the organization of the loss control programs, other AAWSA management and organization problems, stores practices and procedures, maintenance practices, and operation of the distribution system.

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BIBLIOGRAPHY

1. I.W.E., Proceedings of Symposium on Waste Control, 1974.

2. D.O.E./N.W.C., Leakage Control Policy and Practice, Standing Technical Committee Report No.26, 1980.

3. I.W.E.S., Proceedings of Symposium on An Understanding of Water Losses, 1981.