

A Practical Approach to Developing a Sustainable Water Loss Reduction Strategy in Sandakan, Sabah, Malaysia

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Abstract

The combination of the increasing demand for water and diminishing resources means that the reduction of water loss through leakage control is vital in today's world. All water networks in the world suffer from water loss it is only the amount of loss that varies. The volume of water loss depends on the condition of the mains and service connections that make up the network, local factors such as the type of soil, the utility's operational practice, the level of trained manpower and standard of equipment applied to controlling the losses.

The components of water loss need to be measured and understood before a reduction strategy can be developed and implemented. The International Water Association (IWA) has developed an accurate terminology, a standardised water balance and recommends a component-based methodology for calculating the losses from distribution networks. This paper discusses how the diagnostic approach has been applied to the distribution system in the city of Sandakan, in the state of Sabah in Malaysia, that has not only one of the highest levels of Non-Revenue Water in the country but also suffers from a shortfall in its water resources.

Once the losses had been assessed in Sandakan using the IWA methodology (prior to this project there had been a variety of definitions relating to water loss) a strategy appropriate to the local situation was developed and this paper details the methods used to develop and undertake the most effective solution.

Background

Sandakan is the second city in the Malaysian state of Sabah situated in the north east of Borneo Island. Sandakan has a population of approximately 450,000 of which quite a number are non-registered immigrants. Most of the activity in Sandakan centres on the docks and wharves where local produce such as rattan, timber, rubber, copra and palm oil is exported or transported to other parts of Malaysia.

The State of Sabah has had one of the highest levels of Non-Revenue Water (NRW) in Malaysia and in the nineties the level was calculated at almost 60% of system input volume. In 1997 a NRW reduction contract was let to a company named Patterson Candy (at that time Patterson Candy was part of Thames Water) and their objective was to design and implement District Meter Zones and reduce physical losses by 25%. The term District Meter Zone is widely used in Malaysia but is effectively the same as the term District Meter Area. The result of this project was that In Sandakan they designed and implemented 31 DMZs (that covered approximately one third of the Sandakan distribution system), set up and trained a 3 man leakage team but, unfortunately for Sandakan this contract did not result in the reduction of water loss to alleviate a water shortage. The water shortage in Sandakan has been brought about by a combination of a rapidly

increasing population, high water loss and lack of funding to construct a new water treatment plant.

In the spring of 2003 Jabatan Air Sabah (Sabah Water Board) let another NRW reduction contract which was aimed at reducing real or physical losses from two directions, improving and expanding the current active leakage control activities and replacing the mains with the highest burst frequencies. This contract was for a period of 30 months and was undertaken by Halcrow Water Services in partnership with a Malaysian Company, Salcon Engineering. In July 2005 the project is being brought to a successful conclusion and a stage 2 is being considered which will concentrate on the reduction of apparent or commercial losses.

The Sandakan Water Supply and Distribution System

The city of Sandakan receives its water from three sources. The major source is a treatment plant that takes its water from Sabah's longest river, the Kinabatangan, and this plant is located some 70 km from the city. This source provides approximately 65Mld and two borehole sources close to Sandakan produce 8 and 7 Mld respectively.

It is currently estimated that there is a current shortfall of water of 30% and the true demand is in the order of 115Mld. Jabatan Air Sabah have plans for a new water treatment plant that should be operational by 2008/09.

The Sandakan transmission main and distribution system totals almost 600km pipework and has approximately 36,000 service connections. A particular feature of the Sandakan system is the 70km single 900mm diameter transmission main linking the main source of water, the Kinabatangan Water Treatment Plant, and the town of Sandakan. In recent years, this pipe has become a problem in terms of both physical losses and non-physical losses (mainly theft of water).

The Sandakan distribution system like many others in Malaysia has a predominance of Asbestos Cement pipe much of which is close to reaching the end of its useful life. The result of which is that the system suffers from a high burst frequency.

Assessment of Water Loss for Sandakan

The Sandakan Water Balance Calculation

Prior to the current NRW Reduction project there had been a variety of definitions used relating to water loss for example the level of leakage was expressed as a percentage of distribution input. Jabatan Air Sabah were introduced to and happy to adopt the IWA's recommended terminology for water loss and use the IWA's standard approach for water balance calculations.

In order that the water balance can be calculated the constituent pieces of data need to be measured or estimated. In Sabah concessionaires are responsible for water production and as a consequence all source meters are calibrated twice a year. Thus the value of the key component, system input volume, is considered to be accurate. The other main component, billed metered consumption of registered customers, contains three categories – residential, commercial and industrial. The data for Sandakan was checked for billing and data handling errors and was considered to be reasonably accurate. An issue in Sandakan is unauthorised consumption either by theft or vandalism to fittings such as air valves.

