NON REVENUE WATER
AT KUALA LIPIS

NOR ALINA BINTI ALIAS

B. ENG (HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name : NOR ALINA BINTI ALIAS

Date of Birth : 18 JULY 1994

Title : NON REVENUE WATER AT KUALA LIPIS

Academic Session : 2018/2019

I declare that this thesis is classified as:

☐	CONFIDENTIAL	(Contains confidential information under the Official Secret Act 1997)*
☐	RESTRICTED	(Contains restricted information as specified by the organization where research was done)*
☑	OPEN ACCESS	I agree that my thesis to be published as online open access (Full Text)

I acknowledge that Universiti Malaysia Pahang reserves the following rights:

1. The Thesis is the Property of Universiti Malaysia Pahang
2. The Library of Universiti Malaysia Pahang has the right to make copies of the thesis for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

_______________________	_______________________
(Student's Signature)	(Supervisor's Signature)
_______________________	_______________________
940718-06-5744 Date: MAY 2019	PUAN WAFTY BINTI ABD RAHMAN Date: MAY 2019

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor Degree of Civil Engineering

____

(Supervisor's Signature)

Full Name : PUAN WAFTY BINTI ABD RAHMAN

Position : SUPERVISOR

Date : MAY 2019

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : NOR ALINA BINTI ALIAS

ID Number : AA15271

Date : MAY 2019

NON REVENUE WATER
AT KUALA LIPIS

NOR ALINA BINTI ALIAS

Thesis submitted in partial fulfillment of the requirements
for the award of the
B. Eng (Hons.) Civil Engineering

Faculty of Civil Engineering & Earth Resources

UNIVERSITI MALAYSIA PAHANG

MAY 2019

ACKNOWLEDGEMENTS

First and foremost, praises to Allah, the Almighty, who give permissions that allows me to complete this thesis. There are a lot challenges that I have encountered throughout the completion of this thesis. With the patience and consent I have been able to overcome these challenges.

I would like to take this opportunity to express my sincere appreciation and gratitude to my supervisor, Madam Wafty binti Abd Rahman who provided helpful guidance and advice that helped me to implement this thesis.

I would address my thanks to Pengurusan Air Pahang Daerah Lipis (PAIP), especially Encik Abd Zakiyazid bin Muhamad Saibani and National Water Services Commission, Kuantan Branch (SPAN) on the cooperation that I received for the data and information needed for this thesis.

My sincere appreciation is devoted to my family whom I owe a debt of attitude for their prayers and moral support, to my friends especially Siti Fairuzalina who have helped and support me during completing this thesis.

ABSTRAK

One of the main challenges faced by water utilities is the high NRW level in the water distribution system. In 2015, the NRW rate for Pahang was 52.8% compared with the national average of 35%, the third highest rate among the states in Malaysia. To address this issue, Pahang Water Management Berhad (PAIP) has set up a NRW management unit for its district to monitor NRW rates. For the initial stage, there are only three districts in Pahang State which have special units to control the NRW rate of Kuantan, Kuala Lipis and Pekan. However, this research focuses only on NRW in the district of Kuala Lipis. The NRW unit in Kuala Lipis was established in 2016 after the establishment of DMA. There are nine water treatment plants (WTPs) around Kuala Lipis district equipped with 52 DMAs. The establishment of the DMA commenced in 2014 and completed in 2015. To analyze the effectiveness of NRW management in Kuala Lipis district, the discussion focuses on existing conditions, withdrawals, bills and NRWs for every nine WTPs. Comparison for all WTPs has been made to achieve overall NRW management performance from 2016 to 2018. In addition, NRW components were also identified to know factors that contributed to the rate of NRW. Generally, based on the standard water balance there were three components of NRW that consist of physical losses, commercial losses and unbilled authorised consumption. Based on the analysis made, it shows that the main factor that contributed to water losses is the physical losses as proven by the analysis of water losses for each kilometre pipe of each WTP in this report. It shows that there was 2,027 m^3 of water losses occur per day for each kilometer pipe for the year of 2016, 1,800 m^3 for the year of 2017 and 1397 m^3 for the year of 2018. It is about 5,224 m^3 of water loss every day in each kilometre pipe along these three consecutive years. In order to compare flow before and after NRW unit establishment, the analysis made based on the volume of production, billing and NRW for each WTP for three years (2016 until 2018) after the establishment of NRW unit. The comparison of the flow was made based on the baseline rate before the establishment of NRW management. Referring to trend of NRW for all nine WTP, it shows that the rate of NRW varies from year to year and directly proportional to the production and billing rate. There was a lot of difference between the production and billing that occur due to water losses. From all WTP around Kuala Lipis area, only Jelai WTP shown consistence decrease of NRW. This situation occur due to Jelai WTP is the priority since it functions to supply the clean and safe water to the Kuala Lipis city with the highest population rate when compare than others WTP. The highest rate of water losses may lead to insufficient water supply for surround population. Therefore, the overall monitoring and management started at the Jelai WTP which provide supply to the town. For other WTP, the overall monitoring and management would be carried out according to priority due to lack of manpower.

