It is now increasingly common to use alternative expressions for losses that are more specific and the use of these terms is highly recommended. The most common are:

litres/property/hour	Relevant primarily to densely populated urban areas
litres/km/hr	*Relevant to more sparsely populated rural areas*

3.2 WATER BALANCE AND NETWORK FLOW MEASUREMENT

Flow measurement is an essential precursor for good network management and also necessary for UFW control evaluation and prioritisation. As with a factory operator, who wants to know how many goods he has produced and sold and what happened to any others, so the water supply utility needs information on the volumes of water that it handles.

A water supply network cannot be well managed without at least some degree of flow measurement. Additionally, when UFW control is incorporated in network management, .the calculation of UFW is carried out using the water balance principle.

The results of the water balance analysis, when sufficient data is available, enables not only UFW losses to be determined and cost-benefit assessment to be made on the viability of UFW control measures, but also to prioritise which components are contributing the most to the losses.

3.2.1 Summary of Elements in Water Balance

(1) Production Metering

- *Minimum level of Network metering is production metering in order to know how* much water has gone into the system
- Each point where water enters the supply should have a water meter, such as:
  - Boreholes
  - Water treatment plant outlet (after all internal usage)
  - Reservoir intakes etc if there is no treatment (except Cl2)

(2) Consumption Data

- Consumption data is obtained from
  - Revenue metering (customer meters)
  - Demand estimates as detailed as possible by special Per Capita Consumption studies on different sample groups (e.g. by socio-economic classification)
  - All non-domestic use MUST be metered
- Large users should receive special attention as a small number of consumers will commonly use a large proportion of the total consumption with as significant effect on UFW and revenues (80/20 rule)

(3) Intermediate Bulk Metering by Zones, DMA's, etc

- Any metering in between these two extremes is about dividing the system up and getting increasingly localised information
- The smaller the locale the more specific the data and the better the components (demand/leakage etc) can be identified
- Extent of effort is subject of cost/benefit analysis

(4) Importance of Reliable, Accurate Data

- The more information management has on what is happening in the system and where, the more action and investment can be accurately targeted
- Measurement data and analysis is only as good as the base data, so is essential to have good, accurate knowledge of the network – pipes, valves meters, connections

(5) Constituents of Water Balance

- Production
  - Water into supply surface water
  - Water into supply groundwater abstraction
  - Water treatment plant use and losses
  - Reservoir transfer losses
- Transmission & Storage
  - Transmission main losses
  - Bulk transfer out of supply area
  - Bulk transfer into supply area
  - Service reservoir leakage
  - Cleaning & emptying of reservoirs
- Distribution
  - Network Losses on
    - Mains
    - Services
  - Extension/rehabilitation flushing/swabbing etc.
  - Routine maintenance and repairs
  - Refilling/Re-pressurising of network when supply is restored (intermittent supply)
- Consumption
  - Metered Use
    - Domestic
    - Industrial
    - Commercial
    - Government
    - Military
    - Others
- Un-metered same categories as for metered
- Unmeasured Legitimate use, possibly including

  - Fire service
  - Port supply
  - Public amenity/Municipal
  - Government & Military
- YCDC internal and operational use – taken from the network after production meters
- Illegal connections
- Un-metered user wastage & leakage NOT allowed for in PCC calculation such as
  - Continuously running taps
  - Overflowing tanks
  - Plumbing leaks and bad repairs

Figure G 3.1 shows a typical block diagram of the principal components of Distribution Input

3.2.2 Production

Production meters are essential items in the network and should be installed at all input points. They should be routinely and regularly tested, because even newly installed meters have been found to have large errors. This testing is most easily done by checking volume change in a reservoir or other fixed volume facility, with all other inlets/outlets closed off.

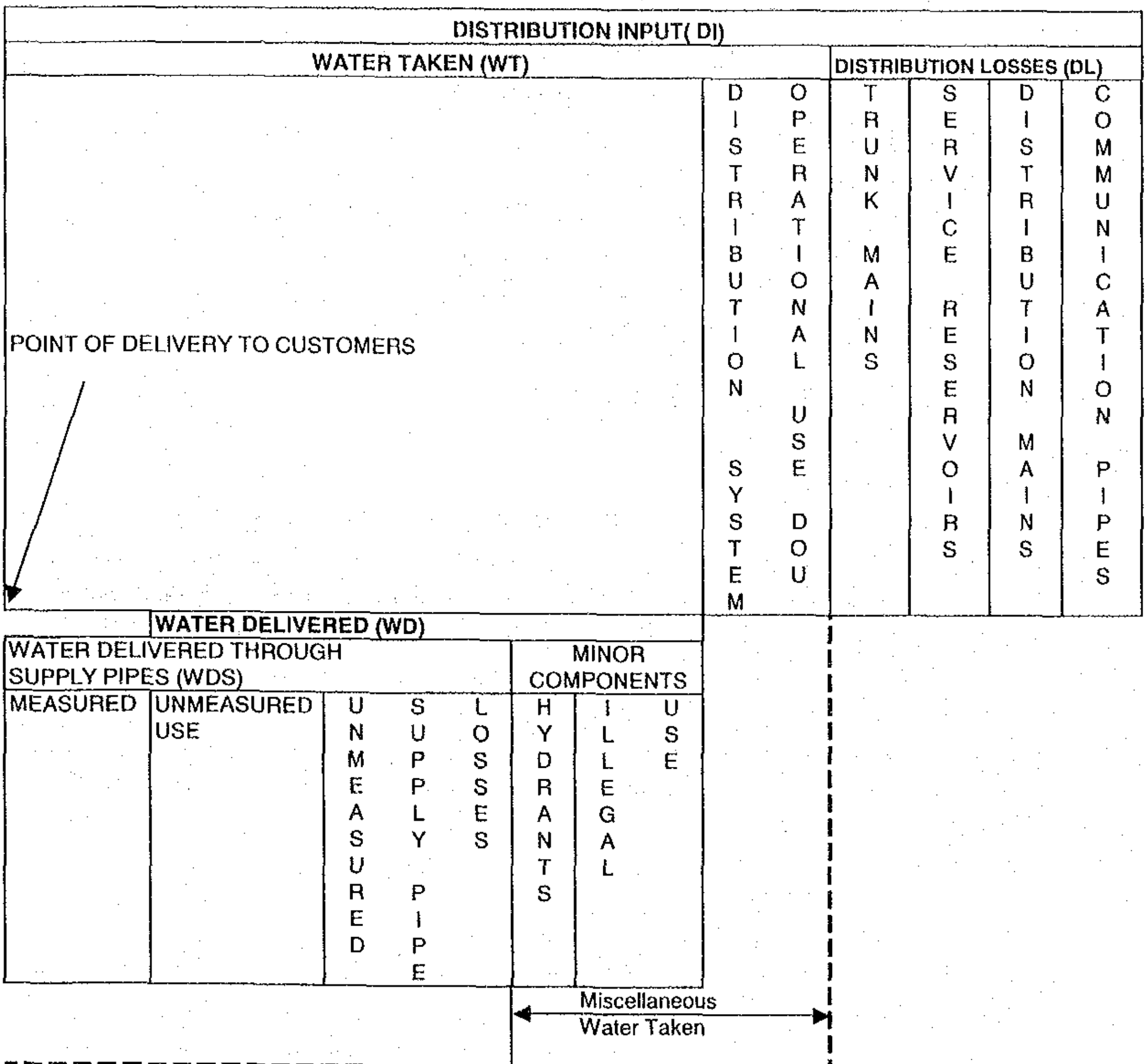
Where meters are not available (yet) or not in operation, pump outputs should be checked similarly by volume changes. Where this is not possible, pump curves may be used with discretion, making due allowance for deterioration with age and differences between system head and nominal duty point head. (For details of pump curves, reference should be made to any good water engineering textbook) Figure G 3.2 shows a typical pump curve.

A short-term option for bulk flow measurement prior to installation of permanent facilities is to use temporary, portable meters. A meter is inserted under pressure without stopping normal flows. Various types of insertion probe meter are available, the commonest being either a small turbine meter, or an electromagnetic probe. They all measure pipe velocities, which is then related to volume flow rate for the pipe size concerned and they are all reasonably accurate over a wide range.

As much data as possible is required from production meters. This must be built up into a continuous historical record that can be monitored for changes, anomalies, trends and seasonal variations.

Ultimately, production metering is usually linked to a control centre for on-line control and for record-keeping. At least, it is advisable that these meters be fitted with means of data logging with periodic downloading.

Fig:G 3.1 Components of Distribution Input



SIMPLIFIED BREAKDOWN OF DISTRIBUTION INPUT (DI)

DISTRIBUTION INPUT (DI)					
WATER TAKEN (WT)					**DISTRIBUTION LOSSES (DL)**
WATER DELIVERED (WD)				DOU	DISTRIBUTION LOSSES (DL)
WATER DELIVERED THROUGH SUPPLY PIPES (WDS)			MISCELLANEOUS WATER TAKEN (WTM)		DISTRIBUTION LOSSES (DL)
MEASURED (WDSM)	UNMEASURED USE (WDSU)	UNMEASURED SUPPLY PIPE LOSSES (WDSL)	MISCELLANEOUS WATER TAKEN (WTM)		DISTRIBUTION LOSSES (DL)

3.2.3 Intermediate Bulk Meters

The criteria for checking, calibrating and operating production meters apply equally to intermediate bulk metering points installed in the network. Sometimes, the stringency of calibration checks and frequency is reduced for this category.

Over time, and with increasing network management more metering within the system will be required. As this progresses there will develop a hierarchy of metering from production to zones to areas to district meter areas. This principle is shown schematically in Figure G 3.3. I this way, the network is broken down into smaller segments and so the data becomes more locally specific for analysis in comparison with consumption data..

3.2.4 Consumption

Along with the collection of data on production volumes, assessment must be made of consumption.

(1) Overall Consumption

It is necessary to calculate the total figure for accounted-for water, which must include not only the water sold by meter but also water that is un-metered to customers and also used for public purposes (government departments, military and so forth).

All non-domestic consumers should be metered to determine their water use, since it will not be predictable or easily averaged, because the numbers are not large, relative to the number of domestic consumers.

This includes categories that are often considered as not needing meters such as free supplies and government consumers, since they are not paying for the water and therefore it is not necessary to know the consumption. This is not the case.

Metered Consumption

Examination of the total supply provided through domestic meters is helpful. If this figure is very low there may be serious anomalies in the meter sales and much of the UFW may be attributable to non-physical loss. Interpretation of this figure will vary according to social conditions. It is also helpful to compare this figure with the total domestic supply as calculated by the total production less the total bulk, industrial, and commercial supply. This survey should reveal any irregularities in the reading of meters that may exist in some cities.

The two principal issues associated with meters are the accuracy, particularly problems of under-registration of flows and risks of damage to the mechanism by "dirty" water.

A sample study may be justified to test the condition and accuracy of the domestic meters, but this