The Sandakan water balance was calculated just prior to the commencement of the project (for the year 2002 and is shown in Figure 1) and it was determined that the total

NRW was 14947 MI/Annum (55% system input volume). Of the total NRW, the physical losses were estimated at 77% and the non-physical losses at 23%. The level of unauthorised use i.e. illegal connections and theft of water accounts for approximately 20% of the total NRW.

The IWA's recommended performance indicator for water loss, the Infrastructure Leakage Index (ILI) was calculated to be 30. The ILI is defined as the ratio between the Current Annual Real Losses (CARL) to Unavoidable Annual Real Losses (UARL).

Figure 1 The 2002 Annual Water Balance for Sandakan (all units MI/Annum)

System Input 27,719 100%	Authorised Consumption 12779 46%	Billed Authorised Cons. 12772 45%	Billed Metered Cons. 12772 45%	Revenue Water 12772 45%
		Billed Unmetered Cons. 0%		
		Unbilled Authorised Cons. 7 1%	Unbilled Metered Cons. 0%	
	Water Losses 14940 54%		Unbilled Unmetered Cons. 7 1%	
			Apparent (Commercial) Losses 3283 12%	Unauthorised Use (theft) 2772 10%
Real (Physical) Losses 11657 42%		Metering Inaccuracies 511 2%		Non-Revenue Water 14947 55%

Where do the largest components of physical losses occur?

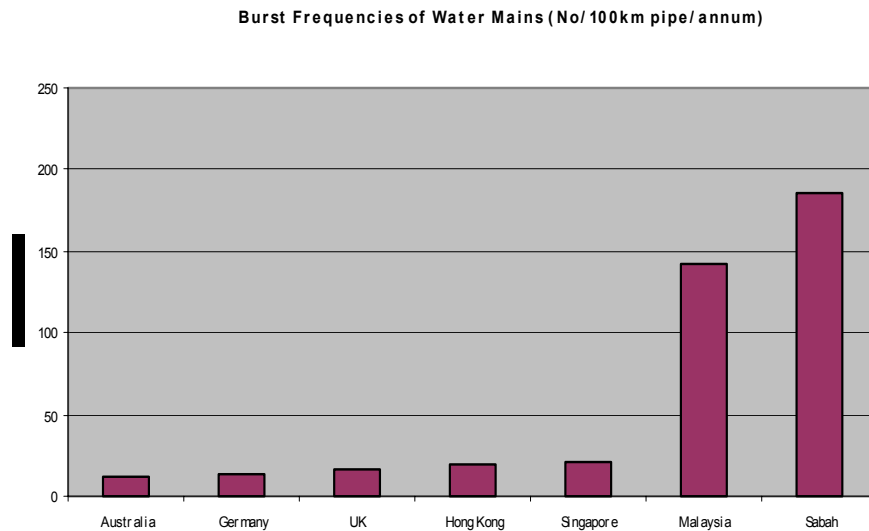
The high level of real or physical losses in the Sandakan system can be attributed to two main causes:

- A high incidence of burst mains and service pipes
- A water resource shortfall of approximately 30%
- Variations in pressure

Similar to the majority of systems in Malaysia Sandakan has a high burst frequency in its mains. This can be attributed to the fact that asbestos cement pipes contributes to in excess of 50% of the pipe material in Malaysia. Burst frequencies in Sandakan are in the order of 185/100km mains/annum compared with the UK figure of 15. Mains burst rates from locations around the world are shown in Figure 2. The number of leaks occurring on service pipes is also high with approximately 9/1000 connections as compared to that of the UK that has 6/1000 connections. Burst flow rates are higher from mains than service pipes and given the great number of burst mains it is evident that, in Sandakan, water loss from mains is greater than that from service connections.

The current water shortage in Sandakan results in some rationing being carried out, with certain areas being shut off for a day at regular intervals. Systems that are subject to intermittent supplies generally suffer from a higher burst frequency due the pressure cycling caused by emptying and recharging the mains and this is the case in parts of the Sandakan system. The problem is exacerbated by the theft of water and increase in leakage due to the tampering of pipes and fittings.