ABSTRACT

Cabaran utama yang dihadapi oleh utiliti air adalah tahap NRW yang tinggi dalam sistem pengagihan air. Pada tahun 2015, kadar NRW bagi negeri Pahang adalah 52.8% berbanding purata kebangsaan 35%. Kadar NRW bagi negeri Pahang adalah yang ketiga tertinggi di kalangan negeri-negeri di Malaysia. Untuk menangani isu ini, Pengurusan Air Pahang Berhad (PAIP) telah menubuhkan satu unit pengurusan NRW bagi daerahnya untuk memantau kadar NRW. Untuk peringkat awal, hanya terdapat tiga daerah di Negeri Pahang yang mempunyai unit khas untuk mengawal kadar NRW; Kuantan, Kuala Lipis dan Pekan. Walau bagaimanapun, kajian ini hanya memberi tumpuan kepada NRW di daerah Kuala Lipis. Unit NRW di Kuala Lipis ditubuhkan pada 2016 selepas penubuhan DMA. Terdapat sembilan loji rawatan air (LRA) di sekitar daerah Kuala Lipis yang dilengkapi dengan 52 DMAs. Penubuhan DMA bermula pada tahun 2014 dan selesai pada tahun 2015. Untuk menganalisis keberkesanan pengurusan NRW di daerah Kuala Lipis, perbincangan ini memberi tumpuan kepada syarat, pengeluaran, bil dan NRW yang sedia ada untuk setiap sembilan LRA. Perbandingan untuk semua LRA telah dibuat untuk mengetahui keberkesanan pengurusan NRW dari 2016 hingga 2018. Selain itu, komponen NRW juga dikenal pasti untuk mengetahui faktor-faktor yang menyumbang kepada peningkatan kadar NRW. Pada umumnya, berdasarkan keseimbangan air standard terdapat tiga komponen NRW yang terdiri daripada kerugian fizikal, kerugian komersil dan penggunaan yang tidak dibenarkan. Berdasarkan analisis yang dibuat, ia menunjukkan bahawa faktor utama yang menyumbang kepada kerugian air ialah kerugian fizikal seperti yang terbukti dengan analisis kehilangan air untuk setiap kilometer paip bagi setiap LRA dalam laporan ini. Ia menunjukkan bahawa ada 2,027 m^3 kehilangan air berlaku setiap hari untuk setiap paip kilometer untuk tahun 2016, 1,800 m^3 untuk tahun 2017 dan 1397 m^3 untuk tahun 2018. Purata kehilangan air dalam setiap kilometer paip sepanjang tiga tahun ini adalah sebanyak 5,224 m^3. Untuk membandingkan aliran sebelum dan selepas penubuhan unit NRW, analisis dibuat berdasarkan jumlah pengeluaran, bil dan NRW bagi setiap LRA selama tiga tahun (2016 hingga 2018) selepas penubuhan unit NRW. Perbandingan aliran dibuat berdasarkan kadar asas sebelum penubuhan pengurusan NRW. Merujuk kepada trend NRW untuk kesemua sembilan LRA, ia menunjukkan bahawa kadar NRW berubah dari tahun ke tahun dan berkadar terus dengan kadar pengeluaran dan pengebilan. Terdapat banyak perbezaan antara pengeluaran dan pengebilan yang berlaku akibat kehilangan air. Hanya LRA Jelai yang menunjukkan penurunan NRW yang konsisten. Keadaan ini berlaku disebabkan LRA Jelai adalah menjadi keutamaan kerana ia berfungsi untuk membekalkan air bersih dan selamat ke bandar Kuala Lipis dengan kadar penduduk tertinggi berbanding dengan LRA yang lain. Kadar kehilangan air yang tinggi boleh menyebabkan bekalan air yang tidak mencukupi bagi penduduk sekitar. Oleh itu, pemantauan dan pengurusan keseluruhan bermula dari LRA Jelai yang berfungsi menyediakan bekalan ke bandar. Pemantauan dan pengurusan keseluruhan bagi LRA yang lain akan dijalankan mengikut keutamaan kerana kekurangan tenaga kerja.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

AC	Asbestos Concrete
DMA	District Metering Area
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FELDA	Federal Land Development Authority
GIS	Geographic Information System
GPS	Global Positioning System
IWA	International Water Association
LNF	Legitimate Night Flow
MNF	Minimum Night Flow
NNF	Net Night Flow
NRW	Non-revenue water
PAIP	Pengurusan Air Pahang Berhad PAIP
POE	Point of Entry
POU	Point of Use
PRV	Pressure Reducing Valves
PVC	Plasticised Polyvinyl Chloride
PVC-O	Oriented Unplasticised Polyvinyl Chloride
SCADA	Supervisory Control and Data Acquisition
SOP	Standard operating procedure
SPAN	Suruhanjaya Perkhidmatan Air Negara
UFW	Unaccounted for Water
WHO	World Health Organization
WTP	Water Treatment Plant
ZPT	Zero Pressure Test

LIST OF ABBREVIATIONS

π	Simple Boost Pulse Width Modulation
“	Inch
A	Cross Section Area
d	Diameter of Pipe
F	Darcy Friction Factor
g	Gravity Acceleration
h_L	Head Loss
k	Losses Coefficient
km	Kilometre
L	Length
LNF	Legitimate Night Flow
m3/hour	Cubic Metre Per Hour
m3/year	Cubic Meter Per Year
m3/day/km	Cubic Meter Per Day Per Kilometre
mg/l	Milligram Per Liter
mm	Millimetres
MNF	Minimum Night Flow
n	Number of Pipe Flushing and Scouring
NNF	Net Night Flow
NTU	Nephelometric Turbidity Unit
Q	Flow
t	Thickness of Pipe
V	Velocity

CHAPTER 1

INTRODUCTION

1.1 Introduction

Currently, water already becomes the most important global issues. Most of the urban water utilities in developing countries faced water losses in the water distribution system. The water management sector in many Asian cities faced a challenge of the high rates on Non-Revenue Water (NRW). Maintaining water sustainability can become more difficult if large volumes of treated water are lost from a water supply system.