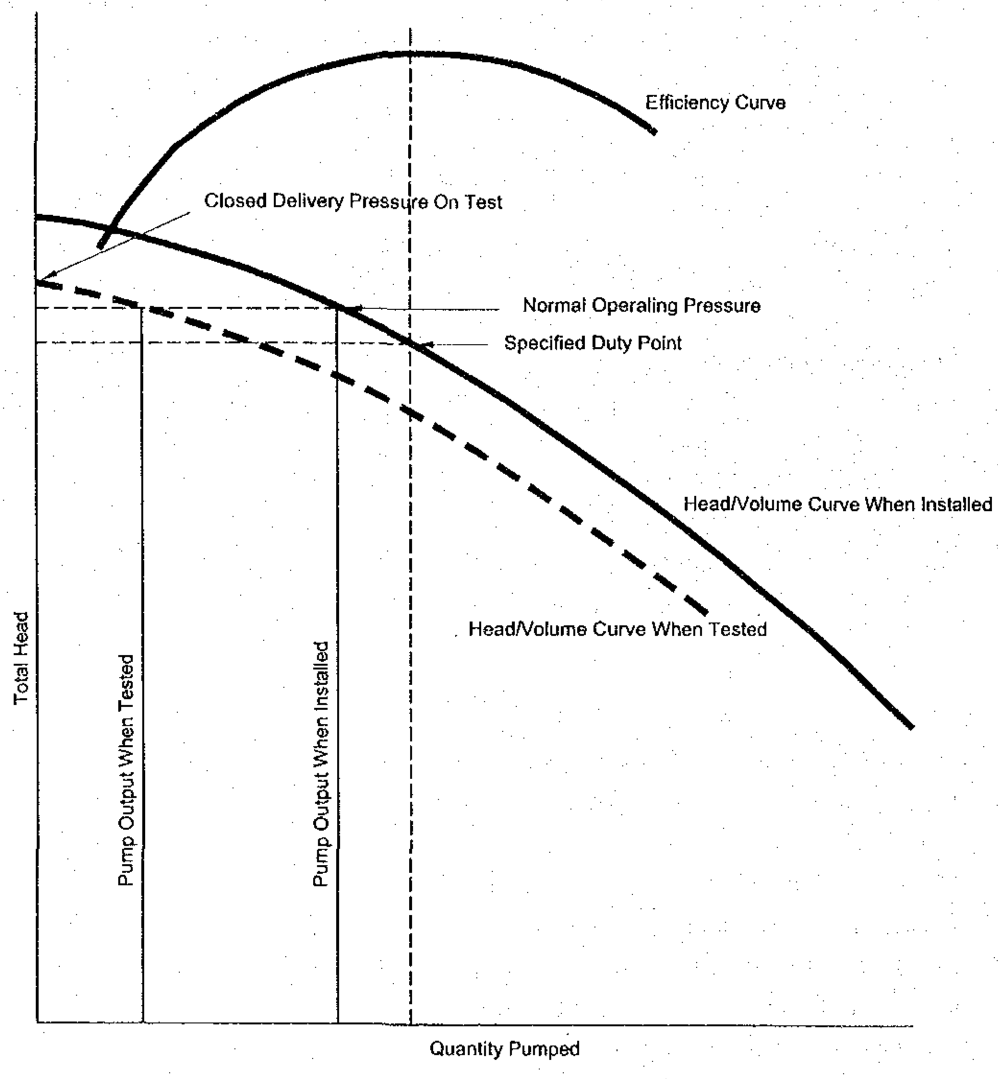


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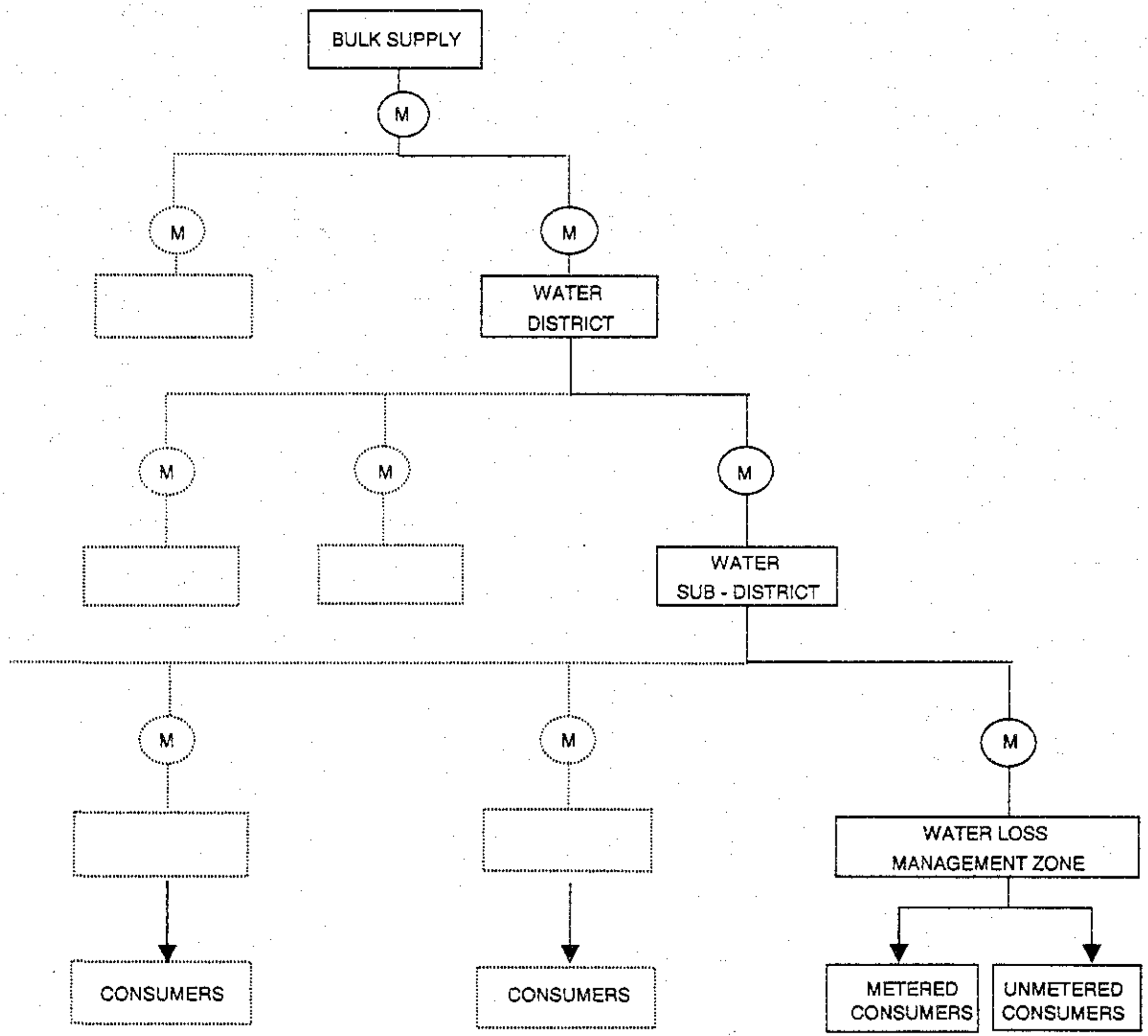
FIG. G 3.2

Typical Pump Characteristic Curve

Estimated Pump Discharge Based onTest with Closed Delivery Valve

Fig:G - 3.3 Typical Metering Hierarchy



TOTAL WATER FROM WATER BOARD or OWN SOURCES

DISCRETE LARGE AREAS WITH INDIVIDUAL DEDICATED BULK SUPPLY AND BOUNDARIES USUALLY FIXED BY TOPOGRAPHICAL FEATURES

SUB-DIVISIONS DEPENDENT ON THE SIZE OF THE WATER DISTRICTS AND IDENTIFIED BY REZERVOIR, TOWER, PUMP, PRESSURE ZONE OR TOPOGRAPHICAL FACTORS,
(TYPICALLY 3000-30 000 CONNECTIONS)

CONVENIENT AREAS SIZES FOR GROUPS TYPICALLY NUMBERING UP TO 3000 INDIVIDUAL METERED CONNECTIONS must be undertaken with care to give meaningful results. Of particular importance is the accuracy at low flows, measured by calibration checks on a test bench.

Particular problems arise when all the supply passes through a ball valve to a large private storage tank. When the ball valve is new, the period of shutting (when low flows occur) is short, but when the ball valve is old, extended closing periods occur and much of the water is taken so slowly that the meter does not register.

This is serious enough, but the problem is compounded if the storage tank is large (and the inflow maybe even throttled), under-registration then becomes continuous. Some studies suggest that in almost half the properties with tank supplies, significant under-registration may be expected.

Turbine-type meters are the most susceptible to error and should be replaced by the semi-positive displacement type when possible. (If the water supply contains large amounts of grit or rust particles, this may not be practicable.) Nominal domestic flow rates of domestic meters are usually 1.5 cubic metres per hour, but recent developments suggest that meters with a nominal flow rate of only 0.75 cubic meters per hour can be used where the supply is to a storage tank. A wholesale change may well be justified by the potential increase in revenue

Reference has been made to the importance of accuracy at low flows of domestic meters. It is particularly important to ensure that the utmost emphasis is placed on the testing of all meters at very low flows and, where accuracy at such flows cannot be achieved, to replace the meters.

Un-metered Consumption

Where a significant proportion of the consumers have un-metered supplies, it is necessary to find some means of assessing per capita consumption (PCC) to a satisfactory level of accuracy. The common method used for this is routine (or sometimes continuous) PCC surveys.

A sample survey (of sufficient size for statistical analysis) is made of actual domestic consumption as revealed by test meters (or by normal meters after calibrating). This has to be done for different areas where social conditions differ. True domestic consumption may then be assessed for this particular water supply area. The greater the number of groups (socio-economic or other) that are sampled, the more specific can be the estimate of domestic consumption.

However, it also requires good data on the number of members of each group. Multiple PCC values is more useful than adopting a single standard such as 100 litres per capita per day, but must be weighed against the complexity of and work involved in obtaining the data and performing the calculations.

In the event that not all non-domestic consumers are metered, then the same principles of survey and assessment must be applied to the relevant groups. These results will be subject to more variability, given the lack of uniformity of water use between non-domestic users.

(2) Large Users

Large users should receive continuing special attention due to their disproportionate consumption of water by a relatively small number of customers. The definition of the category and the customers on the list should be adaptable and may be changed periodically to reflect changes.

Initially, when a large user list is created, sample checks on the accuracy of large users' meters using test meters, or possibly by volume changes on private tanks, is normally a simple procedure. The total "large meter" demand may then be adjusted to allow for the estimated inaccuracies based on the sample study.

On a routine basis, concentrated attention to ensuring the accuracy of the large meters can be well worthwhile by paying handsome dividends in increased revenue from water sales. This may be rewarding work that yields a rapid return for the increased effort. Thus a policy adapted to local conditions should be formulated relating to frequency of checks and calibrations on large user meters. Typically, all meters should be checked once a year and preferably calibrated.

Large users meters should be read regularly and possibly considered for logging. It is especially important for this group of consumers that the meter is correctly sized. Historical data should be monitored and possibly specific assessments made to ensure that the fitted meter is adequate for the flows encountered, especially low rates. It is to be remembered that the consumption of a given industry or enterprise may change over time.

3.3 Physical Losses Activities (Leakage)

In this section the common techniques and practices of UFW control related to physical losses are explained briefly. First, however, the main factors affecting the leakage are presented.

3.3.1 Factors Affecting Leakage

There are several factors which affect the leakage from a supply and distribution system. These can be put under broad headings as follows:

(1) Pressure

Pressure can affect the losses from a system in a number of ways, some of which are described below.

Rate of leakage

For a system with a number of leaking or broken pipes and leaking or faulty fittings, a change in the pressure will change the rate of loss of water through those faults. The effect of pressure on leakage from a distribution mains system is very much greater than that predicted by the theoretical square root relationship.

Frequency of bursts

Increase of the pressure within a system, in some cases only by a few metres, can result in a fairly large number of bursts occurring within a relatively short period of time. Similarly, reducing the pressure may reduce the frequency at which future bursts occur. Instances of both of these effects have been reported. These effects, however, are likely to be transient and the burst frequency may eventually return to that recorded before the pressure change was made. The time taken for the burst frequency to return to its original frequency will depend upon the rate of corrosion or weakening of the pipe and can vary from a few months to many years.

Location of leaks

Higher pressures will increase the rate of loss of water from an individual leak and this may cause that leak to appear sooner. This higher rate of loss usually makes the leak easier to locate using sounding methods; only occasionally is it more difficult.

Pressure surge

Surges, sometimes greater than the design strength of the pipeline, can be caused when a pumpset or booster is switched on or off or when a valve is opened or closed too quickly. The effects of surges can cause the main or service to fracture, thrust blocks to move or joint sealant to be blown from the joint cavity. There is also some evidence that surges or other fluctuating pressures cause pipes to flex and move against rocks or other firm obstacles, resulting in local stress concentrations and sometimes failure of the pipe.

(2) Soil movement

Among the causes of soil movement are changes in moisture content, particularly in clays, changes in temperature, frost heave and subsidence. Movement of the soil may cause a pipeline to break, joints to move, or result in local stress concentrations within the pipe or fittings which eventually lead to its failure.

There is some evidence to suggest that small amounts of soil movement can also cause local stress concentrations, and hence the onset of fissure corrosion, in grey iron pipes.

(3) Deterioration of water mains and pipes

The most serious problem is the corrosion of metallic pipes.

Internal corrosion is generally more severe in soft waters from upland sources. In the case of iron water mains it takes the form of tubercles, on the pipe bore. These are associated with pitting. As corrosion of iron and steel pipes proceeds, the residual thickness of metal is reduced and hence the ability of the pipe to withstand internal pressure diminishes.

Ultimately, this process leads to complete penetration of the pipe wall and failure of the pipe with resultant leakage. The common forms of failure are hole formation and transverse or longitudinal fracture of the pipe.

External corrosion can arise from a variety of causes including differential aeration, bimetallic corrosion, variations in concentrations of dissolved salts and microbiological action. The effects of external corrosion are similar to those of internal corrosion.

Corrosion of concrete or asbestos cement pipes can be caused by soils or waters containing high levels of sulphates.

(4) Poor quality of fittings, materials and workmanship

Leakage in this category occurs in the apparatus of both the water supply utility and the consumer. The possible causes of leakage are far too numerous to list. Careful design and specification of installations and components coupled with a high standard of supervision of construction are required in order to keep faults to the minimum.

(5) Soil characteristics

An important factor which affects the running time of individual leaks is the permeability of the soil in which the pipes are laid. In some soils, water from underground leaks may show on the surface fairly quickly whereas similar leaks in soils such as chalk can run indefinitely without showing.