Figure 2 Burst frequencies from different locations worldwide



In recent years the 70km long transmission main between the Kinabatangan WTP and Sandakan has become a problem in terms of both physical losses and non-physical losses (mainly theft of water). In the early stages of the project a thorough survey was conducted in the transmission mains and 45 leaks were located, mostly on washouts and air valves. A 90 metre length of pipeline was identified as being in need of replacement and re-alignment. Some of the leaks on fittings, such as air valves, were thought to have been caused by people tampering with them in order to obtain water. During the course of the project three surveys have been conducted on the transmission main and flows were measured before and after the remedial work was completed, approximately 6Mld water will have been saved. In respect of the tampering of air valves - all air valves have been replaced and more secure chambers have been constructed. In addition to this at the air valves where theft has been prevalent a small diameter pipe has been installed with to provide a supply but the flow is restricted by an orifice plate

The reasons for the high water loss in Sandakan can be put down to:

- poor materials/infrastructure
- operational practice due to water shortage
- damage to fittings by people stealing water
- fluctuating pressures

With respect to apparent or commercial losses there is currently a customer meter change programme in progress and Jabatan Air Sabah's enforcement section are constantly finding and disconnecting illegal connections to the distribution system.

The Current Water Shortage in Sandakan

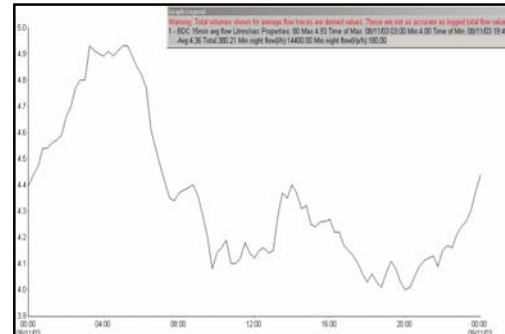
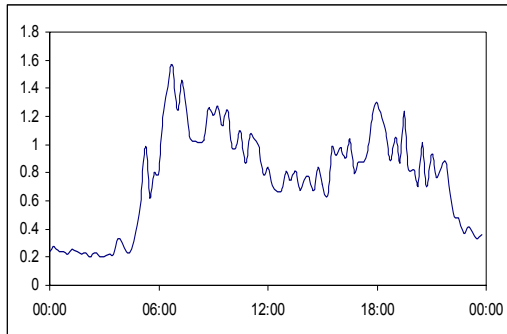
As stated previously there is currently a water resource shortfall of almost 30% in Sandakan. Thus, there is some rationing being carried out, with certain areas being shut off for a day at regular intervals. It is the intention to introduce pressure management to these areas and re-introduce a continuous supply. In other parts of the town, certain valves are throttled in order to restrict flow at the normal peak water usage times in the

morning and early evening. As a consequence, the normal daily pattern changes and water is taken when there is adequate pressure in the system. For example, at night it is evident that storage tanks start to fill as the pressure increases. Leakage levels are often monitored by the measurement of night flows but this is not practical in the instance of abnormal daily water usage patterns. The standard diurnal and throttled flow profile is illustrated below.

Figure 3 Diurnal flow profiles in Sandakan

Example of a normal diurnal flow pattern

Example of a 'throttled' flow profile in a Sandakan DMZ



Developing a Water Loss Reduction Strategy for Sandakan

Once the losses had been assessed and the situation in Sandakan understood a strategy was developed. Although there are several important stages to a water loss management strategy there is no standard approach and, as in Sandakan, it had to be tailor made to suit the local conditions. It was decided to tackle the problem in two stages. The target for Stage 1 (to be completed by August 2005) is to reduce Real Losses by 5,500 Megalitres/annum (15Mld) this will result in a level of NRW of 30% thus achieving the target set by the Malaysian Federal Government. In practical terms the rationing will be greatly reduced and Jabatan Air Sabah will have an increase in revenue as each cubic metre of water that can be saved can be sold. In many water distribution systems, losses can be reduced to an acceptable level by the introduction of an active leakage control programme i.e. proactively 'finding and fixing' leaks but, in Sandakan, parts of the infrastructure were in such poor condition that some pipes were in need of replacement. Thus, the problem of water loss had to be tackled from two directions – leak location and repair and selective pipe replacement. The Sandakan Strategy included the following activities:

- Updating the existing records system
- Construction and verification of a hydraulic model
- Re-establish 31 existing District meter Zones (DMZs)
- Develop and implement DMZs to cover 75% of the system
- Increase manpower in the leakage section
- Specify and procure leakage equipment
- Identify scope for pressure management
- Reduce physical losses by 15Mld
- Identify the mains that require replacement

- Develop a mains replacement programme
- Executing the mains replacement scheme

Updating the Existing Records System

Geographical Information System (GIS) is a system of computer software, hardware and data, and personnel to help manipulate, analyse and present information that is tied to a spatial (geographical) location. Geographic Information Systems is an interactive database that links geographic information (where things are) with descriptive information (what things are)

Unlike a flat paper map, where "what you see is what you get," a GIS can present many layers of different information.