NRW represents the difference between the volume of water that distributed to the water distribution system and the volume that is billed to consumers (Lai Chee Hui, 2013). Normally, there will be different between the volume of water that distributed to the water distribution system and the volume that is billed to consumers. This is due to two main factors which are water losses and authorised consumption. Water losses consist of physical and commercial components. The authorised consumption is divided into unbilled authorized consumption and billed authorized consumption. However, the billed authorized consumption is not categorized as the component of NRW since the revenue will be collected in term of cost of water that used by consumers.

The main components of NRW are physical losses, commercial losses and unbilled authorized consumption. The physical loss is caused by leakage of pipe on the pipeline, storage facilities, problem with the main distribution and service connection. Pipe leakage may occur due to several factors such as low quality of the pipe, improper connection, high pressure and others. However, the commercial loss is due to meter problem, illegal connection, database error and also technical error. The last component which is unbilled authorized consumption occurred due to the usage of water for firefighting, tanker and also operation purpose. There is a lot of factors that contributes to NRW, but one of the factors is the components of NRW.

In Malaysia, the national average of NRW rate is around 35% to 36%, while the rate of NRW in Pahang state is 48% (Anon., 2017). The high rate of NRW is detrimental to the financial viability of water utilities as well as the quality of the water itself. It is impossible to control the rate of NRW by a hundred percent, but it does not mean that we can do nothing with this problem. In order to reduce the rate of NRW, the proper methods execute is needed such as the pressure control, proper leakage detection, schedule pipe replacement and the quality work installation.

1.2 Problem Statement

It is found that the total of water flow that distributed from water treatment plant to the water distribution system is not the same as the total of water flow that billed to the consumer. Logically, the flows that come in must be the same with flows that come out. If such a situation is not achieved, there is a problem of water losses occur along that water distribution system before it reaches the customer. This phenomenon is known as NRW. This resulted in the amount of water received by the consumer becomes less or no supply at all.

Currently in Kuala Lipis district, records on water production at treatment plant do not tally with the billed consumer. The Pengurusan Air Pahang Berhad (PAIP) of Kuala Lipis district received complaints from the consumer on the lack of water supply or nor supply at all. This confirmed that the NRW is taken place at Kuala Lipis district. The highest level of the NRW is detrimental to the financial variability of water utilities as well to the quality of the water itself. This issue must be tackled seriously and necessary action to be taken in order to avoid a big amount of losses in the future.

1.3 Objectives

The objectives of this study are:

i. To identify the components that contribute to NRW at Kuala Lipis.
ii. To compare the flow before and after NRW unit establishment.

1.4 Scope of Study

The scope of this study focused on the NRW that occurs in the water distribution system at Kuala Lipis district. Comparison between the total flow that distributed to the water distribution system and the total flow that billed to customer for each water treatment plant (WTP) was held to identify the rate of NRW which are the total flow that already lost along the water distribution system. The analysis would be based on production, billing and NRW of each WTP for three years (2016, 2017 and 2018) after the establishment of NRW Unit.

Based on the different of total flow that distributed to the water distribution system and the total flow that billed to the customer, an analysis of NRW components was held to see the flow of water losses that contribute to incremental of NRW rate. The data and information on the physical and commercial losses and unbilled authorised consumption were used as evidence that contributes to water losses and incremental of NRW rate. In order to reduce the rate of NRW in the water distribution system at Kuala Lipis, some analysis was conducted in order to choose the appropriate method to execute to reduce the rate of NRW.

1.5 Significant of Study

For this study, factor contributing to the water losses were identified. Such identification can provide solution to overcome the lack of water being supply to the consumers. It also can reduce the rate of NRW by controlling the water losses through the replacement of aging pipe infrastructure.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The government already deal with the NRW issues a long time ago since 1996 by the invested huge amount of money in Eighth, Nine, and Tenth Malaysia Plans from 1996 to 2010 for the NRW reduction program. However, the investment did not show positive results as NRW rates have risen from 36% in 2000 to 36.4% in 2010. Almost half of the states in the country were recorded NRW rate more than 40%. Some states in Malaysia such as Sabah, Perlis, Pahang and Kelantan even recorded NRW rate as high as 50% or more. This is not a good sign for water utilities in Malaysia. The high rate of NRW may lead to unnecessary high water tariff (Liemberger, 2010).

Based on the analysis of the NRW problem in Malaysia, it shows that water management in Malaysia is not in good condition. SPAN has set the target to reduce the NRW rate to 25% by the year of 2020 (SPAN, 2018). According to that situation, water utilities need to play an important role for the country to achieve the vision. Based on the historical data from 2000 to 2010, existing NRW reduction program not yet achieve the NRW target set such high rate of NRW indicated a poor management of water utilities (Lai Chee Hui, 2013). The management of NRW in Malaysia need to improve the performance of reducing the rate of NRW especially for those state with a high rate of NRW.

2.2 Non-Revenue Water

Non-Revenue Water is a familiar issue to the concerned people and an important policy making tool for the management. It is can be defined as the difference between system input volume and billed authorized consumption. NRW consist of three components which are physical losses, commercial losses and the last one are unbilled authorized consumption. There are a few aspects that lead to these systems such as unplanned development of distribution system, delayed in maintenance work, lack of professional and ethical execution, lack of preventive maintenance, malpractices of revenue collections for personal gain and other purposes, illegal connections, lack of coordination among waste prevention, absence of monitoring of follow-up actions and others (PAIP, 2018).

