Typical photo of faulty household tank ball float. When the tank fills up the ball valve does not cut off water but allows water to rise to overflow point.

Above ground leak. The householder attempted to repair the leak at the connection by taping around the leaking fitting.

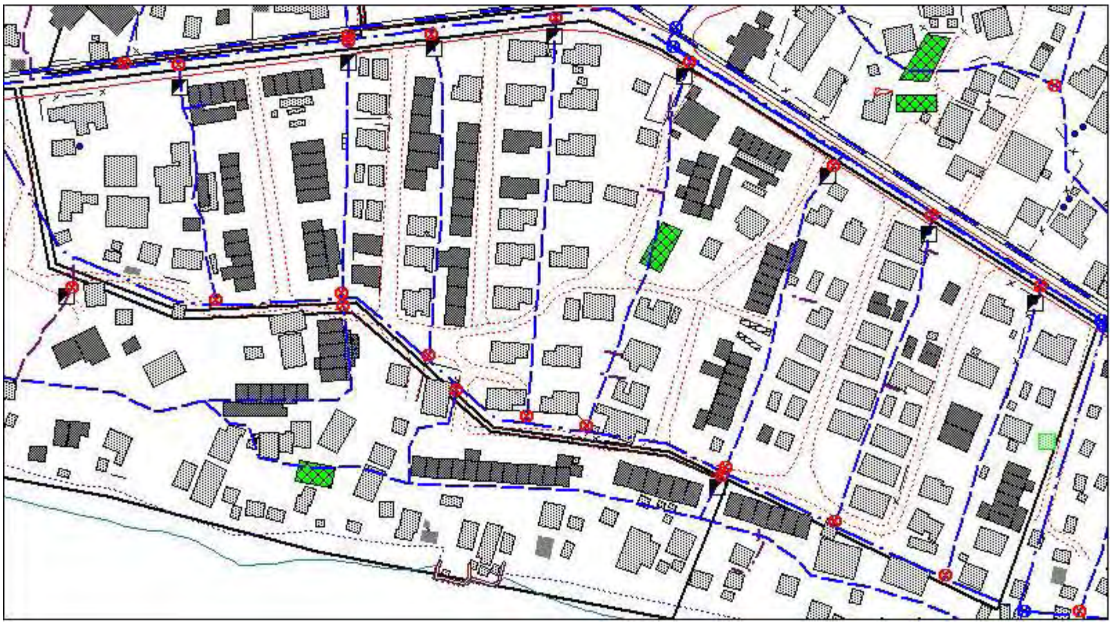
The largest underground leak detected and located. The actual leak had not been uncovered. This was aprox 25 cm below surface, and no moisture was visible on the ground. The leak was caused by some digging by the householder and hitting the pipe, probably with a shovel point. (See following photo)

When the line was isolated and the pressure on the leak decreased it became possible to see the cut points where the line had been cut.

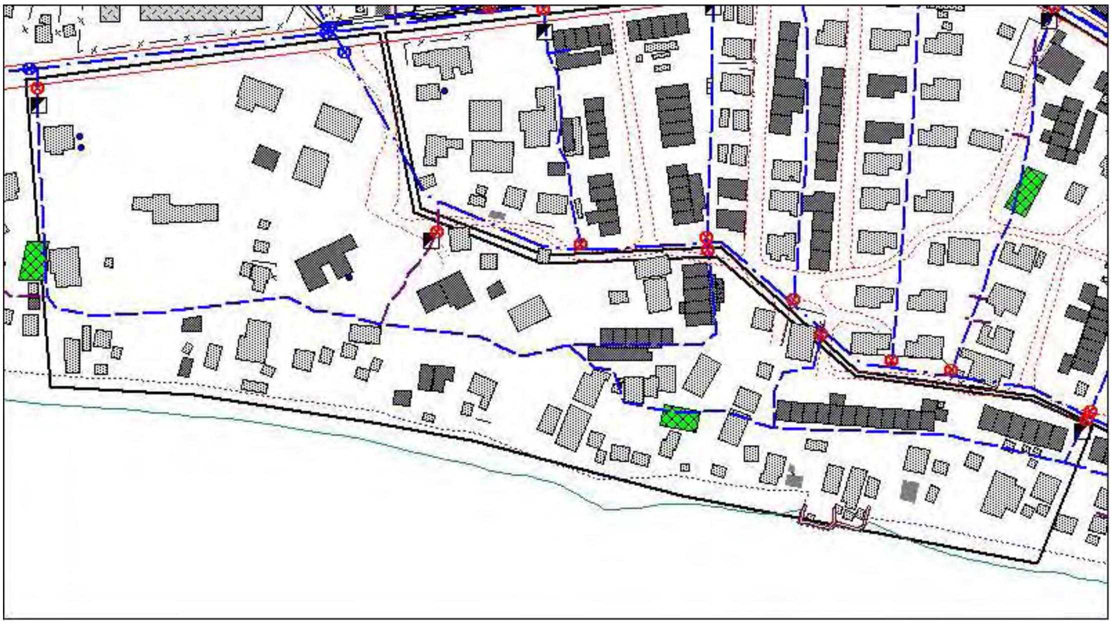
Leak found on 50mm pipe with the aid of gas detector. Leak was caused by 2 cuts from a shovel