A Geographical Information System (GIS) was implemented in 1989 but it had not been updated for several years and, thus was in need of revision. Unfortunately, the existing system had become obsolete and thus the plan is to convert the data into a modern format and update and include missing information.

Construction and Verification of a Hydraulic Model

The objective of constructing a hydraulic model includes:

- Gaining a comprehensive understanding of the behaviour of the existing system
- Identification and resolution of existing system anomalies
- Designing of DMZs
- Designing of pressure management areas
- Future planning of the system

Re-establish 31 Existing DMZs

The concept of DMZs is to provide continuous monitoring of small discrete parts of a distribution system for the purposes of proactive leakage management.

31 DMZs were established in a previous contract in 1997/98 but several had been suspended or no longer used.

Extend the Coverage of DMZs

Designing and implementing approximately 25 DMZs would give 75% coverage of DMZs in the Sandakan system. The process of design would to be undertaken once the hydraulic model had been constructed and validated. It was planned to design and implement these DMZs with the first 15 months of the project.

Increasing the Manpower Level of the Leakage Section

There was one existing leakage team in Sandakan and this team has been seconded to the consultants for the duration of the project. The purpose of this action is to help focus the effort and introduce further training. Two additional teams have been recruited and trained in order to accelerate the leakage reduction effort.

Specify and Procure Leakage Control Equipment

The existing team had been provided with equipment under the previous contract but some of this is now outdated or has fallen into disrepair. The contract provided for the provision of:

- Flow and pressure data loggers
- New computers
- Listening sticks
- Leak Noise Correlators
- Acoustic loggers

Identify Scope for the Introduction of Pressure Management

The potential for pressure management will be identified by using specialised diagnostic techniques in the new and re-established DMZs as well as using the calibrated hydraulic model.

Identify the Mains that Require Replacement

- The criteria for determining those mains that require replacement are:
- Failure rates and water loss
- Operating pressure
- Water quality
- Maintenance costs
- Interruptions and complaints

Examination of failure statistics or burst frequency can provide:

- Assessments of network condition and performance
- Evaluation of weak points in network
- Planning of specific maintenance measure
- Planning of specific rehabilitation measure
- Selection of sustainable materials

The types of material to be used for the pipe replacement were specified by Jabatan Air Sabah are uPVC and cement lined mild steel.

Progress to Date

The project has been running for 28 months and the progress that has been achieved so far is:

- Conversion and updating of the mapping system has been completed
- Construction of the hydraulic model has been completed
- All existing 31 DMZs have been re-established
- Design and implementation of the 25 new DMZs has been completed
- Approximately 100km of the “worst” mains have been identified.
- 102km Mains have been replaced (almost 20% of the Sandakan system)
- Two additional leakage teams have been recruited
- Water savings of approximately 17 - 18Mld have been achieved.

- Training of JAS staff for mapping, modelling and leak detection is ongoing

Updating the Existing Records System

Jabatan Air Sabah had specified that the Strumap software, produced by MVM, was to be used on the project. The software was supplied by Jurukur Berjasa, in their capacity as sole agents for MVM in Malaysia.

The work on setting up the GIS system for Sandakan using Strumap began in July 2003 and was completed around January 2004.

Construction and Verification of a Hydraulic Model

The Sandakan hydraulic model of the transmission mains and distribution system has been built using the network data and customer data taken from the GIS system. There was extensive amendments and verification of the network data and data collation for the hydraulic features such as pumps and reservoirs. For the pumps, generic pump curves were used as specific ones for the existing pumps were not available. The model was constructed in 2003 and field testing was carried out in February 2004 and validation was completed in April 2004.

Re-establishing 31 Existing DMZs

All existing DMZs were checked for integrity by examining the accuracy of the meter and carrying out zero pressure tests and updating the number of connections in each DMZ. The reasons why certain DMZs had been suspended were investigated and in all cases these DMZs were reintroduced. There were a variety of reasons why the existing DMZs fell into disrepair, such as the system had been extended or changed or poor pressures had been experienced.

Extend the Coverage of DMZs

Twenty five new DMZs were designed and implemented in 2004. The programme was accelerated in order to assess whether any of the mains in the new DMZs should be included into the mains replacement programme.

Increasing the Manpower Level of the Leakage Section

The existing Jabatan Air Sabah leakage was seconded to the consultants for the duration of the project. Two further teams were recruited during 2003 and training was provided on all aspects of leak location.

