# BACKGROUND LOSSES REDUCTION BY EXCESSIVE PRESSURE CUT-OFF

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Bismillahirrahmanirrahim...

Tesis ini didedikasikan khas untuk insan-insan yang teristimewa:

Untuk isteri tercinta Zaharah Elias, dan
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# ABSTRACT

It is one of the greatest challenges water utilities are facing in striving to reduce and control Non Revenue Water (NRW) within an economic level. While supplying the population with sufficient water, the reduction of NRW has been a key issue in judging the performance of all water utilities. Background loss is one component of physical losses which is the most to contribute to NRW. This study aimed on pressure management method conducted at a site to reduce background loss. The pressure management method used is by the installation of a Pressure Reducing Valve (PRV) with timer-based pressure cut-off controller as an on-site verification. The BE59 - Kg. Melayu Pandan, one of the District Meter Area (DMA) in Johor Bahru has been selected as a case study. The Step Tests are carried out to analyse and identify the steps with high background leakage and to find suitable location for the purpose of PRV installation. The DMA meter and a data logger are used to measure and record pressure and flow profiles to determine leakage at each step and to establish leakage baselines, before and after the activation of the PRV. The results indicated a high reduction of background loss and given significant impact on the NRW level in Johor Bahru. In financial terms, volume of water saved and the monthly expenditure shows the return of investment (R.O.I) is in a period of 6 months. This research findings show a higher reduction on background loss can be achieved by optimising the cut-off controller, analysing further excess pressure cut-off based on pressure profiles in the existing or new DMA with a PRV and controller in a large scale. Comparisons with other methods of pipe replacement and Active Leakage Control (ALC), indicate that, the pressure management by excess pressure cut-off is the most feasible, economical and effective method in the NRW reduction.

# ABSTRAK

Pihak pengurusan perkhidmatan bekalan air berhadapan dengan satu cabaran besar untuk mengurangkan dan mengawal kadar kehilangan air tidak berhasil (NRW) kepada paras yang ekonomik. Pengurangan kadar NRW merupakan petunjuk utama dalam menilai peningkatan prestasi sesebuah operator perkhidmatan bekalan air, selain memastikan air yang mencukupi dapat dibekalkan kepada penduduk. Kebocoran di bawah tanah yang di kategorikan sebagai kehilangan fizikal adalah merupakan komponen utama penyumbang kepada kadar NRW berbanding komponen-komponen NRW yang lain. Kajian ini menumpukan kepada kaedah pengawalan tekanan yang dijalankan ditapak untuk mengurangkan kebocoran di bawah tanah. Kaedah pengurusan tekanan digunakan melalui pemasangan Injap Pengurang Tekanan (*PRV*) dengan pemotongan tekanan terkawal berdasarkan penetapan masa sebagai pengesahan melalui kerja di tapak. Satu *District Meter Area* (*DMA*) dalam Johor Bahru, iaitu BE59 Kg. Melayu Pandan telah dipilih sebagai kajian kes dan Ujian Berlangkah dijalankan untuk menganalisis dan mengenalpasti kawasan dengan kebocoran di bawah tanah yang tinggi, disamping mencari lokasi pemasangan *PRV* yang sesuai. Meter kadar alir *DMA* dan alat merekod data digunakan untuk mengukur kadar aliran masuk dan taburan tekanan bagi mengira kebocoran pada setiap *step* dan penentuan garisan dasar nilai kebocoran sebelum dan selepas pengakifan *PRV* pada *DMA* tersebut. Hasil kajian menunjukkan pengurangan kadar kebocoran di bawah tanah yang tinggi dan ini membantu mengawal dan menurunkan paras NRW di Johor Bahru. Dari sudut kewangan, nilai isipadu air yang dijimatkan dan perbelanjaan kos bulanan menunjukkan kadar bayaran balik *R.O.I* adalah dalam masa 6 bulan. Hasil kajian ini telah menunjukkan pengurangan kebocoran di bawah tanah yang tinggi juga boleh dicapai menerusi pengoptimuman penggunaan kawalan pemotongan tekanan berdasarkan penetapan masa melalui analisa taburan tekanan yang lebih terperinci yang dibuat pada *DMA* sedia ada atau yang baru dan juga perlaksanaan berskala besar pengurusan tekanan dengan penggunaan PRV. Berbanding dengan kaedah penukaran paip dan pengawalan kebocoran aktif (ALC), didapati kaedah pengurusan tekanan melalui pemotongan tekanan lebihan ini adalah lebih efektif dan ekonomik untuk pengurangan paras NRW.