7 Pilot Zone Maps

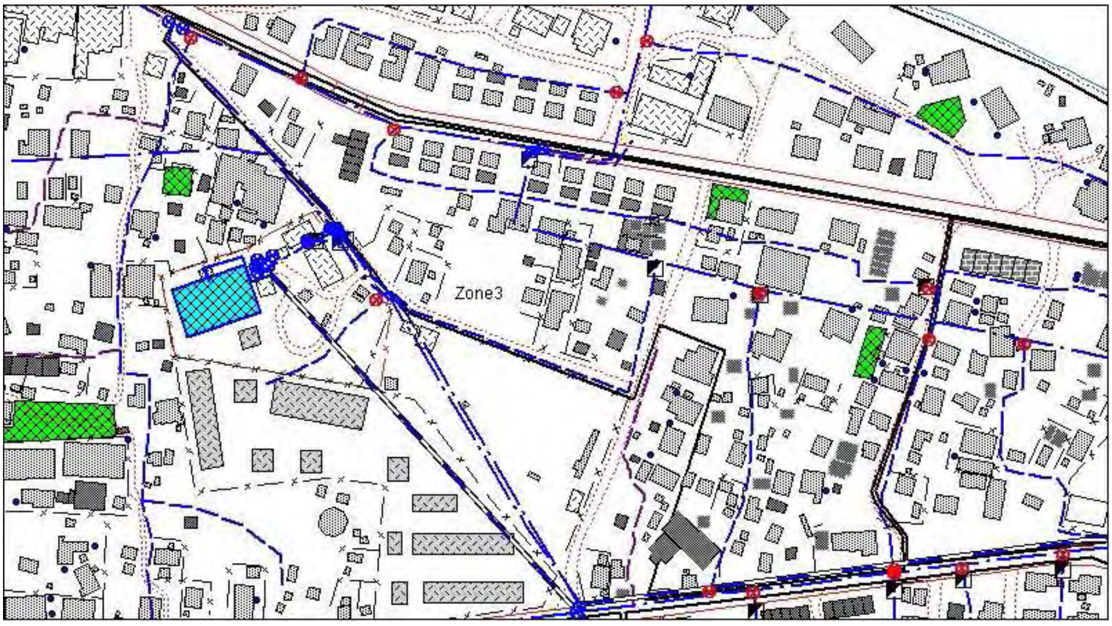
Zone 1



Zone 2



Pilot Zone 3



Annex 1: Terms of Reference

1.1 Scope of the Assignment

The scope of this Technical Assistance activity is to plan, manage and conduct a staged program of leakage detection and rehabilitation works within a selected area of the Betio water distribution system, including overseeing the isolation of the pilot zone(s) by PUB staff and making recommendations for materials required for leakage repairs, provide training to staff of the PUB Water Engineering Division, and provide recommendations for further work beyond this activity.

The Consultant will be Responsible to: KAPII Project Director and will be:

Cooperating / collaborating with:

- Manager Water Engineering, Water Engineering Division (WED) of PUB
- Ministry of Public Works & Utilities (MPWU).
- Water Master Planning Specialist and Water Awareness Co-ordinator (to be engaged under KAPII).

1.2 TOR Tasks:

- In conjunction with the PUB Water and Sewerage Manager, review existing water distribution network on Betio, water supply problems, including leakage from main pipeline and household connection plumbing, and available metered flow information. Note: the distribution pipe network is shown on detailed plans and a GIS at PUB.
- Identify the area in Betio to be selected for the pilot leakage control study. It would be preferable if this area could be isolated from the rest of the distribution system and still be fed as required from the head tank at the PUB water facility in central Betio. Some modifications to the existing distribution system (e.g. insertion of additional stop valves and 'district meters') may be required.
- Plan the detailed work program to conduct leakage detection and control work in both the main reticulation pipeline (primarily 100mm PVC pipe), distribution lines (50 mm polyethylene pipes) and household service lines (PVC and other).
- Prepare an initial report including the proposed methodology and work program, performance targets (e.g. % reduction in losses, % increase in pressure, % water service available), materials and equipment list, expected contract labour requirements and estimated costs. Submit the written report and present to the KAPII Project Director and the PUB Manager Water Engineering.
- Identify materials and equipment required to undertake leakage detection, and for materials required for repairs to the reticulation system, and prepare specifications for, and assist with the procurement of, recommended

equipment and materials. (Note that the current budget allocated for physical improvements is A$250,000 (item GD7 of the KAPII Procurement Plan).