(6) Traffic loading

The effects of vibration and high roadway loading caused by heavy lorries and other traffic is thought, by many engineers, to be a major factor affecting the failure of buried pipelines. There is insufficient data to quantify this problem. In any event, good practice in installation in terms of adequate depth of cover, pipe bedding etc. is essential for pipes under roadways.

(7) Age

Many of the factors listed above are time-dependent i.e. their effect will be greater as time goes on. Consequently age of a pipeline can appear to be the most significant factor affecting the likelihood of leakage but, on its own, age is not necessarily a factor.

3.3.2 Summary of factors affecting Leakage

With the exception of pressure, none of the factors listed above can be easily altered by a water supply utility once a pipeline has been laid. It is, therefore, extremely important that due consideration of these factors is taken during the design and construction stages and that adequate supervision is given to ensure that the desired standards are obtained.

The other major factor which affects leakage from a supply and distribution system is the method or methods of leakage control undertaken. This is, of course, within the complete control of the or methods of leakage control undertaken. This is, of course, within the complete control of the water undertaking.

3.3.3 Methods Of Leakage Control

There are six basic methods of leakage control currently practised. Five of them involve leakage detection; the remaining method, pressure control, can be considered to be supplementary to each of the other methods. Each method requires a different level of staff input and equipment and consequently each has different capital and operating costs.

Each method will reduce leakage to a different final level. So, different types of leakage control will be appropriate in different situations, according to the costs of supplying water and the characteristics of the system.

A short description of each of the methods of leakage control is outlined below.

(1) Pressure control

Leakage reduction by pressure control is probably the simplest and most immediate way of reducing leakage within the distribution system as detection of leaks is not involved. Pressure reductions may be achieved in a number of ways such as reducing pumping heads, installing break pressure tanks and, most commonly, using pressure reducing valves.

Although this method of leakage control has limited application, it has been found to be more beneficial than theoretical considerations suggest. It is likely to be most worthwhile not only in areas with generally high pressures but also where the pressure rises to high levels at night.

Measures to prevent or reduce surges are also part of pressure control for reducing bursts.

(2) Passive leakage control

This requires the least effort on the part of the water undertaking but in most cases also results in the highest levels of leakage. No attempt is made to measure or detect leaks and generally only those leaks are repaired which are reported as a result of either water showing on the ground surface or of consumer complaints such as poor pressure or noise in the plumbing system. Reports of this nature are normally made by the police, public, or water undertaking personnel going about some other duty. Leak location may still be required for some of these self-evident leaks.

This type of leakage control will not normally be cost effective except in areas where water is very cheap and/or soil conditions are such that underground leaks quickly come to the surface.

(3) Routine or regular sounding

Leaks are located by deploying teams of inspectors who systematically work their way around the system sounding all stopcocks, hydrants, valves and other convenient fittings listening for the characteristic noise of leaking water. The frequency of sounding varies from undertaking to undertaking.

The arguments normally put forward in favour of these methods are based on the premise that most leaks are located by sounding and each part of the distribution system will always contain a certain number of unknown leaks. Consequently, time spent on metering can be more effectively used for locating leaks. These conclusions would be true provided leaks were evenly distributed throughout the system and occurred at evenly spaced intervals of time. This, however, is not usually the case. Therefore although this method of leakage control normally costs less to implement than those incorporating metering, it results in higher average leakage levels.

Regular sounding will probably be most effective in areas where the value of saving water is fairly low and where the soil conditions are such that large leaks show themselves fairly quickly so that only small underground leaks need to be detected by inspection staff.

(4) District metering

Flow meters are installed at strategic points within the system so that areas of about 2,000 to 5,000 properties are supplied via meters and the integrated flow into each area measured.

Meters are normally read at regular periods, weekly or monthly, and the results analysed to determine any areas in which significant increases in supply have occurred. If no legitimate reason can be found for the increase in an area, the inspection teams sound all stopcocks, hydrants, valves and other fittings searching for the characteristic noise of leaking water. District meters may benefit from the use of loggers.

This method of leakage control has the advantage that the inspectors are always working in those districts where leakage is anticipated to be highest and therefore are likely to return the greatest benefits for their efforts. It also has the added advantage that information regarding flows and use of water within the network is obtained which can be useful for the day to day running of the network and for the planning and design of future extensions or rehabilitation & reinforcement.

District metering is not as sensitive to changes in leakage as is waste metering nor does it so closely determine the position of leaks.

(5) Waste metering

Waste metering involves setting up areas of, ideally, between 1,000 and 3,000 properties such that when appropriate valves are closed these areas can be supplied via a single pipe in which it is possible to site a flow meter. The flow meter used is one which is capable of measuring low rates of flow and is normally referred to as a waste meter.

The waste meter, which may be permanently installed on a by-pass, or carried as a mobile unit and connected temporarily into the system via hydrants or specially provided connections on a by-pass, is normally used only to measure night flow rates. A logger is put on to the waste meter and the night flow rates recorded for later analysis. If the minimum night flow rate has increased above some predetermined level or if it is above the previously recorded minimum night flow in that waste district, then it is indicative of leakage and the area is inspected.

The inspection may consist of sounding the entire area supplied by that meter or more commonly by repeating the measurement and successively closing valves within the district, thus isolating sections of the district and enabling the corresponding reduction inflow rate to be determined. A large reduction inflow rate indicates the existence of a leak within the section last isolated. This procedure obviously has to be performed at night and is generally known as either a step test or a valve inspection. At the end of the step test, those sections showing evidence of leakage are investigated by the inspectors.

Night flow rate measurements are normally made on a regular, typically two to six times per year.

This type of leakage control has the advantages that it is sensitive to small leaks and also establishes the position of that leak between valves. The disadvantage is that time must be spent in monitoring districts where no leakage has occurred and hence no benefits obtained. This type of leakage control is likely to be appropriate in areas where the value of saving water is fairly high.

(6) Combined district and waste metering

This method of leakage control consists of a combination of the last two methods discussed. District meters are used to monitor large areas (ideally 2,000-5,000 properties) of the system and when these indicate an increase in consumption, waste meters are used downstream of them to determine more precisely the position of the leak. By suitable selection of district sizes and of meters, both waste and district meter areas can effectively coincide.

3.3.4 Leak Detection and Repairs

At the start of any programme for UFW control and before investigating any possible reduction in leakage, a study must be made of the existing organisation and effectiveness of leak detection already being undertaken by the authority. Typically, the only action taken is "passive." That is, there is no team of employees actively engaged in looking for leaks.

Action results only from loss of pressure and supply or actual leaks observed at ground surface by employees or the general public. Reports are received and action is then taken by inspectors to trace the source of leakage before a repair team is called in. Leaks not showing at the surface probably discharge directly into sewers and drains and are not easily found.

A review is required of the leakage found and the delay in repair. Where there are inspectors already engaged in locating pipes and sounding for leaks, data is required showing the number of leaks mended, volume of water saved and, particularly, the personnel, equipment, and costs of this work in relation to the estimated benefit.

(1) Sounding

Active leak detection can take various forms as described above, each with a variety of specific techniques and equipment. The simplest approach would be to call in experienced inspection teams to undertake methodical observations and sounding throughout the day or at night, listening for leaks over the whole system. Methodical observation by experienced inspectors can be very effective. Possible leaks may also be located visually from damp ground, discoloration of walls, recent excavations, crossings by other services, uneven road or pavement surface, and so on. All valves and hydrants call for special attention.

Sounding is best carried out by listening on consumers' stop taps, main valves, and hydrants. In some systems the consumers' stop taps are covered over and not accessible, or else are on their premises and are not accessible at night. There are then only very few places where direct contact with the mains or service connections is possible at night. Sounding must then be carried out on the ground surface, but this is not normally very rewarding. Whether to undertake sounding at night or in the daytime depends on labour costs and operating conditions.

Sounding in the daytime is difficult not only because there are many extraneous noises, but also because pressures are low and the sound, as well as the actual volume of leakage, is reduced. Sounding has been found less effective for most leaks when the pressure is less than about 15 metres. One major problem is that large leaks can occur without much noise being produced, whereas small leaks may make a great deal of noise. Initial training followed by long experience are invaluable identifying real problems.

The use of conventional sounding rods by experienced personnel is often the most cost-effective method of leak detection. In developing countries where labour costs may be low, the employment of large numbers of detection teams with simple equipment rather than a lot of very sophisticated equipment and metering systems may prove to be best in economic terms. Conversely, it must be remembered that sounding is an acquired skill, requiring considerable experience to be most effective, so it is not just a case of employing large numbers of unskilled staff.

(2) Leak Localisation

For many systems the precise location of the service connections and of most of the mains are not known. They are located normally by using specialised electromagnetic equipment which, with careful use, can reveal the depth as well as the line of the pipe.

A device for determining the precise location of a leak is the leak noise correlator. This equipment is valuable for the accurate location of a leak not traceable by other means, but is dependent on knowing the details of the pipe including the position and direction of the pipe on the ground.

For normal leaks, the traditional means of sounding is effective and much quicker. The correlator is invaluable at certain times, but its use has to be restricted for detection to be effected economically. Thus, it is mainly used to pinpoint a leak that has been detected and localised to a given section of pipe, by sounding or step testing. This avoids or reduces the number of "dry" holes and time spent by repair gangs getting to the leak.

(3) Leakage Control Team

It is an essential part of implementing an active leakage control programme that a core team of leakage inspectors is set up. The members should be trained in a logical approach to the problem, in coping with the various difficulties encountered in the detection of leaks, and in the use of modern equipment to make the tasks less difficult

Initially, where no in-house capacity exists, some carefully selected employees should receive ten weeks of training, possibly by a water authority in another country or by a specialist company coming to the host country. The first trainees should normally include semi-skilled employees as well as one engineer/technician who will subsequently be able to undertake the training of additional inspectors at home.

Consideration should be given to the benefits of external assistance for implementation in addition to the training needs. This assistance is likely to be required for specialised advice on active leakage detection techniques and procedures, initial testing, and on district meter installation and operation during the early stages of development of active waste detection.

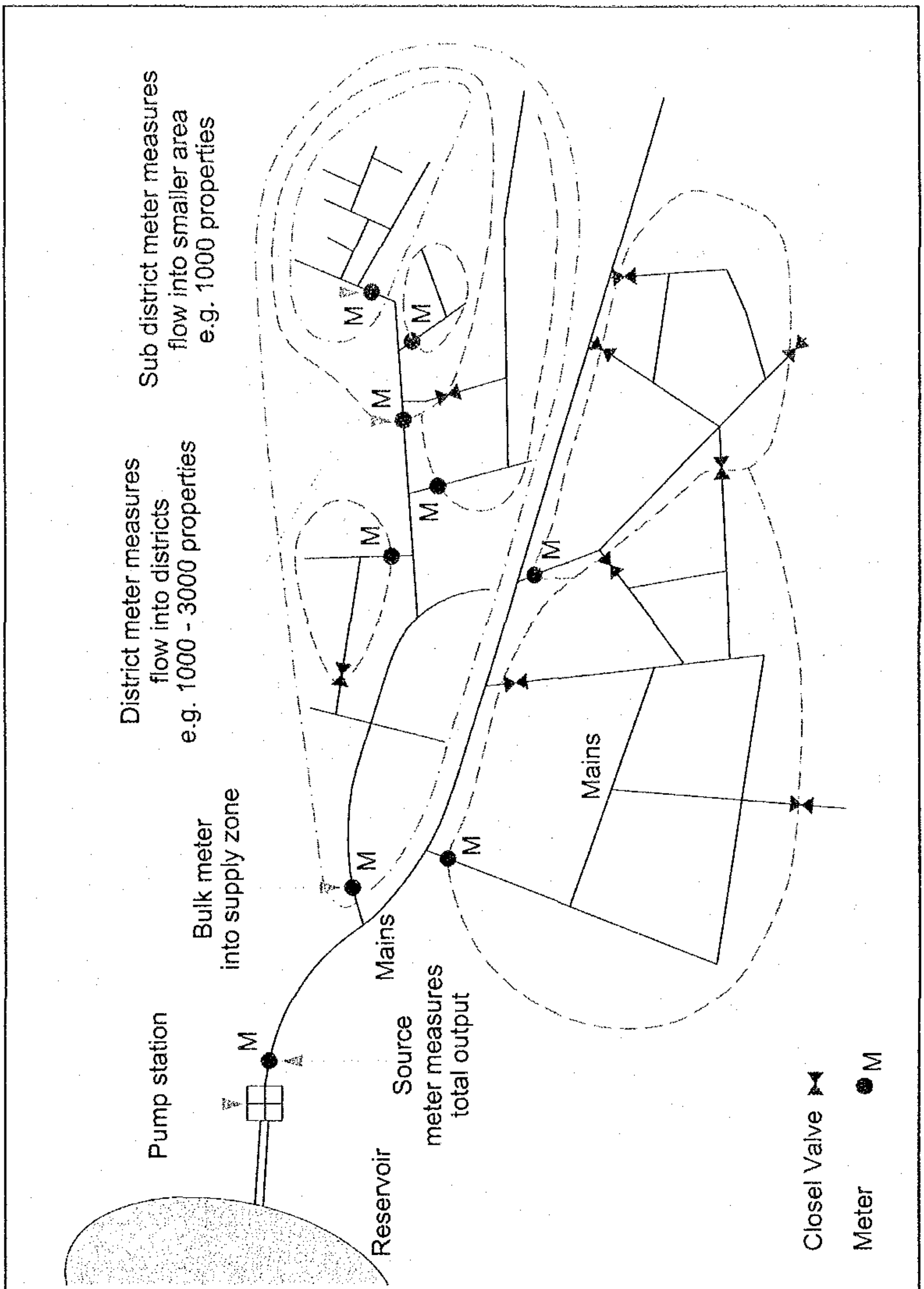
(4) Repair of Leaks Located

Leaks once located should be repaired as soon as possible to minimise the time the leak is running after being found.

