UNACCOUNTED FOR WATER

AND LEAKAGE ASSESSMENT

PREPARED FOR KAP II PROJECT

TARAWA, REPUBLIC OF KIRIBATI

AUGUST 2010

Pipeline Network Analysis
PO Box 1345
Southport, 4215
Queensland Australia

Table of Contents Page

1. Abstract

On South Tarawa, the PUB has estimated water loss from leakage in distribution pipelines is occurring at unacceptably high levels.

In 2005, The SAPHE Project laid a new transmission pipeline between Bonriki and Teaoraereke, which reduced the leakage in that area to acceptable levels along this pipeline. However, many of the local distribution centres suffer from low pressure which can be a sign of large scale leakage.

Leak detection and control work is a necessary ongoing activity as part of effective water supply system management. In order to determine if leakage rates are as high as estimated, the World Bank, has stepped in by providing funding for a leak detection and leakage management program under the KAP II Project.

The Betio distribution system and household connection plumbing was thought to have probably the worst leakage problem, maximum benefit would be derived from work there. For this reason, part of the Betio distribution system and household connection plumbing networks were selected and set up as a pilot project under KAPII.

While some training in leakage detection and control work had been provided to PUB staff during the SAPHE project and some equipment had been left behind, very little continuing work has been done in leakage detection as most of the staff briefly trained did not have a depth of training to pass on their skill. Much of the equipment was also not suitable for leak detection work under existing conditions in Tarawa, and has not even been usable.

Further and more extensive training in available techniques for leakage detection was identified as a priority. This training was best done as part of the pilot project to investigate and control leakage in both the main distribution pipelines and the household connection plumbing. While the training was successful, the pilot leak detection survey, covering approximately 10% of the Betio water supply network found that in the areas surveyed, leakage from the PUB system was not in any way significant. There are problems in household connections after the PUB network, but even these are relatively minor. Water wastage may be contributing to overall water loss, but leakage is <u>not</u> the cause of low pressure problems.

2. Leak Detection in Tarawa

In 2005, as part of the SAPHE Project, 2,229 500 L storage tanks were installed in households in South Tarawa. These had a constant trickle flow feed to allow a constant supply and allow each household approximately 500L of water per day. However, difficulties with supply and tampering with tanks has resulted in an intermittent supply in which households receive 500L every second day. To further complicate matters, low pressures have seen many householders de-mount their tanks from the elevated platforms and put on ground level or unused altogether. Many households have run their own lines to more convenient spots on their properties or even inside their homes and use whatever water storage containers are available.

None of these tanks or “home-made” lines are metered either for consumption or revenue purposes , which make any determination of leakage levels difficult at best. However, by isolating consumer supply from the network with shut off valves at each water tank or near the customer supply lines, it is possible to determine leakage levels in zones that are “off” by introducing water into these zones and monitoring leakage by flow via installation of zone meters. This means that control valves will be necessary, one per service line, and flow meters for test zone will need to be installed

The inherent problems of using conventional leak detection in intermittent supply systems is all but impossible. In 24/7 systems, there are usually times at night when demand is at a minimum, that conventional sounding or use of correlators and noise loggers may be used to detect, and locate leaks. This is not possible with an intermittent supply.

As more sophisticated leak detection equipment cannot be used, both basic listening sticks and tracer gas (N2H2 95%/5% mix) with a gas detector will be the primary leak detection equipment.

2.1 Training

Three staff from PUB were selected for training in leak detection. These were different personnel from those initially selected, as the original group were not satisfactory.

These staff were briefed initially on the uses of the listening stick, the theory on how they work, and when, where and how to use them. Reasons for conducting leakage detection were discussed and a process on setting up zones and the reasoning of the zonal approach were shown. In the initial stages the consultant would be doing all leak detection work and the PUB would be learning by observation and on the job training. In later stages, the PUB staff would conduct their own operation with the Consultant assisting. In the third stage, Staff would conduct operations with the Consultant advising and intervening when necessary.