- Oversee the isolation of the pilot zone by PUB staff. This will involve ensuring that all boundary valves to the pilot zone are located and tested and replaced if necessary, and ensuring that all household tanks in the test zone have been identified and necessary isolation valves have been installed. It is assumed that PUB will do most of the work prior to the consultant arriving to oversee this work.

- Prepare a report supporting and justifying using a Force Account contract to PUB in order to repair the leakage to the reticulation system that are identified during the leakage detection Water system leakage at the Betio pilot isolated leak detection site.

- Conduct the first stage of the leakage detection and control work including training of selected staff from PUB. Depending on the work required, it may be necessary to hire contract labourers for some of the work (e.g. digging near joints, suspected leaks). Input from the Water Awareness Co-ordinator (and associated personnel) may be required to advise people about the work in relation to household connection plumbing.

- Maintain records of work including tests undertaken, leaks found, repairs undertaken and costs involved.

- Prepare progress report at end of the first stage. The report should contain findings and recommendations regarding ongoing work required. In particular, it should contain advice to PUB on the advisability of establishing a permanent group to undertake leakage detection and control work (in both main distribution system and household connection plumbing) based on economics.

- Advise the Water Master Planning Specialist and Water Awareness Co-ordinator on aspects that may require their attention or involvement.

- Conduct the second stage of the leakage detection and control work including training of selected staff from PUB. This may be follow-on work from the first stage and may involve additional or a modified approach, depending on the findings from the first stage. At all times, it should include on-the-job training of PUB personnel involved in the leakage control program. Additional input from the Water Awareness Co-ordinator (and associated personnel) may be required.

- Prepare a simple instruction manual for PUB staff giving steps involved in selecting and isolating a zone for leak detection and the process of leak detection

- Prepare a final written report and provide verbal presentation to PUB staff, KAPII Director and other appropriate personnel at end of the second stage. The report should contain steps undertaken, detailed findings from the whole project, comments on the success of the work undertaken and recommendations regarding further work beyond KAPII, including any changes to staffing etc in PUB to ensure that the pilot project work is ongoing.

Appendix 2:

2 Leakage Detection and Control

As leakage effects all utilites in similar ways, it is essential that a thorough understanding of the whole concept of leakage detection, reduction, and control be outlined.

The PUB water supply in Tarawa does not at present have a 24 hour, seven day per week water supply, but operates on a rotating “zone” system where water is supplied on a zone by zone basis for approximately one and one-half hours per zone. However, some customers, rather than relying entirely on PUB supplied water, buy their water directly, transporting it in water tanks for use.

2.1 Leakage and Usage

2.1.1 Definitions and Terminology

Water loss may be defined as that water which having been obtained from a source and put into a supply and distribution system is lost via leaks or is allowed to escape or is taken for unauthorised purposes. ‘Water loss’ is usually considered as leakage, and ‘water loss reduction’ is usually referred to as ‘leakage control.’

Water loss is usually quantified on the following basis:

Water Loss = (Quantity of water put into supply) – (Non-domestic use + Domestic consumption)

2.1.2 Non-Revenue Water

Non-Revenue Water is the difference between System Input Volume and Billed Authorised Consumption. It consists of Unbilled Authorised Consumption and Water Losses. The following definitions will assist in further understanding NRW components.

- System Input Volume is the annual volume input to the water supply system.
- Authorised Consumption is the annual volume of metered and non-metered water taken by registered customers, and others who are implicitly or explicitly authorised to do so. It includes leaks and overflows after the point of customer metering.
- Water Losses are the difference between System Input Volume and Authorised Consumption. They consist of Commercial Losses and Physical Losses.
- Commercial Losses, sometimes referred to as apparent losses, consist of Unauthorised Consumption, all types on meter inaccuracies, as well as long-term unpaid water charges.

- Physical Losses, sometimes called real losses, are the annual volumes lost through all types of leaks, bursts, and overflows on mains, service reservoirs, storage tanks, and service (household) connections up to the point of customer metering.