3.3.5 District & Waste Metering

More effective leak detection may be achieved more quickly and economically by concentrating efforts in those areas where leakage is prevalent due to the age, material, and condition of the pipes or to ground conditions or other factors. However, these parameters do not necessarily mean that high rates of leakage will occur. So, this selection and prioritisation can be logically developed by district metering.

The supply network is broken down, by isolating valves, into different districts each of which can be metered to determine demand either over 24 hours or at night. Such districts occur naturally where there are different pressure zones, but these may be divided further as appears practicable. It may not be possible for districts to be isolated permanently (that is, in a ring main system), but temporary isolation and monitoring is usually feasible. A typical schematic of division of a network into district metered areas (DMA's) is shown in Figure G 3.4.



THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG. G 3.4
Typical Schematic Showing Division of Network into Metered Areas by Installation of Meters and Valving Off.	

Regular tests for each district will show where leakage appears to be most extensive and will also show any changes occurring due to increased leakage. In earlier stages of UFW control of a network , the district may be larger than ideal and contain about 5,000 to 10,000 properties. The net night demand in each district is a crucial figure to obtain.

District metering has the additional advantage of showing management how the system is working.

Gradually the areas can be broken down by progressively reducing the size of each district to, for example, 2,000 properties and, in developing countries, this may be the most effective method of active waste control

Action may be concentrated still further (if found to be justified in economic terms) by breaking down each district into separate waste meter districts, each of which can be effectively isolated by valves that shut off tight.

Each such 'waste district can be supplied through a single logged waste meter and, by sequential valve operation on a night test, the night demand can be recorded for each street in the district. Regular "step" night tests of this type show up variations in night demand normally attributable to leakage, and this determines where detailed inspection can be concentrated to produce the most effective results. Step testing will be found impracticable unless there is adequate pressure, during the night

A sensible first step in any improved leakage control program is to introduce district metering. In most developing countries this alone can be a mammoth task because valves are frequently inoperable and most if not all have to be changed to ensure that district isolation is achieved.

In parallel, pilot areas can be set up for measurement and analysis of supply, demand, leakage etc. and this pilot exercise repeated until eventually the whole supply or district area has been covered.

3.3.6 Monitoring District Flows

When a district is first established, all waste detection should be concentrated in that district and consumers' meters should be checked in order to determine the bases for demand and consumption. As conditions improve over the years, these bases may be lowered. But they are needed at this point for comparison with the flows recorded each time the district demand is monitored.

Regular monitoring of district flows is the simplest method of locating areas of probable high leakage and, if inspectors are concentrated in those areas, of effectively controlling leakage. One important method of improving control, particularly where waste metering districts cannot be operated, is to gradually break down the main district into smaller districts, each of which can be metered.

Where district meters have not yet been installed, they should now be regarded as essential. Once installed, the meters must be tested for accuracy. at least once a year. Any necessary improvements should be made in metering, in order to facilitate regular monitoring of flows

Isolation valves between zones should be checked regularly to ensure that they are not "letting by" at any time. Valves between districts should not be "letting by" during flow tests. It is likely that this will entail considerable work on valve reconditioning -- or scrapping and replacement.

Pressure checks both inside and outside the boundary are necessary to test valve integrity and to ensure that there are no unknown cross-connections. This is usually done by means of a pressure zero test, where the area is isolated except for one inlet point. This valve is then closed and the highest point in the area monitored to ensure that the pressure drops to zero. If this does not happen then water is entering the area via an unknown pipe or faulty valve.

District meters must be of a size suitable for measuring the whole range of flows with reasonable accuracy. They are normally installed on a bypass but, where this is impracticable, turbine meters inserted under pressure are very valuable. They should be integrating and recording as well as indicating, unless it is found that standards of maintenance are such that the simpler indicating meters are more reliable. A common size meter for small districts is 6 inches; for larger districts, two or more entry points with 6 inch meters may be better than using a larger meter.

The presence of large private tanks and indirect plumbing may limit accurate testing to low demand periods, when flows can be monitored to give meaningful results of net night flows. But tests made at times of high demand can also provide valuable information and should be undertaken when feasible.

3.3.7 Pilot Areas

In developed countries the monitoring of district flows and the consequent concentration of active leak detection in areas with high night flows has been shown to be economically justified in many cases. The level at which it economic is likely to be very different in developing countries, depending on the cost of labour and production.

Certain information is required to assess the break down of each zone or district into a number of smaller meter districts in order to further concentrate leak detection activity. This information can be gathered by establishing a pilot meter district.

(1) Pilot Meter District

The pilot waste-meter district should be located in an area where there is considerable leakage.

For test purposes, it must be isolated from the rest of the network; thus it is essential that all isolating valves be operating effectively. The area chosen should, preferably, be one of the areas selected for accurate measurement of actual consumption

It may be found that to ensure effective valve operation the simplest course is to replace all valves in and around the pilot area. In the process, care should be taken to flush out all the mains thoroughly in order to remove grit and stones.

The area chosen should be operating under a high working pressure at all times and should serve about 1,000 properties. If the area includes a number of non-domestic meters, the night flows through these meters should be readily determinable. Other factors for consideration are demographic levels, ages of mains and services, and previous history of leaks.

The aim is to be able to isolate the pilot area and to supply it through only one connection. To accomplish this, a waste meter of size appropriate to the maximum and minimum flow ratio should be installed on a bypass.

The rate of flow into the area must be measured over a 24-hour period. By comparing the flow with the total metered consumption, total physical loss can be determined. By using a logger on the meter, the night flow can also be studied as well as the total diurnal flow.

The pilot area should then be subjected to night time "step tests" to determine the night flow to each street, or sub-area. This will locate those parts of the area producing the greatest leakage and enable leak detection to be concentrated in those limited areas. Repeated tests, leak detection, and repairs will demonstrate how much water has been saved and indicate both the threshold for acceptable leakage and the cost of detection and repair.

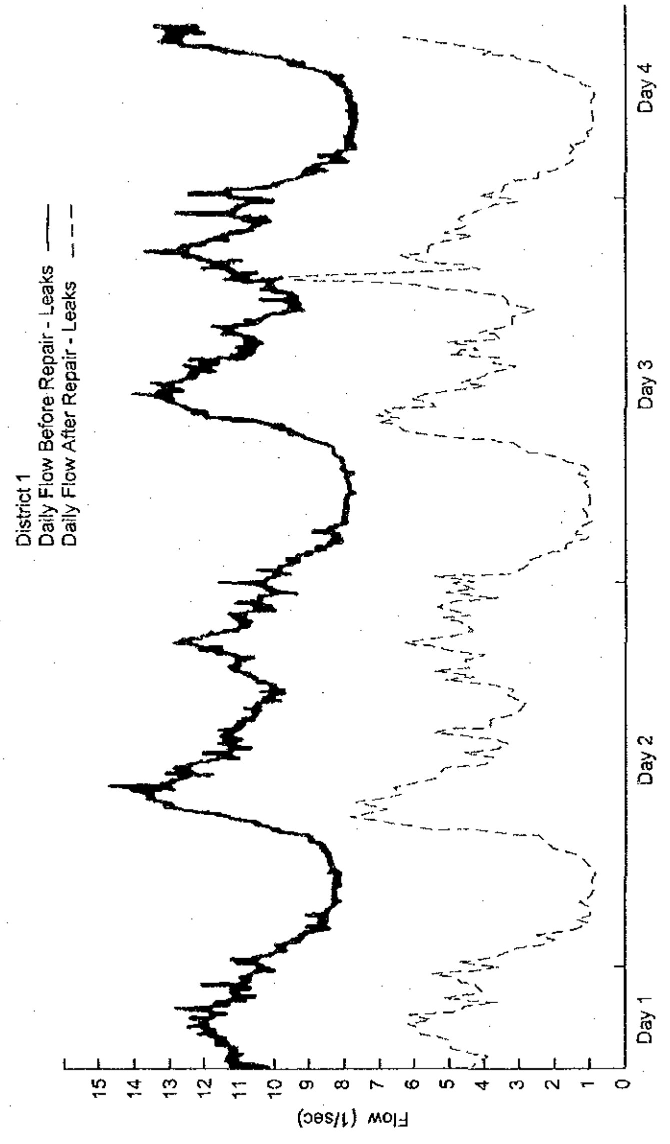
Where flows are logged the savings will be seen on the graphs of flow as illustrated in Figure G 3.5

This investigation will be invaluable in determining the extent to which other pilot meter districts should be established in order to optimise the benefits from improved leak detection. Where operating pressures are very low, however, such meter districts are not practicable.

3.3.8 Night Flows

(1) Nightlines

The only practical way of obtaining an acceptable figure representing the level of leakage in an area or district is by making an estimate of unmetered consumption (either total daily consumption or night consumption). The inherent inaccuracies of any such estimate result in the figure obtained for leakage being somewhat approximate.



JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG. G 3.5
Example of Net District Flow Before and After Active Leak Control		

Of the two methods available for making this approximate estimate of leakage :
- Total integrated flow
- Total night flow rate

the latter is more accurate. Both estimates are made in a similar way, that is by subtracting from the measured input, the metered consumption and the estimated unmeasured use; the remainder is the unaccounted for water of which a substantial part is leakage.

Total Integrated Flow
Total integrated flow is based on the figures recorded on the register of the meter and only provides a total for the meter reading period covering both day and periods and including all components of demand and losses.

Total Night Flow rate
Estimation of leakage form total night flow measurements requires more effort than the total integrated flow method, but is likely to yield a more accurate and reliable figure. The formula used is similar to that used for the integrated quantity method, but each of the measured terms is a flow rate rather than a quantity. In addition, the allowance for domestic consumption is expressed per property rather than per capita.
The total night flow rate measurement method for estimating leakage essentially consists of subtracting small flows, subject to certain errors, from relatively large flows, in order to obtain a relatively large flow. The method is therefore inherently more accurate than the total quantity method. The figure obtained form this method is strictly an unaccounted for night flow rate, but by eliminating as much legitimate use as possible the leakage element becomes dominant.

At night water demand is at its lowest and so the relatively constant rate of leakage corresponds to a larger proportion of the total. The period 01:00 –05:00 is usually considered to be optimum.

Information on gross (Total) night flows if monitored over time (especially graphically from loggers) will give useful indications of probable leakage and areas requiring investigation.

If the nightline is established for an area after an intensive leakage survey and the repair of all leaks found the minimum night flow will serve as a baseline. Not all leakage has been eliminated but it has bear minimised.

If later nightlines show a marked increase then this area should be checked to see if there are any obvious changes in consumption (e.g a new hospital opening). Otherwise the increase is likely to be due to new leaks occurring.

According to cost factors a night flow level may be set to decide when leak detection for the area will be justified. When this level is exceeded a leakage survey is carried out and repairs made till the baseline or exit level is achieved.

This is shown in Figure G 3.6

(2) Night Flow Losses

The clearest indication of physical losses is reflected, by the figure for minimum net night flow from sources, adjusted by gain or loss from service reservoirs. This figure should not generally be more than 20 percent of the average domestic demand.

This figure may be higher in other cities depending on social conditions, hours of work, shift working etc. In recent years night domestic demand in some cities has increased due to the operation of domestic washing machines at night, in order to use off-peak electricity. Excessive figures for night demand are a clear indication that high leakage is one cause of high levels of UFW.