Reducing levels of NRW can contribute to attainment to reduce the proportion of people without access to safe drinking water and insufficient water supply. But the problem is not easy to solve since the solutions need to be tailored to local circumstances due to variation in the cause of water loss and the mechanisms available to manage them. When we compare the situation between developing countries and developed countries, the system of developing countries has a greater proportion of water loss being of a commercial nature such as customer meter under registration, data-handling errors and theft of water. Equation 2.1 to 2.8 are typical equations in calculation losses in NRW.

$$\text{NRW} = \text{System Input Volume} - \text{Billed Authorized Consumption} \qquad 2.1$$

$$\text{NRW} = \frac{\text{System Input Volume} - \text{Billed Authorized Consumption}}{\text{System Input Volume}}\ x\ 10 \qquad 2.2$$

Calculation for water losses:

$$\text{Broken pipe, } Q_1 = 0.62 \text{ x } A \text{ x } \sqrt{(2gh)} \text{ x } t \qquad 2.3$$

Where A = Cross Section Area of Pipe
g = Gravity Acceleration
h = Height Above the Ground
t = Thickness of Pipe

$$\text{Dewatering, } Q_2 = (\pi d^2 / 4) \text{ x } L \qquad 2.4$$

Where d = Diameter of Pipe
L = Length of the pipe separated by the valve closure

$$\text{Flushing and Scouring, } Q_3 = n\,(0.62 \times A \times \sqrt{2gh} \times t) \qquad 2.5$$

Where
A = Cross Section Area of Pipe
g = Gravity Acceleration
h = Height Above the Ground
t = Thickness of Pipe
n = Number of Pipe Flushing and Scouring

$$\text{Consumed of Leakage from Main} = \text{Number of Reported Burst} \times \text{Average Leak Flow Rate} \times \text{Average Leak Occurring Duration} \qquad 2.6$$

$$\text{Total Commercial Losses} = \text{NRW} - \text{NNF} \qquad 2.7$$

Where
NRW = Non Revenue Water
NNF = Net Night Flow

If NNF = 0, then, NRW is directly calculated commercial loss and leakage is proportional to pressure but exponential to the number of increasing of leakages as in equation 2.8.

$$\frac{\text{Leakage Rate 1}}{\text{Leakage Rate 2}} = \frac{\text{Pressure 1}}{\text{Pressure 2}} \,/\, \text{Number of Leakage} \qquad 2.8$$

2.3 Water Supply System

Generally, water supply system consists of two methods which are gravity action and pump delivery (PAIP). Mostly, the water treatment plant is located at the higher place in order to make sure that the treated water can be supplied to all consumers. According to the different elevation, the water can manually flow by gravity action to the nearby service area. However, there are some cases where the water treatment plant (WTP) is located lower than the service area. Normally, as we know that most of the water sources are located at the lowest area, so in order to distribute the water to consumer, the pumping delivery method is used. This is due to no highest place nearby the water sources that is suitable to place the WTPs.

The selection of a suitable location for WTP is important for cost saving and maintaining the quality of services. There are a few criteria in selecting the best location for WTP, which are near to water sources, located at the high and suitable place in order to run their operation and also to distribute the treated water to the consumer. The water treatment plant must be placed near to water sources to facilitate the water treatment process, water quality monitoring as well as maintenance work that involves the structural and component used at the intake. Other than that, it will minimize the distance of the piping system as it reduces the risk of pipe problem such as leakage, blockage pipe, broken pipe and so on (PAIP, 2018).

Normally, the water sources are obtained from the river nearby. The water from the river will be pumped through the intake to the WTP through the piping system. For the purpose of treating the water, it involves a relatively long process starting with the aeration process, coagulation and flocculation process, sedimentation, filtration, until the last process which is the disinfection. All of these processes are very important and should be carried out according to the Standard Operating Procedure (SOP) to ensure that the treated water is clean and safe to use. After all the treatment process is completed, it is followed by some tests such as water parameter test and jar test to make sure that the water that supplied to consumers comply with the standard of Water Quality Index 2009. Table 2.1 shows the water parameter guideline that needs to be complied with for the water parameter test. After that, the water will be distributed to consumers through the water supply system. Figure 2.1 shows the schematic diagram of the water supply system that distributed clean water from water treatment plant to consumers.

Table 2.1 Water Parameter Guideline

Parameters	Maximum value
NTU	5 NTU
pH	6.5 – 9.0
Free chlorine	>0.2 mg/l
Alum	0.2 mg/l

Sources: (PAIP, 2018)

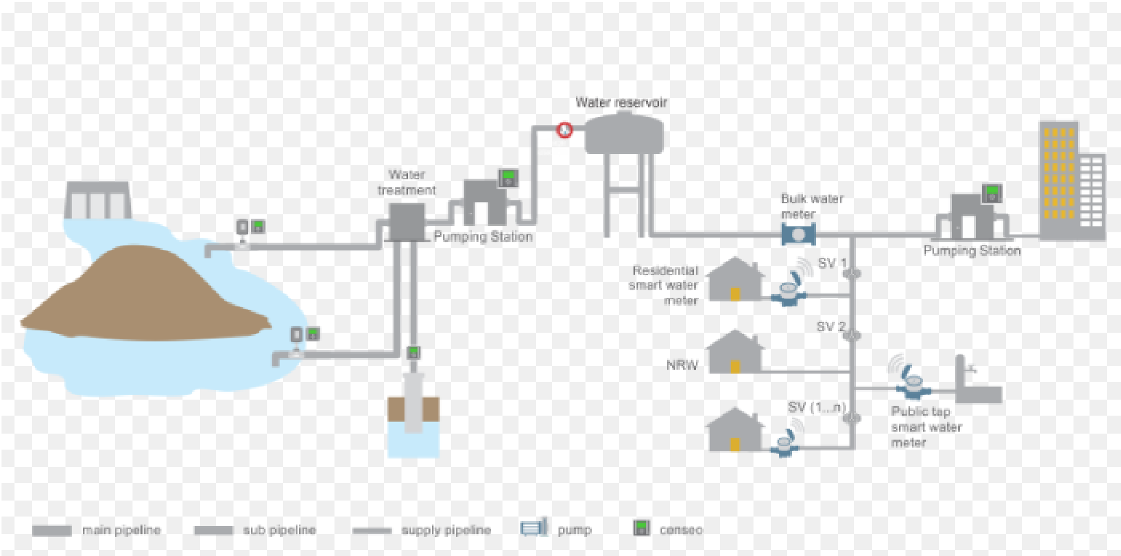

Figure 2.1 Water Supply System

Sources: (PAIP, 2018)