2.2 Sources of Leakage

2.2.1 Treatment Works

At the beginning of the water operation, up to 7% of water can be lost as part of the treatment process. With Best Practice and recycling, this can be reduced to 2-3% and is not usually included when leakage control is referred to.

2.2.2 Trunk Mains

Trunk mains can carry raw water into a treatment works, or treated water onward into the reticulation system. There is no definitive size range but for the purposes of this report, we will regard 150mm diameter and larger, trunk mains. Leakage from trunk mains is usually only a small part of overall leakage.

2.2.3 Reservoirs and Water Towers

Again, leakage is only a small proportion of overall water loss. It is nevertheless necessary to maintain and monitor reservoirs and water towers carefully for leakage from cracks and overflows.

2.2.4 Reticulation Lines

Reticulation mains (including trunk carrier mains within them) represent the major source of leakage in a water system. These systems are generally of different pipe materials, age and condition, and leak at different rates from a variety of causes and reasons. For the purposes of this report, we will regard 50mm lines as reticulation lines

2.2.5 Valves and Stop Taps

Valves and stop taps need glands to operate effectively. The gland seals will deteriorate with time and sealing surfaces become worn with repeated and constant usage. This creates leakage that must be controlled by the necessary maintenance.

Periodic operation of a valve goes a long way to help prevent the need for repairs. Maintenance of all valves is not an economical activity, but strategic valves and trunk main valves may warrant this attention. *All flow control valves should have regular inspections and planned maintenance.*

External corrosion is generally not a cause of failure. However, internal corrosion can be a significant problem, and may prevent a leak-tight shut off. The types of failures experienced with stop taps are usually from joints, corrosion in the valve or washer failure

Leaking mains ferrules will generally have to be replaced

2.2.6 Pipe Joints

Pipe joints are a major source of failure. Joints may have been fabricated in a faulty manner and remain watertight for a few years only. Ground movement as a pipe trench settles can then overload the joint and induce leakage.

2.2.7 Domestic Service Lines

These are a large source of leakage. Connections at the reticulation line can be a major source of leakage if not properly made, if improper materials are used, or when soil settling occurs during wet-dry weather cycles.

2.3 Factors Influencing Leakage

2.3.1 Type of Mains

PVC is the material of choice in Tarawa, and while more durable than many other materials, can fail at improperly fitted or glued connections. In areas where there is exposure to constantly wet conditions, such as river crossings or tidal areas, joints are the weakest point ain the lines and can fail if not properly supported.

2.3.2 Soil Conditions

Clearly soils influence corrosion and leakage rates. Some, such as Lias clays or alluvium are very aggressive, and trench backfill of sulphate rich ashes is especially corrosive. In Tarawa, the major soil material is sandy and can soften of harden duting wet/dry periods.

2.3.3 Climate and Ground Movement

Seasonal variations have a marked effect on leakage. Monsoon areas, which vary from long dry periods to intensely wet periods, cause ground movement, which can cause severe strain on pipe joints and service lines.

2.3.4 Workmanship

There is no substitute for good workmanship of the initial installation in preventing future leakage. Pipe handling, bedding, laying, jointing and backfilling must be to a high standard. Extra care should be given to repair work, as a repair represents a potential weakness to the integrity of the system.

2.3.5 Quality of Materials

It should be obvious that all materials used in the distribution system must comply with relevant standards for long term usefulness, be of a high quality, be appropriate to the surrounding conditions, and be of correct operational capabilities. It should also

be ensured that the same standards apply to repair materials, and poor substitutes are not used for permanent repairs.

2.3.6 The Size of the Leak

It should be obvious, but it is still very important to note that a small increase in the size of any leak has a big effect in the terms of volume leaked. The longer a leak is left to run, the bigger the leak will get.

2.3.7 Duration of the Leak

A fast location and repair of leaks is essential to reduce water loss levels. A leak left to run for a long time can waste as much water as a catastrophic burst on a trunk main, which is repaired quickly. *Leakage will only be reduced by sustained, determined detection and repair program.* This applies to both above and below ground leaks.

2.3.8 Disturbance of the Distribution System

Severe pressures can be generated by the operation of isolating valves, causing bursts and leakage. Rapid re-filling of the system after a system shutdown or repair work can cause damage and create leakage. This is especially true with opening and closing valves in intermittent water supply networks.

2.3.9 Age of the System

The aging process cannot be stopped, and increasing leakage is indicative of deteriorating structural condition. It should be recognized that a *realistic and consistent* level of infrastructure renewal is an essential part of leakage strategy development.