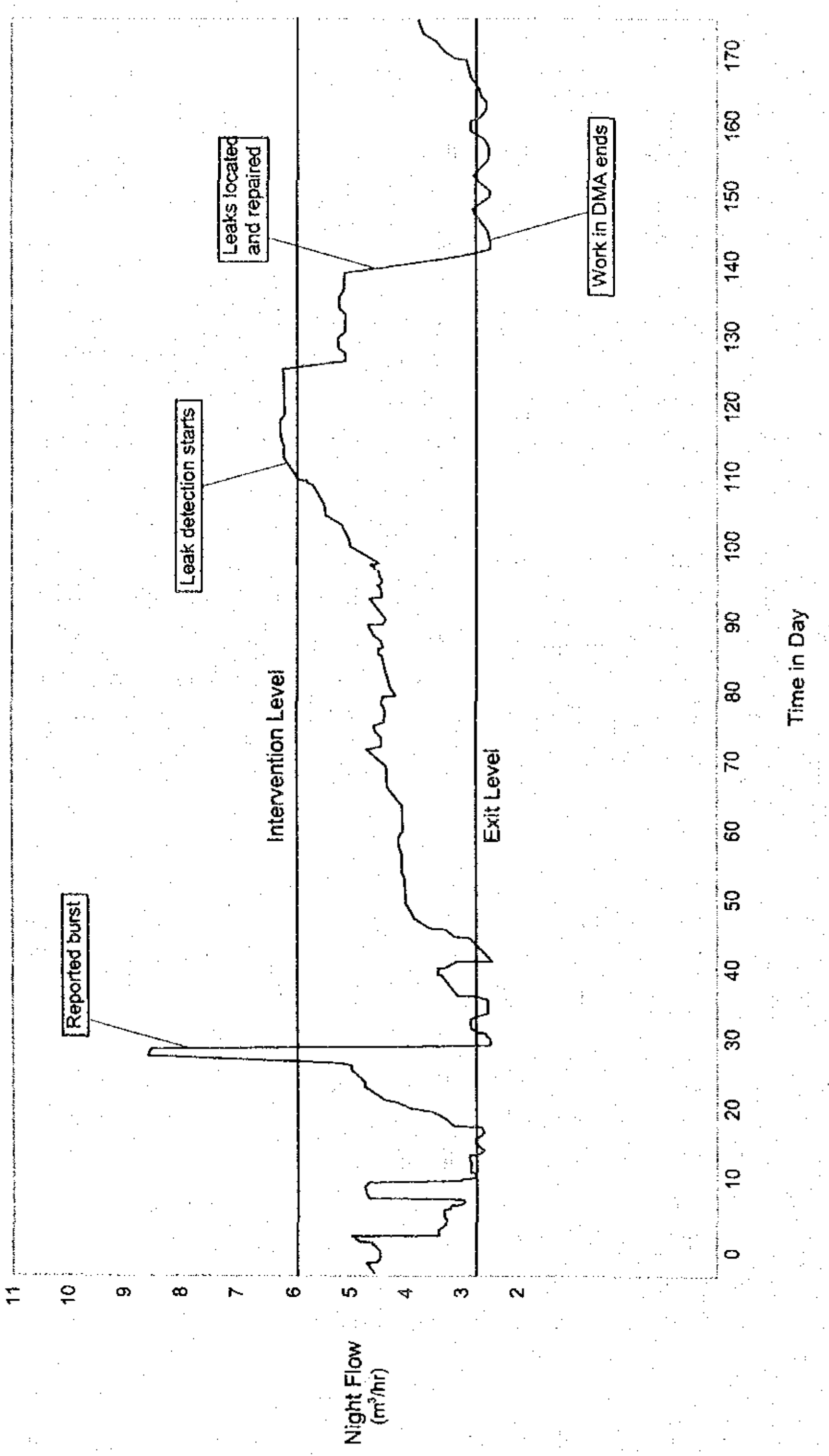
Having determined the night demand figure for the whole area, it may then be possible to calculate similarly for each zone or district in the system. Losses from leakage are highest at night, when pressures are high. Where domestic supplies are not metered and the whole of UFW is related to leakage, the current aim in a well organised authority is to maintain the net night demand below 5 to 10 l/prop/hour. (Where no active leak control is practised the figure may be 30 l/prop/h or higher.)

(3) Net Night Flows

Data on inflows to each zone or district are of inherent value since variations in these flows over successive periods will help to reveal hidden losses. But these gross night flows cannot be strictly correlated with losses, because they will almost certainly include night consumption by industry or public services, such as hospitals.

The aim is to determine the night-flow rates, if possible including variations throughout the night, for all the large meters in each district. Un-metered night consumption by public facilities, street cleaning, and so forth must also be estimated. Having determined the figures for non-domestic consumption during the night and deducted this figure from the gross inflows for each district and for the system as a whole, the net night flow can be determined and expressed as a percentage of average demand or in litres per property per hour. This figure will vary for different districts and for different authorities depending on a number of factors, including the average night pressures in the areas where leaks are prevalent.

It should not be greater than 25 percent of average in any system. It should be possible to reduce the figure below six litres per property per hour (4.3 cubic meters/property/month) by intensive waste control measures, but the target in an old system is unlikely to be less than ten litres per property per hour.



JICA	THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR	FIG. G 3.6
	Illustration of Intervention and Exit Levels	

The minimum net night flow is likely to be the best indicator of whether or not there is excessive leakage. The components of night flow into a district are shown in Figure G 3.7

3.3.9 Pressure Management

Pressure management is a very effective means of reducing physical losses in a system. It is only really an issue once the network is well-developed and well-managed, so that high pressures are experienced. It is most commonly advantageous to water supply utilities in areas of large differences in elevation, needing to serve consumers at both the top and bottom of hills..

The effect on leakage of increasing pressures is now fully appreciated even if the exact mechanisms and algorithms are still debated. Previously it was assumed that the leakage flow would be proportional to the square root of the pressure, as when water flows through an orifice.

It is now generally agreed that in water supply networks the pressure flow relationship curve does not follow this formula; instead, it normally curves in the opposite direction, which is much more serious. (One attempt to define this relationship is given in technical report 26 by the WRC, U.K., which is reproduced here in Figure G 3.8)

This is thought to be due to joints opening up under pressure and longitudinal splits in plastic pipes gaping, so that the orifice size increases with pressure. The emphasis is now placed very firmly on effective control of leakage by making all practicable reductions in pressure.

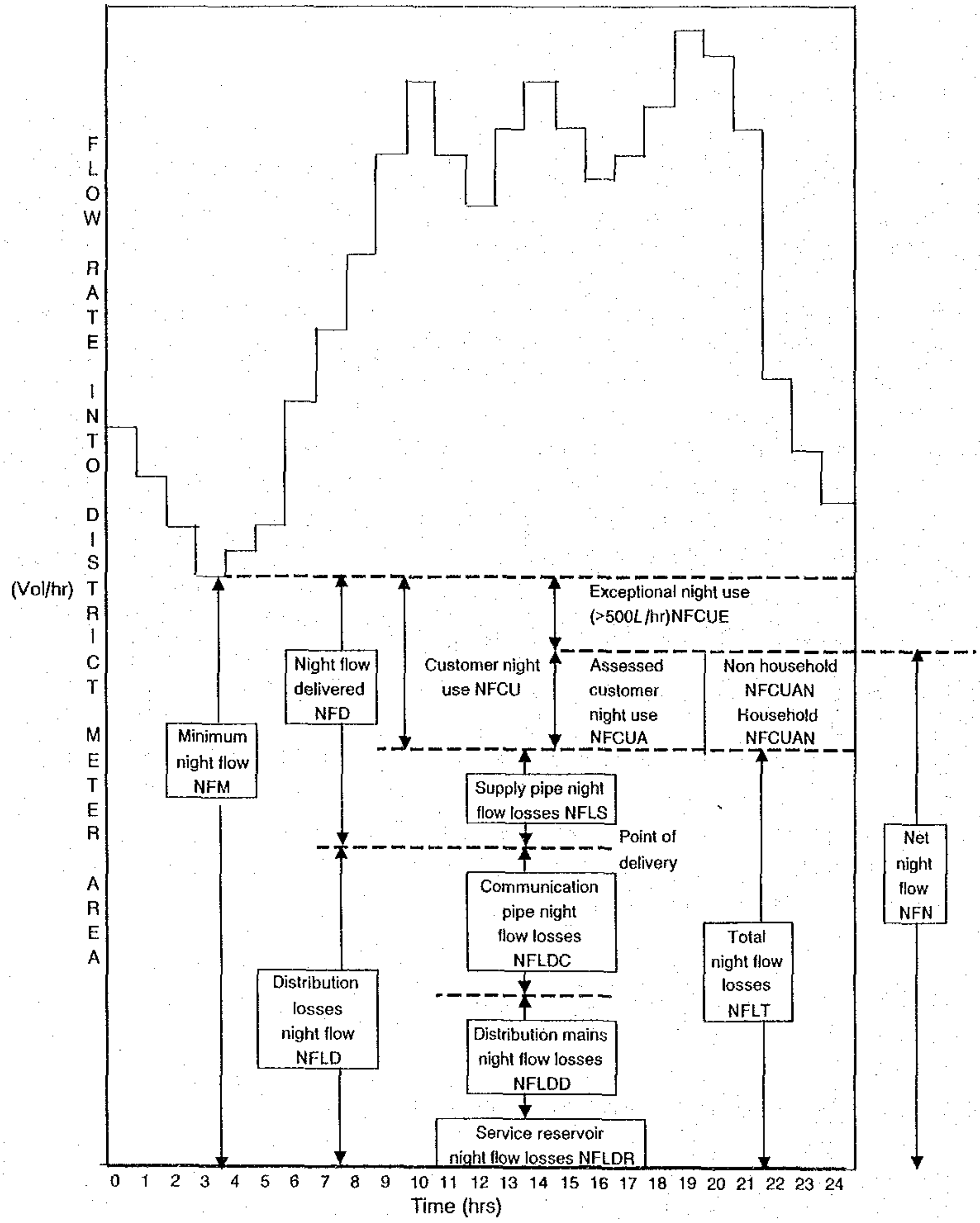
This may be achieved by means such as installing pressure reducing valves (PRV's); utilising break pressure tanks to increase the number of different pressure zones; reinforcing the network to minimise friction losses and permit operation with reduced working pressures; changing the service connections to mains operating at lower pressure; or introducing speed control or other means of reducing night flows from pumps.

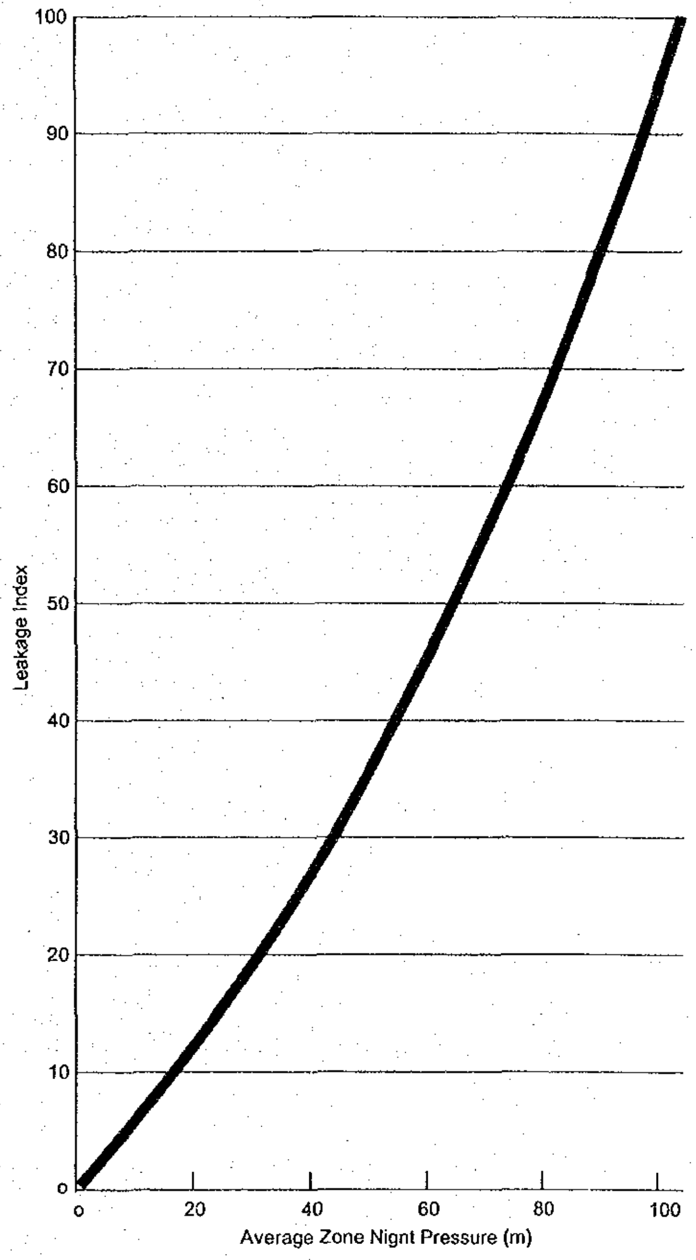
PRV's may be installed in a leading main adjusted to be fully open and to provide no reduction in pressure at times of peak flow but to operate as flows are reduced, thereby preventing the build-up of pressures during the night.