2.4 Continuity Equation

Matter most commonly exists as a solid, liquid and gas. These states are known as the three common phases of matter. Solids have a definite shape and a specific volume, liquids have a definite volume but its shape changes depending on its container, while gases have neither a definite shape or a specific volume as its molecules move to fill its container. Liquids and gases are considered to be fluids because they yield to shearing forces, whereas solids resist them. In physics, a fluid is a substance that continually flows under an applied shear stress. The motion of gases and liquids is called as fluid flow. Motion of a fluid subjected to unbalanced forces. This motion continues as long as unbalanced forces are applied. There are some aspects of fluid flow such as steady or unsteady, compressible or incompressible, viscous or non-viscous, and rotational or irrotational. Some of these characteristics reflect properties of the liquid itself, and others focus on how the fluid is moving. Either the fluid flow is steady or unsteady, its depend on the velocity of that fluid. If the velocity of the fluid is remaining constant at any point, its categories as steady flow, while if the velocity of the fluid is different between two point, its categories as unsteady flow (Dhar, 2011).

The fundamental principles to analysis of uniform flow is known as the continuity of flow or its known as a continuity equation, (Equation 2.9). This principle is derived from the fact that mass is always conserved in fluid system regardless of the pipeline complexity or direction of flow. The continuity equation is a direct fact that what goes into the pipeline must come out. The volume flow rate, Q of a fluid is defined to be the volume of fluid that is passing through a given cross-sectional area per unit time (equation 2.10). The term *cross sectional-area, A* is just a term that often used to describe the area through which the fluid is flowing (Dhar, 2011).

$$Q_{in} = Q_{out} \quad 2.9$$

$$Q = A_1V_1 = A_2V_2 \quad 2.10$$

Where Q = Flow
A = Cross Section Area
V = Velocity

The continuity equation is not really as mysterious as the name suggests since it is found simply by requiring that volumes be incompressible as they flow through a pipe. This equation is quite useful. In other words, no matter where in the pipe we choose to find the flow rate, the value will always come out to be the same number for a given pipe, if the fluid is incompressible. If the area, A of a section of pipe decreases, the speed, V of the liquid there must increase so that the product, AV remains the same. This means that fluids speed up when they reach a narrow section of a pipe and slow down when they reach a wider section of a pipe (Dhar, 2011).

Calculation of flow rate is often complicated by the interdependence between flow rate and friction loss. Each affects the other and often these problems need to be solved iteratively. Once flow and depth are known, the continuity equation is used to calculate velocity in the pipeline.

2.5 Piping System

A water pipe is any pipe or tube that designed to transport water to consumers. There are two types of treatments for water treatment system which are Point of Use (POU) water treatment system and Point of Entry (POE) water treatment system. The selection of system to use depends on what we expect to achieve (KDF Fluid Treatment, 2018).

POE water treatment is installed at the point where the supply enters the house and it is connected to the house water meter. This kind of water systems, treats the water for the whole house. POE water treatment system is installed on side of the meter for the purpose of treating all of the incoming water before it goes into the individual supply lines. POE systems often include softeners, large bed carbon filters, and some systems which are specifically designed to remove sediment, tastes and odours (KDF Fluid Treatment, 2018).

POU water treatment is installed in an individual source line ahead of any or all of the taps, faucets or other dedicated outlets used to dispense water for drinking, cooking or bathing. POU systems are often a combination of pre-filter, RO filter and post-filter to capture whatever escapes the POE system (KDF Fluid Treatment, 2018).

POU water treatment systems have been put forward in recent years as low-cost, scalable, and effective solutions to the significant challenge of providing potable drinking water in lower income settings (Spuhler, 2018). In well planned and designed water distribution networks, water is generally treated before its distribution and sometimes also chlorinated, in order to prevent recontamination on the way to the end user. The varieties of water pipes include large diameter main pipes, which supply entire towns, smaller branch lines that supply a street or group of buildings, or small diameter pipes located within individual buildings. There are many types of pipe that being used to supply water to consumers. The piping selection depends on the uses, condition of the area and also the flow capacity.

2.5.1 Types of Pipe

Pipes can be categorized based on their raw materials such as metallic, cement and plastic.

2.5.1.1 Metallic Pipe

The metallic pipes are divided into three which are steel pipe, galvanised iron pipe and cast iron pipe. Steel pipe is expensive, but it is the strongest and most durable of all water supply pipes. It is can withstand high water pressure, lower installation and transportation cost and come in convenient lengths compare than other pipes. Galvanised steel or iron is the traditional piping material in the plumbing industry for the conveyance of water and wastewater. Although still used throughout the world, its popularity is declining. The use of galvanised steel or iron as a conveyer for drinking water is problematic where water flow is slow or static for periods of time because it causes rust from internal corrosion. Galvanised steel or iron piping may also give an unpalatable taste and smell to the water conveyed under corrosive conditions. The last one is the cast iron pipes. Cast iron pipe is well suited and quite stable for high water pressure. Cast iron pipes are unsuitable for inaccessible places due to transportation problems because this kind of pipe is heavy. Due to their weight, they generally come in short lengths increasing costs for layout and jointing (Spuhler, 2018).