This may be achieved by targeted mains relining. Modern techniques of mains replacement and relining have substantially cut the costs of these operations. It should also be noted that renewal of service lines should be included with this work for the greatest benefit.

2.4 Leakage Growth and Active Control

2.4.1 Natural Leakage Growth

Leakage grows with time, and without action to curb it, would grow to a point where supplies would be unsustainable. Passive control, that is, the repairs of bursts and leakage showing on the surface, and the elimination of poor pressure and flow components, is the minimum possible response.

2.4.2 Characteristic Growth Rate

For any given area in the reticulation system, there will be a characteristic growth rate. This rate will be affected by changes in the physical elements of the system, such as rehabilitation of mains, renewal of service lines, and changes in pressure. Sooner or

later, leakage must be associated with a program of mains renewal in order to maintain a supply/demand balance.

However, mains and service line replacement is expensive, and for the system as a whole, should only be considered a long term strategy.

2.4.3 Reduction in Leakage with Active Control

To reduce the level of leakage at any pressure, a program of leakage detection must be planned, co-ordinated, implemented, and continued. It is not sufficient to put in a high level of time and effort for a short time only, as any slackening of effort will lead to an increase in leakage over a period of time. Given that no two water systems are identical in physical or economic character, it is not possible to determine the most appropriate leakage control policy in a general manner. The best policy for any utility will depend on its own particular characteristics.

2.5 Leakage Control Strategies

2.5.1 The Economic Balance

The economic balance of searching for and repairing leakage, and controlling it to an acceptable level, is a complex issue. Depending on a range of differing factors, leakage percentages of below 10 or even 15% may not be economic to pursue. In any event, the cost of hunting down, identifying and repairing the leakage must not exceed the value of the water saved. Even these remarks must be heavily qualified. Within any water authority, different areas will have their own intrinsic economic leakage levels.

In addition to the volume of water lost, its scarcity and marginal cost are vital factors. In an older area with rising demand, intensive leakage control activity would be essential. In an area that relies upon pumped supplies with high electricity costs, a high degree of leakage control would make sense.

In selecting a leakage reduction strategy, there are two policies that may be adopted: PASSIVE or ACTIVE

2.5.2 Passive Control

This is a policy where water loss is only tackled when leakage is visible or when problems are reported. Adoption of this policy minimizes the day-to-day costs of leakage detection, but substantially increases the risk of water being wasted. It results in an ever increasing upward trend in the annual supply of water being pumped from treatment works since many leaks can go undetected for years until they reach a level that urgent must be taken. In spite of this, it is a perfectly feasible policy to adopt, providing it is “politically” acceptable, and may be carried out with full instrumentation to allow rapid location of leaks.

Such a policy is only applicable if:

- The revenue costs of leakage detection are high
- The costs of production are low, and there is ample supply for current and foreseeable demands.
- Bursts are readily visible and easily repaired.

2.5.3 Active Control

It is increasingly accepted that an active approach of searching for leakage is preferential in cost/benefit terms. Active control usually involves the monitoring of flows in a reticulation network by using a system of permanently installed meters. If unexpectedly high flows are observed, these are noted for investigation.
Obviously, monitoring which is not investigated is unproductive.

An active policy requires a commitment to spend funds on meter installations and associated costs for leak detection equipment or private leak detection companies operating under contract to the authority. The following benefits should be achieved:

- Leakage is minimized, and monetary losses are reduced.
- It results in an overall reduction of water demand.
- Limited water resources are conserves for legitimate use and are not wasted.
- Work is planned, and not reactive.
- Customer perceptions are improved.

Capital expenditure requirements on treatment, reservoirs and mains can be deferred and reduced.

- A well-managed active leakage detection policy ensures that the cost of the leakage detection teams should be quantified against the cost of recovered water. Where different technologies and techniques are employed, these should be measured against each other in a cost/benefit analysis in order to insure that funds spent on leakage detection are most productive. Active leakage detection is applicable where:

- Water production costs are high.
- Water sources have limited capacity and cannot meet normal and/or foreseeable demand.
- Bursts are invisible do to the strata conditions, take their time to surface or are frequent in hilly areas.
- The quantity of water being put into the supply is increasing at an unacceptable rate without a corresponding increase in revenue.

2.5.4 Strategy Development

Leakage reduction and control is a long-term activity, and should be regarded as a part of good reticulation and demand management. Occasional short bursts of effort are unlikely to produce lasting results because system deterioration is a continuing process. If only obvious leaks are repaired, leakage levels will still increase.