The listening stick is probably the most widespread leak detection device used. However operator skill and a high degree of subjectivity can be involved, and classroom and formal verbal instruction an never develop the “ear” needed. As both leak noise and background noise, such as people walking nearby, vehicular engines, and even wind will be picked up by the listening stick, every opportunity was taken to show the difference between leak noise and extraneous, background noise. One unexpected outcome in using the listening stick in Tarawa was that the sandy soil was a readily carrier of leak noise, and even most small leaks could be found from some distance away.

The gas detection was introduced toward the end of the program. As a gas detector operates by a sensitivity to a specific gas, it will only be fully utilised when the exact location of the line is known, as the gas has a tendency to rise straight up and be dissipated by wind. This was illustrated when a leak was detected a, and using the gas detector on locations other than above the line. Produced no result. Once the line was found and the gas detector was placed above the line, the leak location was quickly confirmed.

2.2 Pilot Zones

In early 2009, a pilot zone in Betio was selected for the introduction of leak detection training. The zone was close enough to the main depot and water tower to provide adequate pressure and easy setup. Work on the setup was possible only every other day because of the rotation of water supply zones, and a total of three weeks was allocated for this work.

Boundary valves were identified and tested, household lines were identified, and it was estimated that work in installing the household meters, one reticulation control valve, and the installation of 8 meters should take about two weeks. Monitoring the meters over the third week would establish a base line of leakage.

However, the PUB staff selected at this time for training in the program were not able complete the works in time to obtain sufficient data on leakage/water loss for a number of reasons. Instructions were then left on how to conduct flow/leakage, and data was to be sent to me for assessment. Over the last year, data was produced indicating unacceptable water losses from leakage and/or theft. However, the data produced was inconsistent in the leakage rates, with some data indicating a "spontaneous" reduction in leakage, which simply does not happen. Thus the data itself was suspect.

The actual project commenced project commenced in earnest on 14 June 2010, with 3 new staff selected for training in the pilot zones.

One problem became evident immediately. In the previous visit in early 2009, the Consultant noted that the earphones from the listening sticks were missing It was recommended that two new sets be obtained as soon as possible, but this had not been done. Luckily, the consultant had a set of earphones for an MP3 player that, while not entirely satisfactory, could be used. This meant that only one listening stick was available for training. We requested the original supplier provide a cost for sending new earphones, but after three emails over a three week period, we received no response. The manufacturer was then contacted, and two new units were ordered. In the meantime we found that re-testing of boundary valves was necessary, as they had not been checked since the last visit over a year ago. Some were found to not fully closed and one was found to faulty but was able to be adjusted without needing replacement. Isolation and testing for leakage of the constituent water mains making up the pilot zone was done and all household valves were checked for integrity.

Each line was then tested in isolation by allowing water into the line on days when supply was not scheduled, to allow sufficient pressure to show up leakage by the simple expedient of reading the flow meter. This was concluded on 21 June 2010. The findings were completely unexpected based on data collected over the past year. Only three large leaks and one significant incident of active theft from an illegal connection were found. Several small leaks were located, primarily from faulty above ground connections and improperly working ball valves in several household tanks which allowed “leakage” by overflowing when theoretically full, were repaired or replaced as required. The amount of water loss however, in no way approached the reported amount, and as discovered, incorrectly calculated, as the data itself was based on the total amount of flow into the test zone when the system was active. This was confirmed by reading meters in the isolated zone following repairs. Apparently, all data collected was during periods of supply, which registered consumption as water loss

It should be noted that while all eight lines were, according to available maps, connected to the same reticulation main, two of the meters did not register any flow. It was later discovered that they were connected to a parallel reticulation line supplying a different area altogether.

As no significant leakage was detected, a second zone containing 3 metered areas was set up in an area immediately adjacent to the first pilot zone. As the first zone had a fair number of public housing areas and was relatively new, care was taken to ensure the new zone had primarily private houses and was an older area, more prone to leakage.