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| | |
|---|---|
| % | percentage |
| A.C | Asbestos Cement |
| ALC | Active Leakage Control |
| CP | Critical Point |
| $CP_{cmin}$ | Estimated Elevation Difference between the CP and the Highest Customer Roof Tank Level |
| $CP_{nmax}$ | Average Daily maximum Value for Night-time Periods at Critical Point |
| CV | Cut-off Value |
| $CV_d$ | Cut-off Value for the Daytime Pressure |
| $CV_n$ | Cut-off Values for Night-time Pressure |
| DMA | District Meter Area |
| BABE | Background and Burst Estimates |
| ELL | Economic Leakage Level |
| FAVAD | Fixed and Variables Area Discharges |
| HDPE | High Density Polyethylene |
| IWA | International Water Association |
| KPI | Key Performance Indices |
| LNF | Legitimate Night Flow |
| mH | Meter Head |
| MNF | Minimum Night Flow |
| $MNF_a$ | Average MNF line after PRV installation |
| $MNF_b$ | Average MNF line before PRV installation |
| NNF | Net Night Flow |

| | |
|---|---|
| $NNF_a$ | Daily Average of the Background Losses Value After the PRV Installation |
| $NNF_b$ | Daily Average of the Background Losses Value Before PRV Installation |
| $NNF_d$ | Daily Volume of Background Losses Reduction |
| $NNF_{da}$ | Average Daily Background Loss Volume After Activation of PRV |
| $NNF_{db}$ | Average Daily Background Loss Volume Before Activation of PRV |
| $NNF_r$ | Value of Background Losses Reduction |
| NRR | Natural Rate of Rise |
| NRW | Non-Revenue Water |
| P1 | Inlet of the DMA inlet point |
| P2 | Farthest point of the DMA |
| P3 | Highest point of Step 3 |
| PRV | Pressure Reducing Valve |
| PV | Point of PRV Installed |
| $PV_{dmax}$ | Average maximum value of daytime pressure |
| $PV_{dt}$ | Daytime Pressure Cut-off Target |
| $PV_{nmax}$ | Average Maximum Value of Night-Time Pressure |
| $PV_{nt}$ | Night-time Pressure Cut-off Target |
| PVC | Polyvinyl Chloride |
| R.O.I | Return of Investment |
| SAJ | SAJ Holdings Sdn Bhd |
| SPAN | Suruhanjaya Perkhidmatan Air Negara |
| UFW | Unaccounted for Water |
| VS | Average Daily Amount of Volume Saved |
| WLTF | Water Loss Task Force |
| WTP | Water Treatment Plan |

# CHAPTER I

# INTRODUCTION

## 1.1 Introduction

Non-Revenue Water (NRW) is one of the greatest challenges to most water utilities. Since NRW level as an indicator of the water utility's operating efficiency, they need taken serious consideration on performing and establishing NRW policy and strategies to control, monitor, reduce and accurately quantify the NRW to ensure NRW reduction and control within the economic level. Physical Losses is the main component of NRW contributor and they come in the form of leakage on transmission and distribution main, leakage and overflows from storage tank, and leakage on service connections up to customer meters. Leakages from transmission and distribution mains are usually large events that can cause serious road infrastructure and public assets damages, bigger volume of water losses and severe injuries or death, especially when it happens in remote area such as, in private plantations and farms, private land, abandoned land, where leakage will run undetected for a few months or even years. In Johor the physical loss in 2006 was 23.8% (118.23 Mill. $m^3$/year) and reduced to 23.3% (117.36Mill. $m^3$/year) in 2007 (NRW Control, 2007). High frequency of pipe burst in remote areas that take longer time to be localised, responded and repaired, made it the major contributor to physical losses.