The development of a long-term leakage control strategy is therefore essential if water supply and reticulation systems are to be properly managed. Such a policy must be flexible, with occasional reviews to ensure the adopted strategy is the most appropriate for the situation. Cost/benefit analysis is important in this regard.

The establishment of controllable, manageable areas (District Meter Areas – DMAs) within a reticulation system where demands are easily monitored has been proven to be extremely beneficial for leakage control management. DMAs force plans to be updated. Mains and buried fittings are more accurately located. Defective valves are discovered and either repaired or replaced for better operational control. In the process of setting up a DMA, leakage and wastage is located and repairs made. *It enforces good housekeeping*.

Leakage effort needs to be directed towards the areas of greatest need. Traditionally, this has been done by examining bulk meter flow rates, but this sometimes results in faulty interpretation of data..

2.5.5 Action Plan Overview

The following eleven points comprise key actions within a leakage policy where sustained effort is applied:

1. Locate and repair obvious leakage

2. Sub-divide the distribution system into DMA's and continuously monitor them for leakage control Maintain DMA meters and boundary valves

3. Use active leakage detection policies.

4. Make prompt repairs of reported and detected leakage

5. Provide a sound, reliable leakage information system to base all leakage control activities on.

6. Consistently build up and maintain relevant data

7. Direct leakage control activities to areas with the most urgent problems first.

8. Regulate pressures where required

9. Relay mains and service lines in a controlled, planned manner where needed.

10. Drive down leakage to a pre-planned target, then review the target.

11. Reduce leakage to an economic (or 'politically acceptable') minimum.

3. Metering for Leak Detection

Effective metering is an essential feature of network management, particularly for measuring flows into and out of each zone measured to provide data for the water balance calculation. Continuous flow measurement at the source or reservoir outlets with data transmitted instantaneously to the operational centre is the ideal, but chart recorders or digital data loggers can be effective substitutes. Effective management of the network relies on the ability to monitor flows continuously, at a minimum of hourly intervals throughout the day. An accurate population count is also of prime importance, as derived data such as per capita demand provides information on growth of demand over time, leakage etc. Zonal flow monitoring is the cornerstone of active leakage management in district metered areas (DMAs) and is described later.

3.1 Ranking of Metered Areas

There are three different metered areas which are commonly used for leakage control.

- **Supply Areas**

Metering of a supply area will involve metering of all source works outputs, and all imports and exports crossing the boundaries, to give an accurate daily figure for demand.

Metering at this level is essential to judge overall performance as it includes all possible sources of leakage. However, it is of no use for leakage detection, as any leaks that are not obvious will be swamped by normal daily variations in consumption.

- **Zones**

Zone metering breaks down a large supply area into several zones. Again, all inflows and outflows are measured continuously, including the effect of any increase or decrease in storage.

Zones are too large for identification of small leaks, but can often identify major leakage, especially if daily readings are collected.

- **Districts**

Within each zone, there will be several district meter areas (DMAs). District metering is the first level of metering, which can be used for leakage detection, as zone and supply meters are primarily used for performance assessment and monitoring rather than detection.

Note: Should additional information on the DMA concept be required, a separate report has been prepared as part of an expanded leakage management training manual.

4. Detection Equipment

4.1 Detection Principles

Modern leak detection is dependent on the sound of water escaping from a water main under pressure. This sound emits a sound over a range of frequencies and produces a hissing noise. The particular distribution of frequencies produced by any leak is specific to that leak. The sound travels through the pipe at a velocity, which depends on the pipe material and diameter, and through the ground surrounding the pipe. As the sound travels away from the leak, its character changes slightly, as higher frequencies attenuate with distance, and other frequencies are amplified due to various factors.

4.2 Electronic Sounding Instruments

Where leaks produce sounds inaudible to the human ear, or where the leak noise is low, electronics can help.

These instruments, both listening sticks and ground microphones, usually consist of a microphone, amplifier and frequency filters which can boost the leak noise while filtering out extraneous background noise. They can be used both as a survey to tool to listen for suspected leakage and when applicable, as a final confirmation of a leak position found by a tracer gas.

4.3 Correlators

These instruments do not seek the point of highest sound intensity, but a consistent noise source which is relatively unaffected by background noise. Unlike electronic sounding instruments, correlators offer:

- Accurate leak location in high ambit noise conditions
- Location of leakage with relatively low acoustic output
- Leakage location in systems with few fittings for direct sounding
- No need for an ‘educated ear’

The limiting factor for correlators

4.4 Noise Loggers

These devices are probably the most significant innovation in leakage detection since the correlator. Noise loggers are able to quickly survey large areas quickly and accurately with reduced manpower requirements compared to traditional sounding.