Once again, boundary valves were located and tested, household isolation valves installed and faulty ball valves were found and repaired, as faulty valves would allow many tanks to fill beyond the “turn-off” level and overflow, effectively leaking water.

Very little underground leakage was detected. The major source of water loss was again, above ground from faulty connections and ball float valves in household tanks. However, it was noted that there was a considerable amount of air in the lines in this zone, and the cause will need to be investigated further, isolating the reticulation line from the reservoir or the test zone and any other areas to determine if the line itself is leaking. This of course would allow depressurization, allowing air into the line. (The project at this point has almost two weeks to run)

A third zone, designed by the PUB staff member, Tom Ruatu was set up for more detailed training, and investigation by the PUB staff. This zone is much more complex and with many more properties and took more time to set up with household isolation valves, finding and testing boundary valves, and building meter pits and boxes. Initial “walk through” investigations have found many faulty ball valves, and in one area, considerable amounts of air in the lines. Once again, the primary cause of water loss was in fittings, both above and below ground. The problem is not so much with faulty workmanship or even faulty materials but what seems to be tampering with the screw-in fittings by local handymen. Often a small o-ring either has been damaged or is missing. This is actually a costly repair, as stocks of these rings do not seem to be on hand, and a new fitting needs to be used rather than a simple ring replacement.

One fairly large underground leak was located and exposed. It was found that a shovel or something similar had partly cut the line, and in the sandy soil, no moisture was noted on the surface.

It should be noted that one old toilet was still connected to the water mains system and had no functioning ball valve. When the system was on, this toilet leaks during the entire supply period.

One of the final tests conducted involved the use of and training on, the tracer gas detector. One of the earlier zones investigated showed meter registered water loss that could not be located by sounding with the listening stick. When preparing the zone for re-testing, it was discovered that several household isolation valves had been disconnected by the householders, thinking these valves would somehow restrict water flow. The householders had not disposed of them, but additional time was needed to re-install them to isolate the zone. Staff were briefed on the use of the gas the theory behind tracer gas and what results could be expected.

We immediately determined that a large leak was present from the flow of gas. With the aid of some villagers the leak was located and when opened up, was found the be caused by a shovel cutting the line.

3. Results

From the Terms of reference, and anecdotal, information, large amounts of leakage were expected. In work on three test zones, one initially selected by the Consultant because of its accessibility, one selected by the PUB staff trainee, and one by PUB management because of expected high leakage. Only 19 total leaks were found, plus several very small seepages from faulty connections and water losses from some overflowing tanks. One illegal connection was noted, and one toilet block leak was found.

.However, based on work so far conducted. Leakage, at least in the areas investigated so far, does not seem to be the cause of reduced pressure in the zones tested.

The PUB personnel who have been involved in the project now have the confidence and basic skills to build upon and can continue to design and build the test zones needed for the necessary further work to reduce water loss in South Tarawa.

Show no leakage as positive

4. Recommendations

4.1 Modelling

There does not seem to be any modelling available on the distribution system and this does need to be being addressed. This information is vital for the successful creation and use of DMA’s, which in turn, allow a much greater assessment of water loss, water balancing, any need for leakage detection, analysing pressure and flows, and as a gauge to measure the success of such operations.

The least expensive method to obtain information for modelling is to utilise local knowledge. One likely source of local knowledge is valve turners and repair crews. Often these personnel know what valves control what areas and where lines run.

Mapping of the water system could be started with a mapping crew walking a designated area with valve turners familiar with the area, and building a profile of the area. This data could be used to start an accurate map of the water distribution system on an area by area basis.

4.2 Metering

At the present time, there are no meters to measure the flow of treated water into the distribution network. It is imperative that this is addressed, as meters provide the information required to determine how much treated water is put into the system, consumed or lost. (See 3.1, Supply in Appendix 2) This should have priority over even installation of customer meters.