Latest development on pressure management shows the conventional implementation of Pressure Reducing Valves (PRV) have improved and add a new function by using timer-based pressure cut-off and pressure modulation controller to minimise the excess pressure in the water reticulation, hence reduce the background loss. This timer-based pressure cut off controller is attached to the existing PRV and functions to cut-off excess pressure, where the higher current pressure switches to the lower user setting at a designated time, while pressure modulation will accommodate the pressure increase or decrease based on consumption demand or flow profile of the designated District Meter Area (DMA). This study will identify the impact on reduction of background losses by using the PRV with timer-based pressure cut-off at the DMA inlet and comparing the resulting cost of this equipment installation and operation with total length pipe replacement and Active Leakage Control (ALC) implementation.

## 1.2 Statement of Problem

Controlling and reducing NRW is the biggest challenge to the water operator since there are no very efficient tools and strategy to do so. In developing countries, physical loss, due to background leakage such as communication pipe leaks, burst and pipe breakages, pipe fractures due to pipe aging because of oldest infrastructure and worse assets condition, is a major and the biggest contributor to NRW.

According to the Asian Development Bank the estimated annual volume of NRW in urban water utilities in Asia is in the order of 29 billion cubic metres ($m^3$). Assuming a value of water at USD 0.30 per cubic metre, Asia’s water utilities are losing nearly USD 9 billion per year. By cutting physical losses to half the present level (which is technically feasible), 150 million people could be supplied with already treated water (Frauendorfer and Liemberger, 2010).

Moreover, unmanageable pressure in water reticulation can cause high pressure, sudden changes and wide ranges of pressure transient to occur in the water supply system. This puts a high stress and load to the existing old water system. Pressure and leakage relationship shows a direct relation between these components. High pressures mean high leakage which is directly causing high NRW. This excessive pressure (or over pressure) to the water assets will directly create new leaks at the weak points on the existing assets, and increase the frequency and volume of leakage in the water supply system (Farley *et al.*, 2008).

Pressure Reducing Valve (PRV) is one of the most popular pressure management equipment widely implemented near to DMAs and branches. PRV is the basic pressure equipment which helps avoid the extreme pressures transient in a system. It works as a control by adjusting the maximum and cap the downstream pressure outlet at one fixed pressure line set by the user (Farley and Trow, 2003). In practice, the pressure set at the PRV outlet is the pressure demand on the daytime during peak flow demand. However, the pressure in the system will develop significant ranges more than the daytime (peak consumption demand), when there is less or no water consumed or with low head loss and no flows at the night time. To control and minimise this significant pressure increase in the system during night time, this study has proposed to attach a timer-based pressure cut-off tool to the existing PRV where it would function to provide the additional fix pressure line to control and cap the downstream pressure outlet across the day and night time.

Besides the pipe aging factor, there are no efficient tools to evaluate total pipe assets condition which is beneath the ground level where part of it is submerged under the ground water level. Pipe materials may chemically react with the surrounding nature compounds, for example pipe corrosion due acidic soils.

In developing countries, there are many cases of high NRW, although its level is shown to be reducing and under control. The background losses line shows an increased trend or upset than the NRW level reduction line, as expected. Once all the efforts to reduce background losses have been put in place, the soaring trends may become a major concern to those water operators to overcome in the coming years.

This study focuses on NRW against background losses trends in Johor. Data on volume of losses on monthly basis are collected and an approach used to reduce background losses by installing pressure management strategy using pressure reducing valve (PRV) is utilised. The PRV would cut down the excessive pressure resulted in the water reticulation system.