2.5.1.2 Cement Pipe

The cement pipes are divided into two which are concrete cement pipe and asbestos cement pipe. Concrete cement pipes are non-corrosive, extremely strong and durable but its more expensive. However, the large and heavy sizes cause it is to be more expansive due to more difficult to handle, assemble and transport (Spuhler, 2018).

2.5.1.3 Plastic Pipe

The plastic pipe includes only plasticized polyvinyl chloride (PVC) pipe. PVC pipe are extremely light, non-corrosive, strong, can in long length, easy to handle, easy to transport and lower cost for transportation and installation. However, they are prone to physical damage if exposed over ground and become brittle when exposed to ultraviolet light. In addition to the problem associated with the expansion and contraction of PVC, the material will soften and deform if exposed to the temperature over 65℃ (Spuhler, 2018).

2.5.2 Pipe Size

The pipe used in water supply system comes with many sizes. The water pipes can range in size from giant mains of up to 3.65 m in diameter to small 12.7 mm pipes used to feed individual outlets within a building. The pipe sizes depend on the population size and area to supply the water. Usually, the main pipeline which is the pipe that supply water from WTP to an area, use the large size of pipeline about 4 inches and above. Individual pipeline from tapping to household, use smaller size pipeline. Table 2.2 shows the common size of pipe that being used in pipeline system. It is depending on the connection of the previous pipeline and also the capacity (PAIP, 2018).

Table 2.2 Size of Pipe

Inch (“)	Millimetres (mm)
½	20
¾	25
1	32
2	63
4	100
6	150
8	200
10	254
12	300
15	381

Sources: (PAIP, 2018)

There are several factors that contribute to pipe damage which are the age of the pipe itself, pressure from the surface, soil properties, improper installation and also high water pressure. One of the methods to reduce the rate of NRW is with replacing the old piping system.

2.6 Losses in Pipeline Systems

The losses in the pipeline system are unavoidable, especially for the old pipe. The losses occur due to the resistance of the pipe walls and the fittings to this flow. There are two forms of losses which are major losses and minor losses. Major losses occur due to the friction of the shear stresses between adjacent layers of water gliding along each other at a different speed. The thin layer of water adhering the pipe wall does obviously not move while the velocity of every concentric layer increases to reach maximum velocity at the center-line of the pipe. If the fluid particles move along smooth layers, the flow is called laminar or viscous and shear stresses between the layers dominate. Laminar flow is the smooth fluid flow which never interfered with another (Yunus A. Chengel, 2014).

The pair of laminar flow is the turbulent flow. Turbulent flow is the irregular flow that is characterized by tiny whirlpool regions. The velocity of this fluid is not constant for every point. Another form of losses is the minor losses. Minor losses also known as local losses that occurring at changes of cross sections either sudden expansion or contraction, at valves either open or partially closed, and also at bends, elbows, tees and other fittings. These losses are referred to as minor losses since in long pipelines, their effect may be small in relation to the friction loss. Local losses are expressed as multiples of the kinetic head (Yunus A. Chengel, 2014).

2.6.1 Major Losses

Major losses, as the name implies are the largest contributor to head loss in most piping systems. These losses are illustrating in the pressure drop over a long section of pipe. Friction between fluid molecules as well as friction between the fluid and the walls of the pipe generates the head loss that leads to major losses. These losses have been better conceptualized over the decades of deriving the basic formulations for pipe flow and are used as basic of comparison for minor losses in fitting using the equivalent length method (Guo, 2016). The equation 2.11 show the equation of major losses.

$$h_L = f\frac{L}{D}\frac{V^2}{2g} \tag{2.21}$$

Where
h_L = Head Loss
V = Velocity
D = Diameter of Pipe
F = Darcy Friction Factor
L = Length
g = Gravity Acceleration

2.6.2 Minor Losses

Minor losses are produced in the bends, inlets, exits, valves and fitting of a piping system. Generally, it produces less impactful to head loss as major losses, minor losses can be greater than major losses in small piping systems with many turns and valves. The interruption of flow caused by restriction or changes of flow direction causes these losses through mixing and flow separation. Minor losses have been difficult to compare with major losses due to the vast variation of designs of valves, tees and elbows (Guo, 2016). The equation 2.12 shows the calculation for minor losses.

$$h_L = k\frac{V^2}{2g} \tag{2.32}$$

Where
h_L = Head Loss
k = Losses Coefficient
V = Velocity
g = Gravity Acceleration

2.7 Prior Study of NRW

According to the report entitled Water Supply Leakage and Waste Control produced by the consultant of World Health Organization (WHO) that was issues by JKR

1987, the existing statistical data on 1978 showed that the entire Unaccounted for Water (UFW) percentage of Peninsular Malaysia was 20.3%. The analysis of data from 118 area of water supply showed that the range of UFW percentage on the specific year varies from 13.2% to 57.6%.

UFW is the term used before it was changed to NRW. All of the water loss quality is taken into account for the rate of water loss calculation. The implementation of the apparatus usage and the NRW calculation from the earlier day has evolved especially in the area of:

i. The new method in examining the physical losses and commercial losses is more accurate.
ii. More effective ways of managing pipe leakage and also pressure reduction system with the existence of computerized technology.