While customer meters are necessary to measure consumption for a revenue base and as a spur to water conservation, bulk metering vs. customer metering is the simplest method of setting the basis for a water audit, which in turn helps set the basis for a Non-Revenue water (NRW) program

However, caution need to be applied. There are periods when air feeds into the water zones when the zones are "turned on". Air flowing through any meters register as consumption, whether the meters are customer or supply meters. If raw meter data is collected and used as the basis of supply/water loss or revenue, the collected data will have considerable error factors on the high side which will completely skewer consumption data.

4.3 Creation of District Meter Areas

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.

Once sufficient knowledge of the water main system is created, the establishment of District Metered Areas (DMAs) must be done as a matter of priority.

DMA's are the basic building blocks of a zoned distribution system. They provide manageable units by which zone performance can be measured and compared to other zones.

The fundamental characteristic is that they can be isolated by boundary valves and fed by a single metered input, although this is not always possible. Proper maintenance of the boundary valves is important to insure accurate testing/ flow data can be obtained.

The main benefits of DMAs is that mains characteristics are defined and can be monitored. This allows any required action within the PUB distribution system to be managed and prioritised.

DMAs allow

- Leakage Control
- Proposed Management where applicable
- Asset Maintenance
- Monitoring and Maintenance of water supply
- Planning and Programming of repairs

4.4 Establish an Action Plan

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.

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 <u>where needed</u>.

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

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

One additional step in the action plan that would be specific to the Action Plan for South Tarawa, would be to site water taps as close to the home entrance as possible. This would provide two benefits"

- The householder would have the water supply nearer to their home and would not have a need to interfere with water pipes for convenient use of water
- As householders do not like wet, muddy feet tracking water and dirt into their homes, it would make it less likely that taps would be removed and that the taps would also be turned off after use, reducing the likelihood of wasted water via open taps or hoses.

4.5 Continue the leak Detection Program

The leak detection program has been successful, not so much as what it has found so far, but also for what it has not found. In the areas tested, approximately 10% of the Betio water supply system, little large or severe leakage has been detected. Therefore, if leakage is thought to be a severe problem, leakage is elsewhere in the water network. However, it must be understood, that if large amounts of leakage are not the cause of problem, then other causes such as low water pressure, need to be investigated.

The creation of test zones, and the expansion of the control zone areas allow the team to establish a priority of where work or investigations needs attention, and often, a walk-trough of a zone can identify readily repairable problems. This work does not require a daily effort, but 2-3 days per month, a couple of hours each day would be sufficient.

4.6 Establish a Non-Revenue Water (NRW) Program

There is a great need for a water audit. Water losses from reservoirs/elevated tanks do not appear to be checked on a regular basis, quantities of produced water are recorded, but do not seem to have a tally system to check the total amount delivered to towers, and from there into the general supply, and I do not know if there is a regular methodology of reading what meters exist. In any event, as things stand, it would be extremely difficult to conduct an accurate water audit, or as it is sometimes called, a water balance. To conduct a water balance, we would need, at a minimum:

- System Input volume
- Authorised consumption, billed total and unbilled total
- Estimation of commercial losses – theft and fraud, meter under-registration, data handling errors
- Calculation of physical errors – all leakage

One way to address these and other problems would be to institute a Non-Revenue Water (NRW) program. As NRW is a key performance indicator of network efficiency, a properly designed and run NRW program incorporates numerous aspects of water operations and results in:

- better management of resources,
- improvements in asset management,
- increased operational capabilities and financial performance,
- greater system knowledge which allows the identification of current weaknesses
- the ability to adapt to future challenges

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 <u>after</u> 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

Put another way, commercial losses are losses of water that is consumed but not recorded or paid for. As commercial losses are not visible, many utilities overlook them and concentrate on physical losses. But recovering commercial losses increases revenue and can have a positive financial impact in a relatively shorter time and at lower cost than reducing physical losses. Recovering physical losses, while necessary, primarily reduce production costs, thus not actually contributing to revenue. But in any case <u>the accuracy of production flow meters, customer metering, and billing are the main factors affecting NRW calculation</u>.