## 1.3 Objectives of Study

The objectives of the study has been identified as follows;

1. To determine the volume of background loss that contributes to non-revenue water (NRW) in Johor.

2. To analyse the volume saved due to reduce background loss by using the PRV to cut-off the excessive pressure.

3. To estimate and compare the return of investment and the cost for each cubic metre of active leakage control (ALC), pipe replacement and pressure management methods.

The outcome may contribute to the knowledge of better non-revenue water control and sustain by exposing the pressure management using PRV with excess pressure cut-off for better future selection.

## 1.4 Scope of Study

This study is focused on the implementation of NRW control methods in Johor state as shown in Figure 1.1, highlighting on progress performances, milestone, target, achievements and continued improvement efforts put up by the water authority.

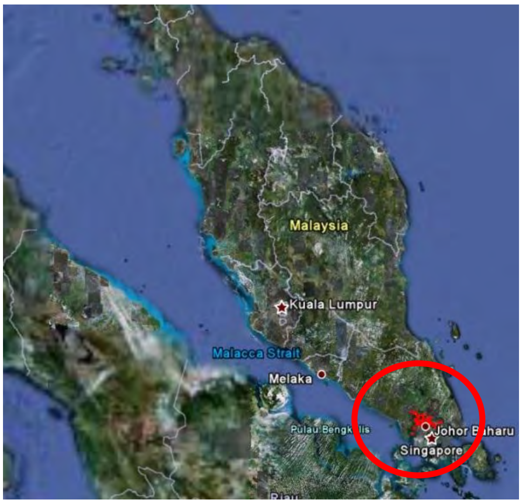


Figure 1.1 Location of Johor state (red circle)

This study has selected Johor Bahru district as a case study is because of the following reasons;

i. Johor Bahru is the biggest NRW and background losses contributor in the Johor state (NRW Control, 2012).

ii. Johor Bahru has also recorded the highest population density, most DMAs and the longest pipe length in the Johor state (NRW Control, 2012).

iii. Since Johor Bahru has the highest consumers, it has a variety of demographic and businesses such as shop house, light and heavy industry and etc.

A case study will be conducted on BE59 – Kg. Melayu Pandan. It is located along the Tebrau – Kota Tinggi main road and covers most of Kampung Melayu Pandan as shown in Figure 1.2. Out of 348 non-problematic DMAs in Johor Bahru district, BE59 – Kg. Melayu Pandan is selected as a case study due to the highest magnitude of background loss in the DMA rank in the Johor Bahru district. Selection of the district and DMA in this case study is discussed in details in Section 4.2.

Part of the pipe configuration will be installed with a PRV, identified as Step 4 pipe line. The PRV shall function as a control and to maintain pressure at a baseline of pressure during peak demand. Excess pressure is cut-off and background loss or Net Night Flow (NNF) reduction is expected in this DMA.


Figure 1.2 Location of DMA: BE59 - Kg. Melayu Pandan in Google map

**1.5 Significance of Study**

Reducing NRW means saving a lot of natural resources, energy, chemical usage, etc. The significance impact in reducing NRW is mentioned as follows;

i. To cater for consumer growth and future demands, water utilities will need to look into large scale project on developing new water resources, water treated schemes and catchment area which involved a huge budget allocation to do so.

ii. Low operational expenditure cost due to less consumption of electricity and chemical usage, and low water abstraction charges. Before it reaches its final destination, the water may have been pumped from the source to treatment plan, where further energy is used in the treatment process. It will then be pumped to a treated water reservoir and may require further pumping into the distribution system. Since water is heavy, all of these processes require significant amounts of energy.

iii. Increase cash revenue to water utility by channelling the volume losses to industrial consumers.

iv. Increase water utilities efficiency and image or reputation especially on managing water losses.

v. Provide sustainable water resources plan for future generations.