2.8 Status of NRW

The report of NRW achievement for each state is collected for each year as reference to know the condition of NRW and also the effectiveness of establishment NRW unit for certain area.

Table 2.3 shows the rate of NRW for each states starting from 2014 until 2018. This table shows that the NRW rate for Pahang State has decreased steadily starting with 53.1% on 2014, 52.8% on 2015, 47.9% on 2016 and 47.5% on 2017. Despite the decline, it is still at the highest rate since the target for NRW national level 2020 is at 25% (SPAN, 2018).

Table 2.3 Percentage of NRW

STATES	NRW (%)			
	2014	**2015**	**2016**	**2017**
JOHOR	25.9	25.6	25.9	24.7
KEDAH	46.1	46.7	46.7	47.5
KELANTAN	49.4	49.0	49.4	49.3
LABUAN	29.5	30.9	30.5	32.0
MELAKA	21.4	19.3	19	19.6
N. SEMBILAN	35.9	34.8	32.7	32.6
PULAU PINANG	18.3	19.9	21.5	21.9
PAHANG	53.1	52.8	47.9	47.5
PERAK	30.6	30.3	30.5	30.9
PERLIS	55.8	56.3	60.7	63.1
SABAH	51.7	55.1	52	53.8
SARAWAK	32.0	33.3	36	37.8
SELANGOR	33.6	32.0	32.2	31.5
TERENGGANU	31.0	31.0	30.0	30.4

Sources: (SPAN, 2018)

2.9 Contribution of NRW

There are many factors that can contribute to NRW.

2.9.1 International Water Balance

An annual water balance is generally used to assess the NRW and its components. However, the various formats and definitions used for such calculations. So, the previous action at national and international comparisons of NRW management and performance has been open to considerable doubt. The water utilities and municipalities have been implementing investigation and estimation of water balance in the water supply system. International Water Association Task Forces recently produced an international 'best practice' standard approach for water balance calculations presented in Table 2.4 with definitions of all terms involved as the essential first step in the practical management of water losses. Until now, it is widely used and accepted by water utilities.

Table 2.4 IWA ‘Best Practice’ Standard Water Balance

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption (including water exported)	**Revenue Water**
			Billed Non-metered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	**Non-Revenue Water**
			Unbilled Non-metered Consumption	
	Water Losses	Apparent Losses	Unauthorized Consumption	
			Metering Inaccuracies	
		Real Losses	Leakage on Transmission and/or Distribution Mains	
			Leakage and Overflows at Utility’s Storage Tanks	
			Leakage on Service Connections up to Customers’ Meters	

Sources: (Simbeye, 2010)

The water that had been processed at water treatment plant will be distributed to consumers through the water supply system. Generally, the processed water is intended for distribution to consumers by authorized consumption. However, the processed amount does not completely reach the consumers due to some factor as shown in Figure 2.2. Based on these factors, calculation will be made in order to identify the amount of losses or it is known as NRW.

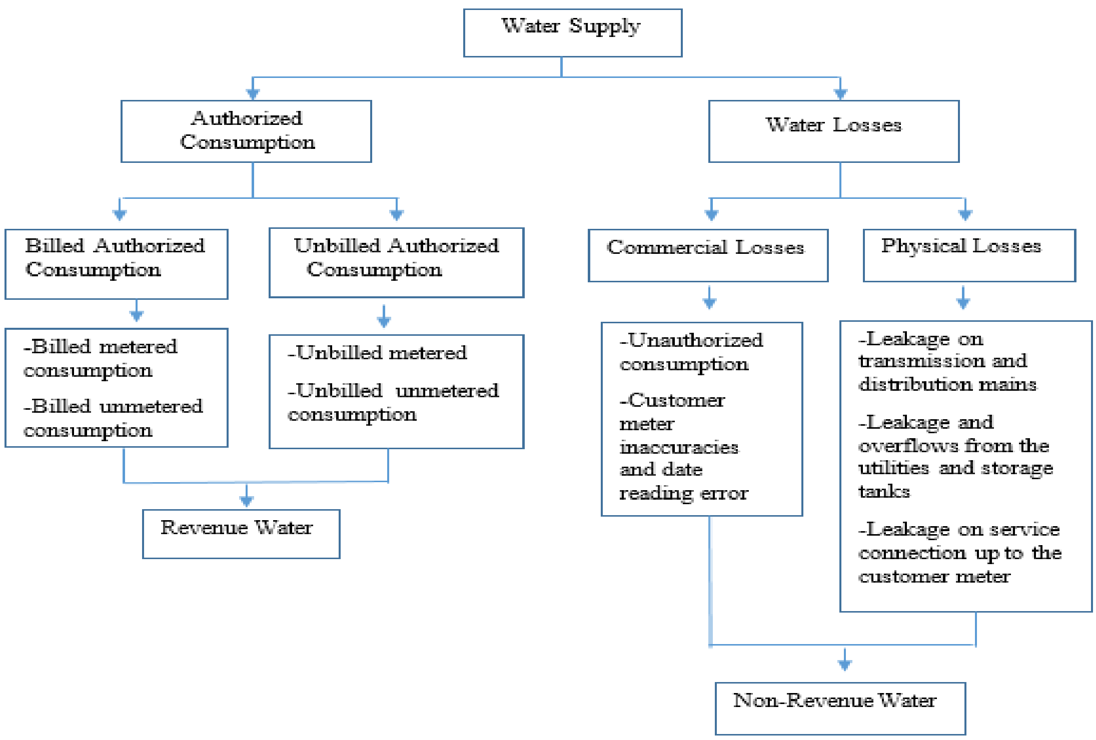

Figure 2.2 Step for Calculating NRW Using IWA Water Balance Table
Sources: (Farok, 2017)

2.9.2 System Input Volume

Each of WTP has its own input and output meter flow. The raw water from the nearby river will be pumped using a submersible pump which is located at the intake to allow the water to reach the water treatment plants. Before the treatment process begins, the water will pass through a flow meter that known as input meter. This meter is important to record the amount of water that goes into the treatment system. Besides that, this meter is very important for determining the appropriate dosage of chemicals to be used to produce clean and safe water. After passing one complete cycle of the water treatment process, the water will be distributed to consumers through the water distribution system. Before that, the clean water will pass through another flow meter but it is known as output meter. This output meter is very important to measure the amount of water distributed to consumers. Normally, the flow meter is located near the water treatment plant.