Unchecked, NRW creates a repeating, damaging cycle that often paralyses water managers into inaction. Physical losses (leakage) reduce treated water from reaching customers, increasing operating costs. Larger amounts of money are then necessary to increase network capacity. Commercial losses from non-paying customers, illegal connections, inaccurate meters and poor data handling reduce income. More simply,

- NRW means expenditure is concentrated in meeting customer demands
- Operational budgets are reduced, especially in areas of network maintenance
- NRW levels increase
- Revenue decreases and operational costs increase
- **The cycle continues**

A key challenge for water utility managers is to reverse the cycle.

- Increase expenditure to include operational improvements
- Investments are made in NRW reduction programs
- NRW decreases
- Revenue increases and operational costs decrease

All parties must understand that NRW components cover the entire water supply and NRW is a key indicator of network performance. NRW management is not a one-off activity but requires long-term commitment and involvement. Management and operational staff need to be committed to managing NRW as a long-term process that incorporates numerous aspects of water operations. Addressing NRW is the responsibility of all management across the utility, including finance and administration, production, distribution, customer service, and other parts of the utility concerned with water supply. Choosing the right team members promotes ownership among the various departments involved in the strategy implementation and develops consensus and support by senior management heads.

The first step would be to ensure team members from all departments understand the need to accurately as possible quantify NRW to provide an indicator of the utility's operating efficiency. This would be followed by mapping a viable and sustainable NRW reduction strategy tailored for the current and foreseeable water supply system in Tarawa. To help develop the strategy, the team should set an initial target for NRW reduction based on the economic level of NRW. The team can balance the financial and water supply objectives using water balance results.

To develop an understanding of the big picture of the water network involves establishing a water balance. This process helps utility managers understand the magnitude, sources, and cost of NRW. The water balance should be used to calculate each component to determine where losses are occurring. Policy changes and operational practices can then be prioritised and implemented.

Awareness seminars would be required at all levels, from top decision makers to the end consumer which is critical for a successful NRW reduction program. All parties must understand their roles and responsibilities in reducing NRW since it requires a long term combined effort from all departments in the utility. Also, reaching out to customers helps increase their awareness of NRW and how reducing water losses results in improved water supply and quality.

Addressing commercial losses, examining physical losses and zoning (creating DMAs, currently accepted international best practice) would follow to help determine critical NRW data and prioritise efforts to reduce NRW to economically viable levels.

As an active leak detection program has begun in Tarawa under KAP II, including designing and creating DMA's, taking flow measurements, leak location and repair, the beginnings of the examination of Physical Losses is in place. But as stated above, leak detection in isolation, while an important component in NRW reduction, will not address other systemic problems. Under an NRW program, this leak detection effort, along with DMA creation would be easily folded in with the other necessary components of an NRW program. This component will be able to be run concurrent with setting up a program to address commercial losses.

Positive efforts in leak detection and management will be one of a range of performance indicators which would become available to managers and supervisors. These PIs would be a positive aid in measuring progress in reducing NRW, developing standards and prioritising investments in the water network infrastructure. Incorporating monitoring programs will insure NRW targets are being met and sustained.

4.7 Investigate the Use of Atmospheric Water Generators (AWG's)

It is a fact that the principal reason for intermittent water supply in South Tarawa is a physical shortage of sufficient water resources. Atmospheric Water Generators use basic air conditioning/refrigeration technology to transform atmospheric humidity to pure drinking water. As parts and maintenance are relatively inexpensive, they can have a life expectancy of up to 15-20 years. While not able to supply water as cheaply as the local utility, they can produce water far more cheaply than bottled water (and with almost little or no environmental impact) or desalination.

Some smaller units have a rated efficiency of 22-30 liters per day under standard temperature and humidity conditions (temperate climates) but given the temperature and humidity conditions in Tarawa, would be able to produce much more water. Smaller units can be run on solar power, and could take a lot of pressure off the PUB supply system by providing households with pure, safe drinking water 24 hours per day, while the PUB network water could be used for cooking or washing purposes. It is recommended that a pilot project, supplying selected households with AWGs be given serious consideration.