In some cases, zone boundaries may be changed to reduce excessive pressures.

Pressures and resulting leakage frequently increase at night, and reductions in night pressure may be achieved by simply installing in-line pressure reducing valves (PRV's) without significantly reducing the daytime pressure necessary to ensure continuous supplies. A careful survey of fringe areas to zones and reconnecting of service connections can be rewarding. Inter-zonal leakage must be strictly controlled.

Fig: G-3.7 Components of night flows (not to scale)





THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN YANGON CITY IN THE UNION OF MYANMAR

FIG. G 3.8

Typical Relationship Between Leakage and Pressure

3.3.10 Data Logging

In recent years the use and availability of data loggers for measurement of flow and pressure has become a lot more widespread and affordable. There are many benefits in their ease of use and the quality of the data obtained and so their potential application should be borne mind

For these activities the application of loggers is very practical and has 2 principal advantages: -

1) Provides a graphical permanent record of pressure over the logging period.
2) Can be left unattended so staff is not tied up taking reading during the logging period.

(1) Flow

Flow data obtained from loggers can provide a great deal of extra information compared to the integrated volumes from periodic reading of a meter. This benefit becomes indispensable when monitoring nightlines in district or waste metered areas.

A logger is connected to a meter by means of a suitable "pickup" or signal detector and records the flow over time. Loggers may not be permanently installed on all network meters. However it is recommended that all meters for the network be specified to have on output for a logger when ordering. Not all meters have such an output. Periodic or permanent logging may also be considered for key large consumers.

When a UFW control program is initiated it will be most practical to limit the number of loggers initially by: -

1) Permanent logging only of key meters (eg. production)
2) Having a stock with the UFW control unit for use in specific investigation in districts.

(2) Pressure

Much useful data about the network can be obtained by measuring pressure around the system and also comparing night pressures with day ones to identity flow restriction problems. Pressure data is also required for checking and monitoring the status of districts to ensure there are no cross connections to other districts.

With suitable fittings pressure loggers can be installed at any tapping on the network such as hydrants.

3.4 NON-PHYSICAL LOSS ACTIVITIES

3.4.1 Consumer Water Use

Wasted water, or simply waste, is an all-embracing term that includes leakage. In countries where domestic water is not metered, waste, whether the wilful failure to turn off taps or drips due to defective fittings, is normally regarded in the same light as water leaking underground from fractured or corroded pipes and joints. Physical action can be taken by the authority to reduce the latter but the former can be prevented only by:

(a) the strict application by bylaws designed to prevent the use of bad workmanship and fittings
(b) by public support, through the proper operation and maintenance of private fittings.

The plumbing inspector is responsible for preventing waste by consumers, which includes advice on supplying and fitting of approved equipment and checking that it is being used properly, as well as finding leaks on service pipes.

In countries where domestic supplies are metered, there has been little concern over waste other than leakage. The view has been that consumer waste is metered and serves to increase the revenue. This view is probably not justified because, whereas normal consumption occurs only for brief periods, waste from fittings as well as leaks on private service pipes may involve only small flows, they are continuous and thus may amount to a significant volume.

It has been supposed that when an authority has completed a project and has surplus water, waste by consumers is actually of financial benefit to the authority. But this is only true if it is recorded on the meter.

In many developing countries it will be found that: bylaws, if they exist at all, are honoured only in the breach; there is no compulsory control of plumbers to ensure a reasonable standard of workmanship or limitation on illegal practices; there are no effective standards for private plumbing fittings; and overflows and drips go unattended.

Where bylaws exist, they have to be put into practice. Where bylaws do not exist, the attention of the central government of the country must be brought to bear on this issue.

The co-operation of the public is probably more valuable than the strict application of bylaws, but both will only be established over a long period by education and the gradual improvement of social standards. A public education program should be considered by management.

3.4.2 Consumer Metering

In the past, some authorities have had serious problems with meters owned by consumers, and this practice has hopefully now been superseded. The consumers' meters must therefore be owned by the authority, which will set an appropriate rental charge to cover the initial cost, installation, and maintenance costs.

The choice of meter type depends on the quality of the water but, for all large industrial or small domestic purposes, rotary piston meters are normally preferable to inferential turbine (multijet or single jet) meters because of their greater accuracy.

The meters should in most cases, be protected by additional strainers to limit erosion or seizing of the moving parts. However, if the water supplied contains large quantities of sediment, sand, or rust it will seriously interfere with rotary piston meter performance and life. There could then be a justification for using inferential turbine meters.

(1) Domestic Meters

Domestic meters are normally 15 millimetres in diameter, but some authorities have standardised on 22 millimetre diameters because of past low pressure problems. Water meters for cold potable water use are normally designed to comply with ISO 4064 or an equivalent standard.

Meters are subject to gross inaccuracy at low flow rates and this inaccuracy increases with age long before the meter fails completely).

Where past supplies have been discontinuous, the practice of installing very large storage tanks to cover periods of deficient supply has evolved. This has encouraged the practice of throttling the supply so that the tanks are filling slowly over most of the 24-hour period, with the result that. under-registration prevails at all times.

In time, as the reliability of the water supply improves, consumers should be encouraged to reduce the capacity of or remove their storage. Once a continuous supply under pressure can be assured, the tank becomes redundant, or its capacity could be reduced.

Some research has suggested that for all normal requirements 15 millimetres is unnecessarily large. It provides for normal flow rates of 1,500 litres per hour (the 22 millimetre diameter will pass up to 5,000 litres per hour) whereas 750 litres per hour is adequate where there is indirect plumbing and could be obtained with 10-12 mm diameter meters.

With 15 millimetre diameter meters the average under-registration of new meters in normal use may exceed 5 percent, with smaller diameter meters of 750 Litres per hour rating, the average under-registration is expected to be about 2 percent.

Selection and procurement of water meters is not a simple matter and can require assistance from specialised consultants.

When an authority reports that 25 percent of its meters are inoperative, it is probable that at least another 25 percent are recording only a fraction of the flow. When a meter is not operating, the practice is to charge based on an estimated flow. This estimate is based on registration recorded before the meter failed, and so is likely to be a very low estimate.

Lack of proper maintenance of meters is thus a prime cause of non-physical loss.

(2) Large Meters

In most cities, whether or not domestic supplies are metered, a very large proportion of the water consumed is sold through relatively few large diameter meters for bulk supplies to neighbouring authorities or to industry, commerce, military camps and large government institutions or other public entities. It is of great importance to ensure that these large quantities are being recorded correctly; as they are few in number this is a relatively easy task.

The first and most essential task is to site check whether these meters do record normal and low flows within the normally accepted tolerance of +/-2 percent. To ensure this, the meters must be tested frequently (at least annually) for accuracy. They must also be changed, cleaned, repaired, adjusted as necessary, and shop tested before reinstallation. These tests must be undertaken at both very low flows and normal flows.

Although accuracy at low flows is difficult to ascertain, low flows may persist for long periods and represent large quantities of water. The larger the meter the more frequently it should be site tested and, if necessary, changed for shop refitting and testing. Depending on the quality of the water, routine replacement of the very large meters every two years may be found cost effective.

The size of the meter should be appropriate to the maximum rate of demand without unacceptable loss of pressure. When demand is very high, compound metering may be necessary. Industrial demands fluctuate with business cycles; where a decline in business activity and in the rate of demand has occurred, a change to a smaller meter may be warranted. Otherwise, an unnecessarily high proportion of the flow may be subject to excessive under-registration.

An independent historical check should, if possible, be carried out to ascertain how consumption relates to the volume of business. If at any time the increased activity is not reflected in increased consumption, an explanation should be sought. Likewise, an increase in metered demand without a corresponding increase in business activity should be investigated. It could be due to a major leakage or other type of waste on the consumer's premises. Irrespective of changes in demand, an independent check is justified to confirm that the size of the present meter corresponds to the maximum and minimum rates of flow recorded.

The site testing of these meters may be by isolation and timed volume change in the consumer's private storage. If this is not possible, provision should be made when the meter is. installed for a spot test at any time by discharge to waste through a test meter. Valves closed for this purpose must be checked to ensure that they shut off flow effectively.

The choice of manufacturer and type of meter is important. For most purposes displacement meters are favoured for greater accuracy but, where failure of supply could have serious repercussions (for example, at a hospital or where expensive material is being produced), local storage is essential. If not possible, an inferential turbine meter would be required, which probably would be less accurate at low flows.

3.4.3 Meter Repairs and Testing

The procedure of changing meters at regular intervals requires the existence of a meter repair shop for cleaning, repair, and testing of defective meters. To be effective, the annual output of reconditioned meters must be about 25 percent of the total number installed (and 50 percent or possibly 100 percent of the total number of large meters).

If the current capacity is inadequate, the location of the site in relation to the centre of demand, traffic problems, and journey times should be reviewed before expansion is planned. Having established the best location, capacity may be determined on the basis of two-to-three square meters for every meter to be serviced per day. This space will allow for receiving old meters, cleaning, repairing, painting, storage, testing, and dispatch, as well as office space for records and storage for new replacement meters.

It is essential to ensure that accurate testing is done at very low rates. For domestic meters and indirect tank supply plumbing arrangements, a low rate would be about 15-to-20 litres per hour; for larger meters, proportionate increases in minimum test flow are allowable. The recorded flow should not show more than +2 percent difference from the flow as measured by tank volume changes.

It is recommended that all meters be painted a distinctive colour to denote the year they were reconditioned. This will help to ensure that all meters are changed at regular intervals.

A study of the records of meter breakdowns and repairs is a necessary preliminary to the formulation of policy on the selection, installation, and maintenance of meters. If no records are available, they must be started as soon as practicable: Records should be kept on cards or in a form by which data can be rapidly retrieved to show manufacturer, type, size, frequency, and nature of failures that have occurred.

If records show very frequent failures because of suspended solids in the water, the use of modern flow limiters through which the flow rate remains fairly constant over a wide pressure range should be considered, and a pilot study should be made.

A study of output per person may be necessary in order to ensure that an expanded meter workshop is designed to minimise the cost of repairs. This study should include the cost of meter replacement, including transport to the workshop.

3.4.4 Meter Replacement Policy

As they become old, meters become inaccurate, generally running more slowly. In practical, after 5 to 10 years depending on meter quality and site condition, meters should be changed.

Samples of each model category should be periodically tested on the Water Meter test bench and other tests and assessment performed to

(1) Meter Replacement Programme

Based on the results of the meter type tests and calibrations, a Meter replacement Programme should be prepared to ensure that all meters are replaced within the time period; at a fairly constant rate per year.

(2) Large Meters & Large Consumers

Particular attention should be paid to the metering and the management of large consumers. It is recommended that the large meters of the networks should be systematically and regularly checked and calibrated on the test bench.

Furthermore, given their relative significance, a separate assessment and development of a replacement programme is required for large customer meters. It is likely that the replacement period of large meters will be considerably less than for small domestic meters.

3.4.5 Un-metered Consumers

In a water supply utility where some or all consumers are not metered then direct measurement of consumption is not available and measures are required to assess and estimate this element of consumption.

It may then seem obvious that all consumers should be metered. However this may not always be the case and the costs and practicality of universal metering should be reviewed before embarking on such a programme. It can be very expensive to achieve initially and will have recurring costs from replacements, repair, calibration, and lost revenues from under registration and breakages as discussed previously. Clearly universal metering is no panacea for all ills. In any case, it should be noted that the meter measurement will only be as good as the quality (and hence cost) of the meter permits.

A number of administrations around the world operate successfully without full metering of consumers, though the trend is away from this. In order for this to work various actions need to be taken and followed assiduously. Some of the money saved by not investing in meters has to be re-directed to getting good quality information on the consumption patterns of consumers broken down into various categories.

Un- Metered consumers is a category generally applied only to domestic users and possibly small commercial and industrial customers. All non domestic consumers of any size should be metered irrespective of the general policy on metering.

(3) Assessment of un-metered Consumption

The general approach to obtaining good estimates of consumption by un-metered users is to carry out in-depth studies of a representative sample of each category to be assessed.

Domestic consumption patterns are found to fairly consistent for a given standard of living and the use of averages is reasonably accurate. The same is not true for non-domestic consumers and any average used for these will be subject to considerable variation.

Domestic consumers with different living standards will have quite different water demands. As a result application of a general per capita consumption rate obtained from total demand figures will distort the consumption figures unless the district being investigated for UFW happens to have a perfect mix of all consumers.

The more the population is divided into separate categories for analysis the more specific will be the consumption data obtained. Set against this it is necessary to have complementary, detailed information on the numbers and locations by district of each group in order to be able to apply the individual PCC rate.