They operate at night when background noise and demand are lowest and pressure is greatest. They can operate in areas where the local mains system is complicated or system knowledge is limited, and are able to ‘create’ a zone where leakage areas can be identified.

Noise loggers do not precisely locate a leak, but can ‘localise’ it, and are particularly useful where the age and condition of the pipes prevents a tight shutoff, with the added benefit that they do not disturb the operational system.

4.5 Non- Acoustic Equipment and Techniques

Unlike the previous methods, the equipment and methods described below do not depend on leak noise. These techniques are seldom used, as they can be relatively expensive and more imprecise than acoustic equipment. Nevertheless, in certain cases, some or all may be a viable alternative.

4.5.1 Ground Penetrating Radar

This is a relatively new technique which depends on being able to ‘see’ through the ground to locate water mains and leaks. It uses a radar signal and electronic imaging of reflected signals to locate underground leakage. As the signal dissipates and blurs when reflecting water, GPR is not practical in rainy conditions, or areas with a great deal of wet soil, but in dry conditions, it can not only be used to locate leaks, but to also locate buried utilities and pipes. On a worldwide scale, it has little track record, but GPR practitioners claim remarkable success.

4.5.2 Gas Tracer Technique

In this method, a non-toxic gas, usually balloon gas (helium), sulphur hexaflouride, or a diluted hydrogen mix is induced into the water supply in the general area of the suspected leakage. Holes are drilled along the main at regular intervals and a hand held detector sensitive to that particular gas inspects each probe hole which will come out of solution as the water leaks. This technique is most suitable for water networks do not have regular contact points for correlators or noise loggers, and can be very effective where intermittent water supplies are standard and/or high leakage levels and associated de-pressurization occur.

4.5.3 Cut and Cap

This is the technique of last resort and requires no special equipment. A section of a main is isolated and a supply of water is fed through a meter. If the flow is continuous, it is obvious there is leakage in the section of mains, and leak detection equipment can be used to locate the leak. The process is then repeated in subsequent sections of mains. The expense is obvious.

5. Leakage Identification and Localisation

5.1 Demand Pattern

Leakage is continuous, but legitimate demand varies. It is this difference that forms the key to leakage identification. Unfortunately, this does not hold true in the case of intermittent supplies, as peak demand is during times of supply only.

In all cases however, leakage is running to waste continuously, although its volume varies with pressure. It is therefore apparent that since most legitimate demand does not occur at night, most of the flow at night will be leakage.

5.2 Night Lines

If Tarawa ever succeeds in providing a 24/7 supply, Night Line theory would be a valuable tool in determining leakage levels, and is included here as a possible future aid. Obviously, effective metering is required.

The flow of water at night is a very important factor in leakage control and detection. It is generally called the Night Line, and is usually registered as the flow through a control meter for 1 hour between 2 – 3 am, or 3 - 4 am. A high Night Line is a good <u>indicator</u> of high leakage levels, but is <u>not</u> a leakage level itself. Where there is legitimate night usage etc., this has to be deducted to arrive at a Net Night Flow (NNF).

NNF is often expressed in litres per property per hour. This enables comparisons to be made between areas and against set targets. It generally eliminates extraneous factors included in UFW figures, but does require specific measurements to be taken rather than using generally available data.

It should be remembered that the rate of leakage is higher at night than the average daily rate because pressure is at its highest at night. To convert night leakage rates to the total daily leakage, the following formula should be used:

Night Leakage x 20 = total daily leakage

The multiplier 20 instead of 24 hrs takes into account reduced daytime pressure. This is called the “20 hour rule”.

5.3 Continuous Monitoring

Worldwide, studies have shown that a continual monitoring for leakage control is cost effective on almost all reticulation networks. This is because of two major influences:

1. The rapid advances in metering technology have expanded the flow range of the well established mechanical meters, and have led to the introduction of other meter types in the size, flow range and cost suitable for leakage management.

2. Data capture has become increasingly sophisticated with techniques ranging from simple remote reading devices to programmable data loggers, telemetry systems, and computer interfaced units.

Advances such as these have encouraged a trend away from those leakage control methods requiring a routine survey (the inefficient regular sounding or labour

intensive regular waste metering/ step testing) to those based on continuous monitoring.