This study will look into the function of a PRV placed in the water supply line. The pressure and background loss or net night flow (NNF) baseline is determined and whatever excess pressure fluctuations that occur in that duration will be cut-off to maintain the baseline pressure. This excess pressure would reduce the volume of NNF, hence reducing the NRW for that particular district.

A District Meter Area (DMA) located in Johor Bahru district is chosen as a case study where a PRV with timer-based pressure cut-off controller is installed. This is done to reduce current background loss inside the DMA; i.e. by reducing the Net Night Flow (NNF). In Johor, the DMA is also called District Meter Zone (DMZ) and currently the water authority, SAJ Holdings Sdn. Bhd. (SAJ) has established 925 DMAs, as tabulated in Table 1.1. Eight hundred and forty six (846) of the DMAs are equipped with permanent electromagnetic flowmeter to monitor and measure background losses in daily basis, while another 79 new additional DMA are utilising portable insertion probe electromagnetic flowmeter for monitoring purposes done quarterly. This new additional DMA in this study is a new DMA, recently established by Active Leakage Control (ALC) team at a new mass development housing estate area, but with leakage level too low and uneconomical to for daily leakage measurement (NRW Control, 2011).

Table 1.1 District Meter Area in Johor, by district (Source: NRW Control, 2011)

| DISTRICT / REGIONAL | DMA Established with Flowmeter | New DMA with Insertion Probe | TOTAL |
|---|---|---|---|
| **JOHOR BAHRU** | **362** | **60** | **422** |
| *i. Johor Bahru* | *134* | *21* | *155* |
| *ii. Pasir Gudang* | *109* | *25* | *134* |
| *iii. Kulai* | *119* | *14* | *133* |
| **BATU PAHAT** | **120** | **5** | **125** |
| **MUAR** | **90** | **1** | **91** |
| **PONTIAN** | **58** | **0** | **58** |
| **KLUANG** | **77** | **13** | **90** |
| **KOTA TINGGI** | **59** | **0** | **59** |
| **MERSING** | **30** | **0** | **30** |
| **SEGAMAT** | **50** | **0** | **50** |
| **JOHOR** | **846** | **79** | **925** |

From economics point of view, large capital investment is always associated with the development of new water resources, water treatment plants, dams and water transfer schemes. However, it can be delayed or postponed for many years due to many unanticipated reasons. However, a postponement can create an opportunity to water providers to gain access in self-generated cash flow, increase in revenue, increase the water provider efficiency and reputation and meet the NRW percentage target as stated in contract between water provider and water authorities.

## 1.6 Limitations of Study

The limitations of study during carry out the site verification has identified and considered two criteria as follows;

i. A collective DMA by magnitude of background loss or Net Night Flow (NNF) according to rank, and

ii. The DMA under squatter areas.

These two criteria are considered due to;

i. Collective DMA ranked by background loss magnitude is close to the objectives of this study. Furthermore almost all DMA have data loggers installed to gauge magnitude of daily background loss or Net Night Flow (NNF) in litre per second. Moreover, the historical data for the other options which involve many parameters or variables in their calculation lack specific formula to calculate monthly values. The database system to cater and record all the data for NRW and losses have not yet been develop, which at this moment is in the feasibility study phase for tendering.

ii. The DMA under squatter area is considered in this study since the residents are staying in this area illegally, with the improper service facilities and physical infrastructures not provided sufficiently, and do not normally meet the local authority standard requirements. Furthermore, in most cases, the land acquisition taken by new land owner or developer can be complex as they are not allowed to do any physical works or any obvious improvement activities on the land. The consequences are; some of the major leakage management activities such as pipe replacement or rehabilitation, Active Leakage Control (ALC) and active leakage detection such as regular sounding are not allowed to be carried out.

iii. Only the non-problematic DMA is considered in this study due to no current or actual data available for problematic DMA. The DMA monthly report for October 2009 is used as a reference for the purpose of this study.

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