The commonest form of division by category is to use socio economic grouping. There are standard assessments available. An alternative might be to use plot area and standard of housing. The choice and number of categories may alternately depend on statistical data already collected and analyzed by government and municipal departments.

(4) Sampling

For each category defined a study of consumption is carried out over a period long enough to establish standard patterns. A sample group of the category is identified and the consumption monitored very closely.

Each connection selected is fitted with a meter of good accuracy and service pipe leaks are repaired. Meter readings are taken frequently and a time based record of consumption patterns established. With enough data an average PCC figure is obtained for the group.

This sampling is either continued or repeated periodically in order to update the data and take account of changes.

The sample group should be treated as un-metered customers, so that they are not influenced by the meter readings and so remain representative of the category of user..

(5) Conclusion

Without this sampling of categories of un-metered consumers consumption estimates will be very misleading and end up falsely identifying areas as having high leakage or the reverse failing to identity areas that really do have high leakage.

This will cause operating expenditure to be wrongly or inefficiently directed and nay have similar effects on capital expenditure.

So although this task will require considerable work with associated costs it is a necessary activity in a utility that does not have universal metering.

3.5 GENERAL APPROACH FOR COST – BENEFIT ANALYSIS

As has been referred to a number of times in this text, the choice of and implementation of various activities for UFW control should be based on an assessment of the relative costs and benefits expected of each element.

The exact method and costs to be used will be determined by the policy and legal status of the water supply utility. The finance department will also define some of the parameters and methods to be used, possibly. Other factors such as allocation of overheads will also have an impact.

Therefore, the approach described in this section is intended only as an *illustration* of the general approach and an example of one method, originally proposed by WrC in the U.K.

The following section describes a procedure for preparing an economic analysis of leak detection (physical losses), which can be fairly readily undertaken at this stage. More uncertain and dependent on internal departmental estimates will be economic analysis of non-physical losses. A structure for preparing this estimate will need to be created at an early stage of the UFW control plan implementation.

There are two main justifications for minimising NPL, which are not just economic but more financial

- To account for water consumed properly so that investment is not wasted seeking Physical losses that do not exist
- Ensuring that income is maximised by collecting revenue for water actually consumed

3.5.1 An Example of Economic Analysis of Leak Detection

Leakage represents a physical loss of water, but the control of leakage entails some cost and normally can be justified only in relation to the cost of producing the water saved by leakage reduction. Additional savings may be achieved if leakage control results in lower costs of sewerage and sewage treatment.

Where water resources are limited, the simple analysis of cost of water saved in relation to the cost of leakage control is not the sole justification for active control. Furthermore, the active control of leakage entails improved control of the water system and is of direct benefit to management and thus to the cost of supplying water.

Leaving aside these associated aspects not readily assessable in economic terms, it is relatively simple to undertake a cost/benefit analysis of leakage control and thus to determine future policy regarding the degree of control to be exercised. The cost of leakage is reflected in:

(a) the variable element of operating costs and
(b) the capital costs of new works, to the extent that the construction of new works may be deferred.

When an authority has a large surplus production capacity and major distribution works, and does not foresee incurring large capital costs in the near future, increased expenditure on leakage control may be less justified. Nonetheless it must be remembered that a reduction in leakage can help to increase revenue by increasing water sales.

3.5.2 Cost of Leakage

Unit cost of leakage = unit operating cost + unit capital cost

(1) Unit Operating Cost

To calculate the unit operating cost (marginal cost) of water, one is concerned only with those water sources where production costs would be reduced by reducing leakage. Normally the large gravity source or the locally pumped source will produce the least costly supply and will be retained.

Bulk supply sources or more recent and more remote pumped sources may entail more expensive pumping and treatment costs where reduction in output will be of greatest benefit. When reductions can be foreseen at more than one source it is necessary to calculate the weighted average of the variable operating costs at each source.

To calculate operating costs, fixed costs that are not affected by variations in quantity produced must be included. The normally calculated total operating costs of water from each source station are not relevant. Variable operating costs include electricity for pumping and chemicals for treatment. Other variable costs usually are not significant.

(2) Operating Costs

To calculate electricity costs if there is no power meter, use the following formulae:

Power input = 1.73 x volts x amps x power factor / 1,000

Unit pumping cost = power input x kWh unit charge volume pumped (m3/h)

Unit treatment cost =annual chemical costs annual quantity of treated water

NOTE: The operating costs are reduced to currency unit/m3

Inflation factors should be ignored because they will apply more or less equally to labour and other costs of leakage control.

(3) Capital Costs

Normally projections are made for five-year periods, but they can be made for a more extended period if large expenditures such as new source works or transmission mains are likely. It is necessary to estimate for each year the capital expenditure for source works, treatment works, pump stations, service reservoirs, transmission mains, primary distribution mains, and distribution reinforcements.

The capitalised fixed costs of operating the future new works must be added to the capital costs. These costs are estimated by reference to the fixed costs of existing similar works; annual costs are capitalised by applying the factor (1 + r)/r, where r is the discount rate. For example, for a 5 percent discount rate the factor is 21.

Where a project cannot be deferred for some good reason, it may be wholly or partially omitted and in this analysis a "demand multiplier" should be applied.

Where a new project will satisfy demand for a long period ahead, its cost should be increased using a capacity multiplier. The total discounted capital cost (TDCC) can be obtained, using the curves for different discount rates in Figure G 3.9.

The unit capital cost is then calculated from the formula:

$$\text{Unit capital cost} = \frac{\text{TDCC x r2}}{(1+r) \text{ x } 3.65 \text{ x d}}$$

r = the discount rate
d = the projected annual rate of increase in demand

3.5.3 Cost of Leakage Control

Having determined the extent of leakage and the unit cost of leakage, management has to set a realistic target for leakage control. This may be a reduction of UFW from say 40 percent to 30 percent (or it may be expressed in litres per property hour as given by net night production).

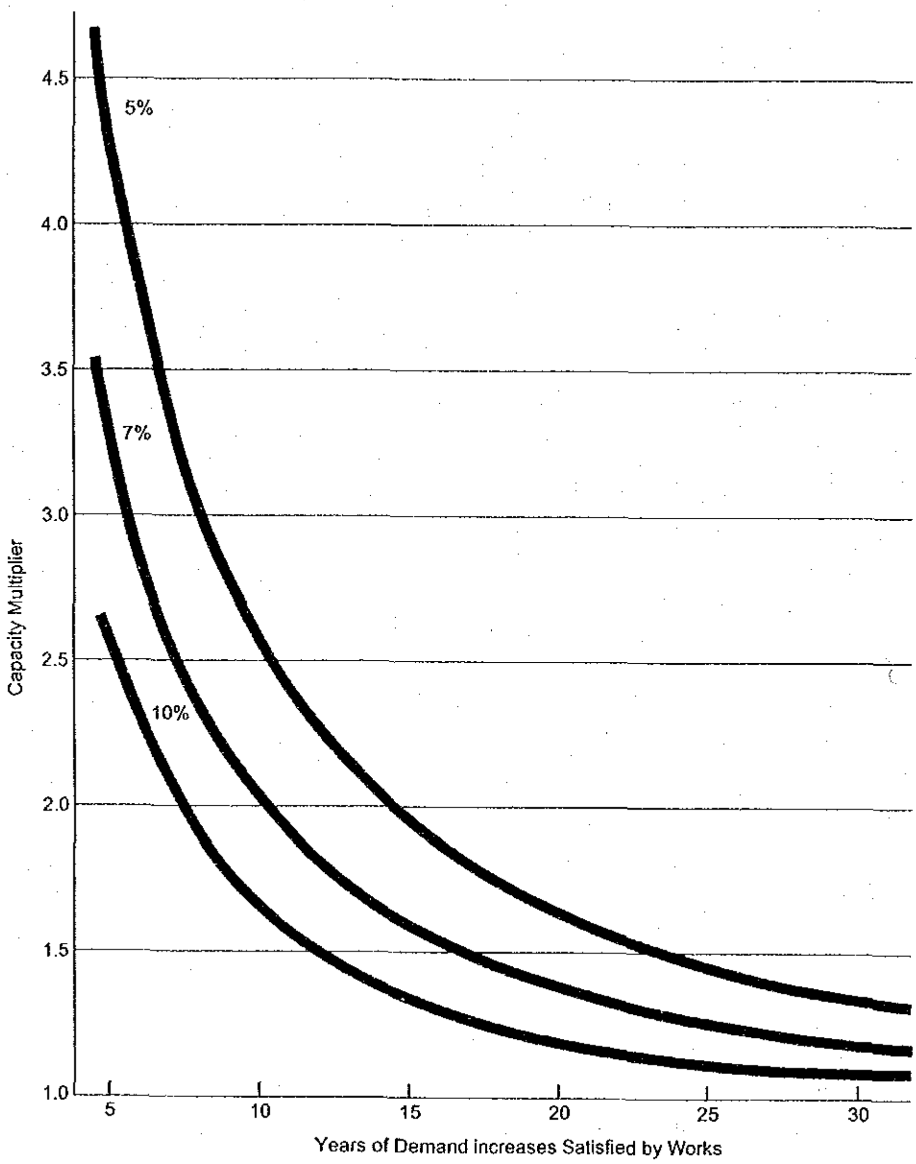


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FIG. G 3.9

Capacity Multipliers for Various Discount Rates

The cost of improved leakage control based on increased labour and equipment then has to be estimated based on the type of control proposed.

The results must be monitored to ensure that the target is being achieved without the cost of control being exceeded. The step-by-step procedure proposed ensures that improved control is maintained within the economic limit justified by the saving in cost of water produced.

Costs of leakage control can vary greatly depending on: labour costs in the particular country; extra costs for night work; and above all, the condition of the system at the outset. If the system has become very run-down due to negligible input on proper operation and maintenance, the preliminary cost of putting the system into reasonable condition could form a considerable part of the total.

Assuming that such preliminary work is charged to general operation and not to the waste detection program, typical costs of various components would be in line with those noted below.

The costs of associated repairs should be readily determined from existing records but, failing that, might be based on: a team of five, plus a driver; repairs to pipe (five hours), to service (three hours), to valve or hydrant (two hours).

(1) General Comment

The initiation of active control can be expected to show a considerable financial return but, as the program is developed and leaks are repaired, the results gradually become less rewarding. The law. of diminishing returns applies, and it is advisable to repeat the economic analysis at regular intervals using updated cost projections to ensure that increasing efforts are fully justified. It must not be overlooked that the most important part of control is to repair rapidly the leaks when they are located.

4 OTHER ACTIVITIES RELATED TO UNACCOUNTED FOR WATER

UFW control is an integral part of network operations and affects or is affected by many other activities and policies of a water supply utility, which cannot always be readily disentangled.

This section presents an explanation of some of those issues and activities, which are not necessarily a direct function of UFW control, but nonetheless have an important role in the subject.

For those already familiar with the subjects or concerned only with the UFW plan of action for implementation by YCDC, this section may serve only for reference.

4.1 MAPPING AND NETWORK SURVEYS

Some opinions in developed countries hold that there is little or nothing to be done in improved UFW control before until existing maps and records have been carefully checked and updated.

In developing countries conditions are often different and although accurate mapping will be necessary before control is fully effective, much can be done to begin reducing UFW while mapping and updating of records is in progress.

There is much that could and should be initiated and will show tangible results before accurate mapping and updating of records is fully advanced. Initially it is necessary to review existing records and decide which parts of the system require remapping and the extent of the survey work required.

4.1.1 Network Surveying & Mapping

A clear, detailed picture of the system must be available both for careful upgrading of the metering of total consumption and for the final planning of separately metered zones and districts. However, in many instances the physical effort of locating all valves and hydrants, testing their ability to open and close, and replacing them when necessary is essential before a district or a pressure zone can be effectively isolated. The accurate location of long consumers' services near zonal boundaries is also essential before the boundaries can be delineated.

The undertaking of an extensive project for locating mains and services and accurately recording them may well not be feasible for the staff of the Water Supply Utility, who are fully occupied with routine operations of the system. It may be practical or even necessary, to let a contract for this work to a specialist company.

Many companies specialise in such work, which may entail no more than visual inspection and location of valves but is much more likely to require that all mains, including buried valves, be electronically traced and plotted on new maps. The cost of this work could be high as it will require many months work for a large city, but it is a prerequisite for effective UFW control.

In considering costs and benefits of this work, it is important to remember and to include the other aspects of operations, maintenance and improvement of the system, that also use this data. Network improvements and rehabilitation design work depends on accurate information about the existing system. Repairs and routine maintenance will be hampered if, for example, the location of valves is incorrect or missing.

Many facets of good water supply system management are dependent on the quality of the network data and the cost of improvement by re-mapping should not be attributed only to UFW.