6. Repair, Follow-Up, and Records

6.1 General

After locating leakage, it is necessary that it is quickly and efficiently repaired with quality materials to ensure that the leak does not re-occur. (It must be remembered that as leaks in a zone are repaired, pressure will increase, and inferior repair materials and techniques will inevitably cause repair failure. This is most wasteful in manpower and material cost as it means that the same job will have to be done more than once.) The total leakage volume is directly related to the length of time leaks are left running. *Leakage detection activities will only retain their credibility if leaks are repaired quickly.*

Where customer-side metering and billing is applicable, it will be the case that some leaks will be on the consumer side of household meter . Many water companies take a view that this leakage has no importance as the consumer is paying for it. While this is true, it must be realized that the cumulative customer side leakage will show up as total leakage. This total is quantified and factored into leakage figures, and consumers should be encouraged to get leaks repaired as soon as possible. Where no customer metering is in place, or no consumption tariffs are charged, all leakage must be found, accounted for, and repaired by the utility.

Please note, in intermittent supply networks like Tarawa, some leaking pipes and fittings can give rise to water ingress during negative pressure. This brings the risk of pollution and contamination of the water supply, and should reinforce the need for prompt and efficient repair.

6.2 Repair Follow-Up

After repairs of leaks, it should be policy that some method of re-testing the immediate area of the repair to insure the repaired leak was not masking other, smaller or quieter leaks. Noise loggers and/or night flows can help determine this.

6.3 Repair Records

It is essential that all repairs of bursts and leaks are accurately and comprehensively reported and recorded, preferably on a data base. This information should include:

- Location
- Area or zone reference
- Date
- Size
- Type of leak, i.e.; burst, fracture, main, service line, joint, etc.
- Mains or service line

- Type of repair
- Was leak detected or reported cost then focus on locating known leaks.

7. Intermittent Water Supply Systems

Intermittent water supply may be defined as a piped water supply service that delivers water to users for less than 24 hours in 1 day. It is a type of service that, although little found in developed countries, is very common in developing Countries The primary cause of intermittent water supply is extending distribution systems beyond their hydraulic capacities to provide 24-hour service, or a perceived lack of adequate supplies for the population served. Other causes of intermittent supply are a failure to meter completely and accurately and a failure to charge and collect on sufficiently high tariffs. It is often said that there is not enough water for 24-hour supply. NRW, in terms of leakage and illegal connections, contributes to intermittent water supply by lowering water pressure in the distribution system. <u>To clarify, if there are 200 connections in an intermittently supplied zone, pressure will be lower because the effect of 200 households all receiving water at the same time will be similar to having 200 same sized leaks in the same zone.</u> One reason given for designing systems to provide water intermittently is the high cost of pumping for 20–24 hours. What is probably not understood is that pumping times are drastically reduced when balance storage is constructed and metering, billing, and collection controls are set. Very low tariffs add to problems related to excessive pumping, since utilities that lack funds struggle to meet O&M costs if there are long pumping hours.

7.1 Consequences

Often consumers without access to a 24-hour supply tend to use more water than others. Because they are never certain when they will next be served, they throw away the surplus “old” water from yesterday to make way for “fresh” new water today. Intermittent supply causes anxiety, and generally one person from each residence has to devote time to ensuring that water is received when it comes. Valve operators can extract bribes from consumers who wish to ensure that they will receive adequate service. Constant valve manipulation increases the need for more frequent valve maintenance and replacement. Last, the quantity of water to be made available over 24 hours has to be made available in fewer hours in an intermittent system, which often requires distribution pipes with larger diameters.

Advantages (perceived)

- Leakage of water is reduced.
- Available water is distributed equally.
- There is time for repairs and maintenance.
-

Disadvantages

- Systems do not operate as designed.
- Reservoir capacities are underutilized.
- There is frequent wear and tear on valves
- . More manpower is needed.

- Contaminated water requires consumer treatment or the use of bottled water.
- Higher doses of chlorine are needed.
- Oversizing of networks is needed to supply the necessary quantities.
- Inconvenient supply times mostly affect the poor.
- Water meters malfunction, which can lead to a loss of revenue and customer disputes.
- Accountability per subzone is not provided.

8. Effects of Intermittent Supply on NRW / Leakage

8.1 General

Intermittent supplies of water create their own unique set of problems regarding leakage. The low pressures usually associated with intermittent supply allow much leakage to “hide” by letting leakage more or less trickle away into the ground rather than burst or gradually surface.

No water from an intermittent water supply system is safe to drink, because under de-pressurization conditions, foul water can be drawn into the pipes. Certainly hygiene education is important under these conditions, which put at risk people connected to an intermittent supply.

Most meters do not register accurately under intermittent supply conditions, due to air in the pipes registering as consumption when a supply zone is resupplied, raising doubts as to the validity of metering at all.