Specification and Procurement of Leakage Control Equipment

All necessary equipment for leakage control equipment was specified and agreed with Jabatan Air early in the contract and was procured by the time the new leakage control teams had been recruited. Classroom and in the field training on the use of the equipment was carried out by the manufacturer and Halcrow Water Services. It was important to purchase the equipment from a supplier who could provide a good after sales service.

Identify Scope for the Introduction of Pressure Management

Pressure Management had never been practiced in Sandakan prior to this contract. During 2004 a pilot zone was implemented to demonstrate the benefits of controlling pressure.

As the project nears completion eight schemes have been implemented and are successfully operating.

Identification of the Mains that Require Replacement

In order that the mains that were nearing the end of their life could be identified burst data for the period 2000 to 2003 was carefully analysed, samples of pipe were cut out and analysed, also operational staff provided 'local knowledge'. By July 2005 the mains replacement programme was almost complete. Some 102 km of mainly 100mm and 150mm of Asbestos Cement pipe had been replaced. Importantly, all house connections were also replaced under this contract.

Leak Location and the Reduction of Physical Losses

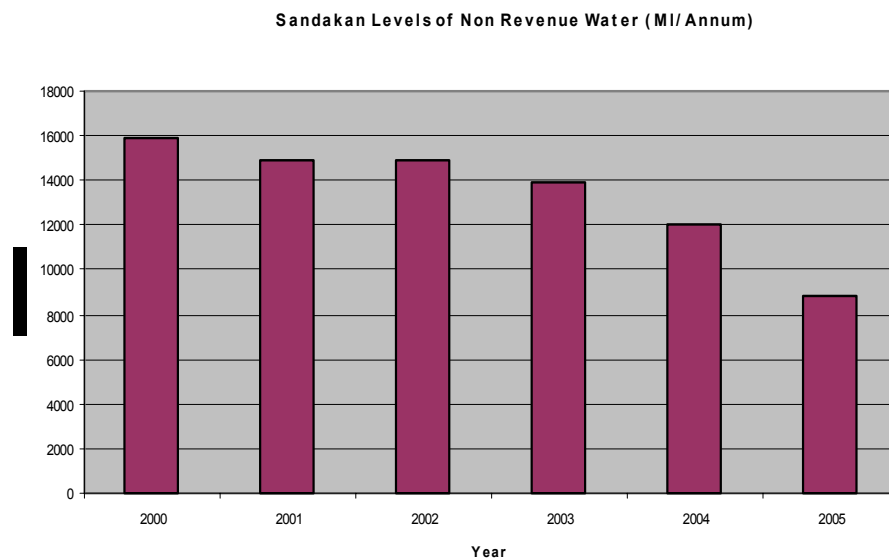
During the course of the project approximately 2,100 leaks have been located and repaired. Under the terms of the contract all water saved has to be recorded and reported to Jabatan Air Sabah. A methodology was devised whereby the water saved through active leakage control and mains replacement would be identified.

At the end of June 2005 physical losses have been reduced by almost 17.5 Mld against the target of 15Mld. 11Mld have been saved through active leakage control and 6.5 Mld by replacement of mains. It is anticipated that by the end of the contract in August 2005 the water saved will be approximately 18 Mld.

The reduction of physical losses has been calculated using the 'top down' approach and the 'bottom up' using DMZ data.

A water balance has been calculated for the period January to the end of June 2005 and the reduction in NRW is shown in Figure 4. The ILI has been calculated at 17.

Figure 4 Actual Levels of NRW in Sandakan



Ensuring Sustainability

The objective of the Sandakan project has been to reduce the physical losses in the transmission and distribution system by a mixture active leakage control and replacing the water mains that are in the worst condition. However, it is essential that the improvements that have been made are sustained. There were several issues to be considered:

- Ensuring appropriate staffing levels

- Staff education and ongoing training
- Appropriate funding for operation and maintenance
- Assessing and monitoring performance

Jabatan Air Sabah is confident that the necessary funding is now available to maintain and even improve the situation in Sandakan after the completion of the project.

Conclusions

The Sandakan situation is a very good example of a transmission and distribution system that is under great stress because of the combination of the shortage of water, high incidence of bursts and leaks on mains and service pipes and further exacerbated by the theft of water and tampering with the pipes and fittings. The operational staff have a very difficult task in trying to provide the customers with a reasonable water supply. This object of this project was to try and alleviate the problem by the reduction of physical losses by almost 18Mld through enhanced leakage reduction techniques and the replacement of approximately 20% of the infrastructure that was in poorest condition.

Good results have been achieved on this project by the application of:

- international best practice in the assessment of losses and development of a tailor made strategy
- Active leakage control using the latest techniques and practices.
- Appropriate training of local staff

Acknowledgement

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