4.1.2 Location of Valves, Hydrants etc.

A major problem in many cities arises from lack of supervision and maintenance of the distribution system over an extended period of years. In fact, high figures for UFW are usually associated with inadequate maintenance of works. The lack of adequate maintenance is often revealed by the failures of valves to operate effectively or even by the loss of valves and hydrants.

The location of all valves and hydrants is an essential part of the mapping process and this must be followed by repair, replacement, and the provision of new surface boxes and marker posts. They must also all be numbered for future reference and use in the leak detection work.

Serious consideration must be given to the appointment of senior inspectors to be solely responsible for the operation of all valves during repair work and for ensuring that valves are maintained in full working order and are not covered over in new road surfacing work. Some organisation of this type must be adopted to ensure that improved standards being introduced will be perpetuated.

If this is not done, remapping will prove of little value. It will also be of little value if after the mapping campaign is complete, an effective system is not put in place to ensure that the maps and other data records are kept up to date.

Control of UFW entails the continual repetition of a series of simple, logical processes and tasks to obtain increasingly accurate detailed data that facilitate ever more efficient detection of deficiencies. Mapping is no exception; it is a continuing process required for meeting the needs of system expansion and new demand.

Follow up to the survey should include finding, exposing, marking, and numbering all valves. This work may best be done in conjunction with remapping of consumers' service connections.

4.1.3 Maps, Records, and Network Analysis

Once the master survey has been completed it can be reviewed and decisions can be made regarding further improvements required, particularly regarding how much can be done in-house and the extent to which specialised contractors should be brought in for any further assistance.

One specialist function to be considered is network analysis. A computer model of the water supply system will be built and this is used as a planning and troubleshooting tool by the utility. But like any computer tool, if the network data used is not good, the results will not be useful and at worst may be very misleading, resulting in ill-advised capital investment decisions.

For the preparation and storage of the surveyed data, most water utilities today use GIS systems in some form. This is the optimum solution available for such diffuse data. The complexity of the various systems varies and consideration of the needs of the water supply utility is required. Specification and introduction of such a specialised system may well require the provision of technical assistance from outside agencies.

If no existing system is in use, then it is advisable for the water supply utility to acquire a GIS (Geographical Information System). It is recommended that this is modular to be suitable for expansion in line with the capacity of the utility and also that it has an open format that will enable other software to access data and supply data.

As an example of its use, if a continuous record of leaks detected and details of repairs carried out is cross-referenced by location, a valuable record would be built up to show where leaks are concentrated and the cost of individual repairs. If displayed on a map as is quite feasible, trends and problem areas will show up very readily. Such data would be useful in determining when complete refurbishment of a section of the system would be justified.

Other information that should be recorded and referenced include material and age of all pipework, valves, and fittings. This information may be built up by studying old records, as well as by getting feedback from repair teams and other investigations.

As well as the requirement for the flow of information inwards to enable records to be updated, it is essential to ensure the outward flow as well. Arrangements need to be put in place for many different categories of staff to be able to gain access to the information they require to facilitate their work.

One of the simplest examples of this requirement is that repair teams, leak detection staff etc. need to have up-to-date copies of maps when they are working on site.

4.2 CUSTOMER SURVEYING AND MAPPING

Associated with the need for accurate up to date information concerning the network is the requirement for the same relating to customers and properties.

4.2.1 Unrecorded and Illegal Connections

An intractable problem in many cities is the existence of numerous unrecorded and illegal connections. They are difficult to trace and, after removal, may frequently be replaced. It is reported that in many cities they represent a major cause of non-physical losses. In such cases a separate mapping exercise to locate, list and map all such connections will be required. Whatever method is used, it will be essential for management to sample check at regular intervals areas that have been surveyed and mapped to ensure that illegal connections that have been removed have not subsequently been replaced.

In order to get and maintain control of customer management a database (information system) of all consumers is required containing all pertinent information about the connection as well as the consumption record. This includes but is not limited to;

- Name of customer
- Address
- Type/ Class of property or Non-domestic connection.
- Connection Length of service pipe
- diameter of service pipe
- metered / un metered
- meter size
- Pumped
- DMA ID - to identify which DMA it is supplied from
- meter reading route or billing / collection route
- Meter reading record.

Also in order to facilitate control and identification of anomalies all streets and properties should be surveyed and mapped. Then those properties that have a connection identified in some way (seeded).

The best policy would be to combine the property survey with the network survey so that.

1) It is more cost-effective to do at the same time
2) If answer there are no gaps or omission between the 2.

Regarding storage and updating of information the same criteria apply to the customer databases as to the network

4.2.2 Customer Database Management

Once the field consumer survey is complete, the emphasis changes to the customer management. The purpose is to maintain the records and data relating to customers in good order and up-to-date, in much the same way as for the network.

As a check, some possible issues for improvement are highlighted here. The improvement of customer management generally includes:

- the keeping up to date of the customer files
- the correction of technical anomalies
- the correction of administrative anomalies
- internal organisation of customer management and the need to expand

(1) Keeping up to Date of Customer Files

Permanent keeping up to date the customer files is important to quickly detect and correct technical or administrative anomalies, and hence to reduce losses and improve the service to the customer.

(2) Correction of Technical Anomalies

The technical anomalies which can be detected during the consumer survey or meter reading and checking or leak detection activities include:

- leaking connections (upstream of the meter), when visible
- leaking connections (downstream of the meter), when visible
- clogged service connection
- damaged service connection
- inaccessible meters - these meters are either buried or the utility staff cannot enter the property for some reason.
- illegal connection, including any case where water is taken upstream of water meters

(3) Correction of Administrative Anomalies

The administrative anomalies can be:

- under-estimated flat rate consumption on un-metered consumer connections.
- non metered legal free supply
- wrong tariff category applied.

a) Under-estimated Flat Rate Consumption

If a tariff structure exists is in use that assesses consumption according to some set of criteria, such as number of inhabitants, plumbing installation, etc then this must be checked periodically and updated as appropriate.

b) Legal Free Supply

These can be service water use for public garden watering, street washing, fire hydrants or special consumers. These service connections, even if not billed should be equipped with meters in order that their consumption is Accounted-For.

c) Inappropriate Tariff Categories

The YCDC applies different tariff code, according to various category of customer: domestic, commercial, industry, etc

When updating consumer files the necessary consumer type and category must be checked.

4.3 MANAGEMENT INFORMATION SYSTEMS

For good practice in network management generally and UFW control in particular a large amount of good quality information is required. Furthermore, the data and results of analyses based on it need to be readily available and co relatable, in order for management and planning decisions to be as informed and directed as possible.

The collection of data is not an end in itself it must be put to good use.

A Water Supply utility is in a fairly unique situation even among utilities in that:

- it has very dispersed customers and assets (the network)
- the capital expenditure is the most important largest part of its investments. The amount of money tied up is large and the return periods are long.

For these reasons,

a) Good management data is very important
b) Large volumes of disparate data are involved.

It is to be noted that the output from any information system, computer or other, is only as good as the data that is input (garbage in, garbage out).

As a result many water supply utilities employ powerful computerised information systems especially GIS (Geographical Information System)and CIS(Customer Information System). Given this demand, quite a lot of products are available to suit different needs. Computerisation is not an end in itself and the under lying capacity of the organisation to use the information effectively remains critical. Nonetheless well-implemented computerised management information systems can be very effective.

Therefore a management strategy policy for information systems regarding mapping billing customer management etc. should be developed. Associated with this a review of computer-based options should be under taken and suitable products identified for further consideration

The following figures show a block diagram of typical GIS and CIS systems and application to UFW. (Figure G 4.1 4.2 4.3)

Fig: G 4.1
Schematic of Typical GIS Arrangements

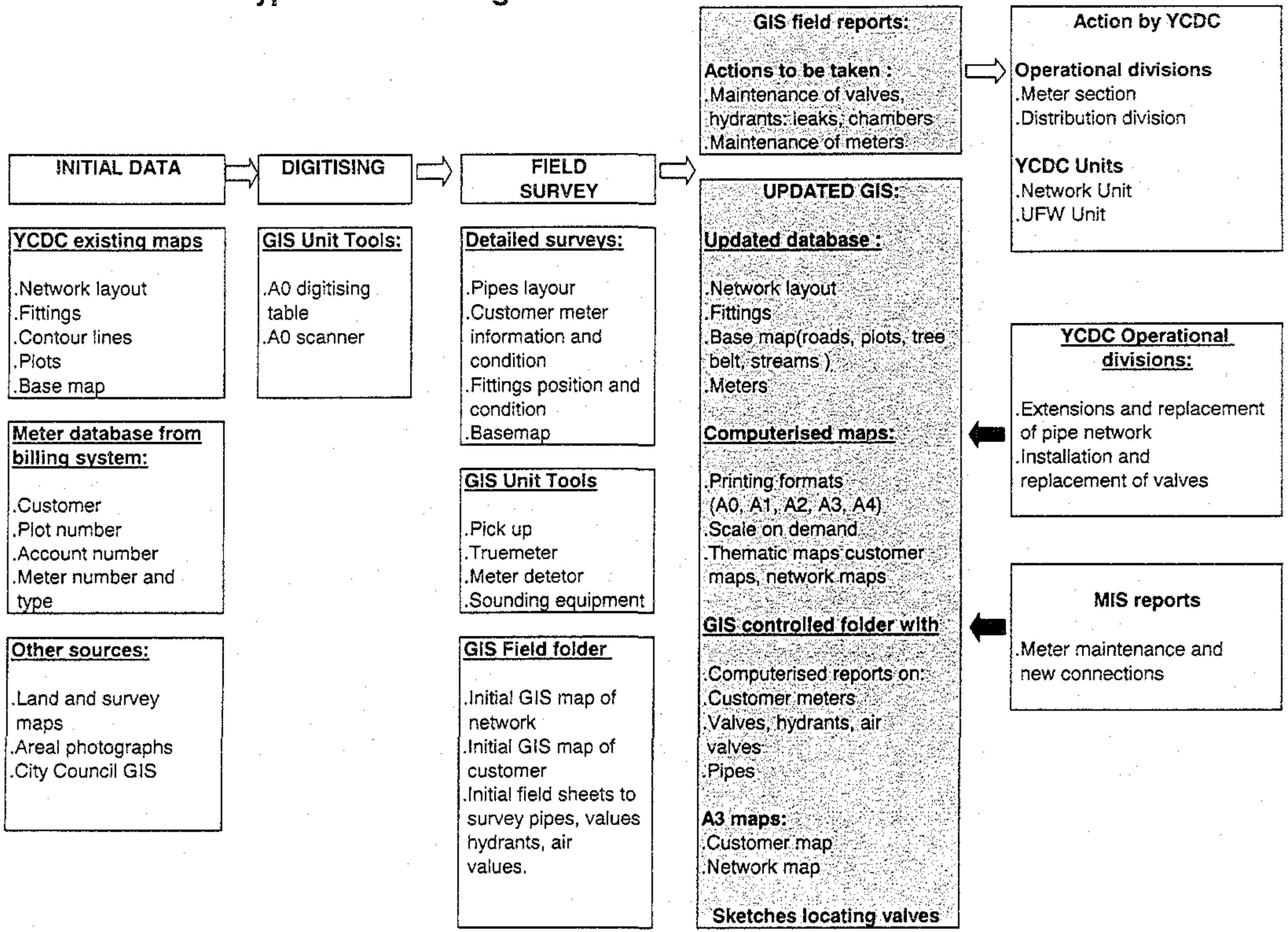

Fig: G 4.2
Schematic Typical CIS System Arrangements

DATA ACQUISITION AND CONTROL	CRITERIA	CONSOLIDATION	OUTPUTS
Pumping hours for each pumping site Extracted treated and supplied m3 Billed m3 per month and area Number of customers per area List of Top 100 big customers Claims to control room(location and type Action by distribution division (location and type) Stuck meters by area Billed kyats per area Dept by area New meter connections Meter maintenance Bulk meter readings (UFW)	**Geographical :** Area District Pressure Zone **Period of interest:** Week Month Quarter Financial year	C O N S O L I D A T I O N	**Reports (Tables):** 1. Total produced,billed and lost m3 2. Produced billed and lost m3 per Pressure Zone 3. Actions in Distribution and Meters per Pressure Zone 4. Produced m3 per site 5. Pumping hours per site 6. Billing per geographical area 7. Actions in Distribution per area and action type 8a.Meter billed on estimates 8b.Actions on meters per area and action type 9a.Claims-faults per area and source 9b.Claims-faults per area and type 10.Pending claims per area and type 11.Stuck big consumer meters 12.Weekly Supply Report 13.Production billing and losses per district **Charts:** 14.Total production,billing ,losses.UFW ratio 15.Distributed,billed, losses and UFW ratio **Thematic maps:** Presentation of outputs by: Pressure Zone Area District

Fig: G 4.3 Schematic of Typical UfW Methods Including GIS and CIS