Larger units can produce over 13,000 liters per day, which is almost twice the daily water requirement of Betio. While not able to supply as much water as desalination systems, they are much easier to service and maintain and have lower operating and maintenance costs. They also do not produce an environmentally damaging by-product, brine. Given the atmospheric humidity in Tarawa, AWG's could be a viable water supply source, and with a smaller footprint that desalination plants, could seen as mini reservoirs and be located nearer areas of need requiring less long distance pumping and help build up the ground water reserves, either by reducing the reliance on those resources, or by injecting excess production back into the lens.

4.8 Obtain Pressure Measuring Equipment

There is currently no means of measuring pressure in the water network. While leakage is certainly a cause of reduced system pressure, undersizing of distribution lines and/or too many connections on improperly sized pipe networks can also result in pressure loss. To be able to measure actual pressure in various parts of the network would help to better understand the system and help in assessing the problem. Therefore, it is highly recommended that pressure measurement devices for the 5mm and higher pipe diameters in the Tawawa water network be obtained.

4.9 Community Information Program

Community involvement is necessary. To prevent or at least reduce the tampering or destruction of household isolation valves, an information program of some kind needs to be implemented. Residents need to understand why works are being done, what newly installed devices such as isolation valves are for, and how it benefits them.

If the problem with household valves is an indicator, the installation of household meters could become highly problematic, with meter tampering and destruction regular occurrences as is seen in many other parts of the world.

5. **Conclusions**

In conducting leak detection programs, there are usually expectations of the discovery of several large leaks or a series of many medium size leaks as the cause of water loss. However, because of a lack of metering in the PUB network beyond any bulk supply point, determining just how much water is being lost to leakage is impossible. The metering which has been done in newly created control zones and the leak detection testing, covering approximately 10% of the Betio water network, would indicate that low levels of leakage in consumer areas is the norm, and even these leaks are small, in some cases, observable, and in any case, easily repaired. While some could see this as a sign that leakage detection is no longer needed, it is imperative to understand that discovery of no leakage (as opposed to no discovery of actual leakage) is a definite benefit to PUB. By determining possible high leakage levels are not the major problem, the actual causes of problems can be narrowed down.

There hasn't been sufficient time to fully investigate leakage in the reticulation mains, but a few mains sections that were related to the testing done in smaller areas showed no leakage. While this is encouraging, much more testing needs to be done on these main, as generally leaks in these lines tend to be large and loose much more water. The supply zones only operate for a short period each day, and even larger leaks, if they are eventually found, would only leak for a brief period. The larger mains operate much more regularly and are therefore potentially a greater source of water loss. There are sufficient meters on hand to install larger diameter meters to begin to build data histories to measure water losses against water supplied., but many more are needed.

The leak detection team as trained is now fully capable of investigation these mains and to further expand the control zone program by designing the necessary zones, determine water losses, and detect and locate leaks on their own. If supported and continued, the leakage program can assist PUB in not only determine problems that need to be addressed in both short and medium terms, but also set a priority of where problem areas that are found need most attention.

However, it is absolutely necessary that the recommendations made be carried out as soon as practicable. Tarawa has limited resources of water, and given projected population growth in the South Tarawa area, all available water resources must be utilised in the most efficient manner

It should also be noted that earlier references indicate that percentage amounts are still being used as a base point for leakage. Rather than percentages, PUB should be using leakage rate per household connection. This gives a clearer indication as to network efficiency.

6 Photographs

Typical illegal connection. Note hose clamp to fasten on to PUB service main. When water in the zone is switched on, the hose is used to fill buckets, and water will continue to flow. This had been covered by a disused 55 gallon drum.

A severed 90 degree connection on disused but still connected line. Years of ground pressure forced the connection to snap at the elbow.

Most typical type of leak found, both above and below ground. A faulty connection or broken "O" ring in the fitting allows water to leak from the fitting. The following two photos are below ground.

A “do it yourself” extension to get the water from the line closer to the house by forcing two pipe sections together. The only reason it didn’t blow apart was because of low system pressure. (See following photo)