Based on the meter reading, the rate of NRW can be determined by comparing it with the amount of water that billed to consumers. Besides losses of water occur along the water distribution system, the losses can also occur due to inaccurate meter reading and also a technical problem with that flow meter. The meter is installed for the purpose of measuring the water flow. So if there is an error with the reading, it will cause big effect on the entire summation of water volume that distributes to the consumers. In order to ensure the meter produces the accurate reading, all the flow meter need to have proper monitoring, service and maintenance from time to time.

2.9.3 Water Losses

Water losses are divided into two parts which are physical losses and commercial losses.

2.9.3.1 Physical Losses

Physical losses are one of the main element in determining the rate of NRW. It is also known as real losses. Physical losses can be defined as total losses minus commercial losses. Physical losses can be classified into four fundamental elements which are leakage on mains, leakage and overflow at storage, leakage on service connection and leakage up to point of consumer metering. Leakage on mains, leakage and overflow at tank are easy to detect because they can be visible through the naked eye. Contrary with the other two leakages since it is not visible and it occurred under the ground along the piping system (PAIP, 2018).

2.9.3.2 Commercial Losses

Commercial losses are also known as apparent losses. It is can be defined as the water that not paid by the consumers. Commercial losses contribute to the higher amount of water losses compare to the physical losses. Commercial losses can be classified into two fundamental elements which are unauthorized consumption and consumer meter inaccuracies. Unauthorized consumption happened due to operation purpose such as cleaning water tank, scouring and other activities. For the inaccurate meter consumer, the consumer uses a lot of water but since there is some problem with water meter, the consumer just need to pay less money for it. It will give some advantage to the consumer but will affect the loss to the water utility in term of financial (PAIP, 2018).

2.9.4 Pressure

Pressure affect the rate of leakage through the broken pipe, connecting error and others. It is also contributing to the frequency of burst when the pressure within the system increase and can result in a fairly large number of bursts occurring within a relatively short period. High pressure may cause that leak to appear. The effect of pressure causes the pipe to move out of place. Even reducing the pressure may reduce the frequency at which future burst occurs, cycling the pressure between high and low value within the design pressure can cause fatigue. This occurs when a pump set or a booster is switch on and off (Farley, 2001).

2.9.5 Ground Movement

Ground movement contribute to the subsequent of pipe failure. It can occur due to the extremely high traffic load imposed on the surface where the pipes are planted at a shallow. Due to high frequency and pressure, slowly it will affect the pipe structure. Expansion and drying of subsoils caused by dry weather or heavy rain can cause pipe structure damage, especially on joints with minimum flexibility such as welded steel. It can also result in local stress concentration within pipes or fittings which eventually lead to failure. The impact of ground movements can be reduced using pipes that allow uninterrupted flexibility, by ensuring proper installation and backfill procedures (Farley, 2001).

2.9.6 Soil Environment

Factors that influence the corrosion of underground pipelines is soil environment. There are a lot of factors that will affect the underground pipeline and one of them are soil properties such as moisture content, plasticity index, pH value, organic content, resistivity and percentage composition of soil corrosive elements. Soil corrosiveness is a major threat to the underground pipeline system especially for steel pipe. Underground pipelines are widely used around the world to transport water, oil and other fluids at several kilometers to serve cities. Even though the pipelines are protected from corrosion but it is still threatened since the pipelines are exposed to various environmental conditions such as the soil chemistry and air constituent to pipeline structures (Farley, 2001).

2.10 Methods of Calculating NRW

2.10.1 Difference Between Volume of Water and Water Billed in an Area

The volume of water supplied from WTP will be obtained from the flow meter or it is also known as output meter that located nearby the WTP while the volume of water billed will be obtained from meter consumers reading. The difference between these two volumes is the losses along the distribution system and known as NRW. The readings will be taken by monthly for monitoring purpose. This method is suitable for determining the physical and commercial losses (PAIP, 2017).

2.10.2 Net Night Flow (NNF)

Net Night Flow (NNF) is the volume of water that lost due to leakage. NNF is obtained by subtracting the LNF from MNF. It represents the volume of water lost within the chosen area. If the value of NNF is more than 10 litter per second, it shows that the rate of leakage at that area is high. It is derived from the following equation 2.13 (PAIP, 2018).

$$NNF = MNF - LNF \quad 2.13$$

Where NNF = Net Night Flow
MNF = Minimum Night Flow
LNF = Legitimate Night Flow

2.10.2.1 Minimum Night Flow (MNF)

Minimum Night Flow (MNF) reading is a focused method of determining water losses due to leakage in a particular area. This method is used for determining the physical losses and is not exhaustive unless all District Metering Area (DMA) has been established for that area. Night flow is where the time that water consumption is at a minimum level. It is crucial in controlling and detecting leakages in the distribution system. MNF is the lowest flow that normally occurs after midnight. In Malaysia, the minimum flow rate usually occurs between 2 am to 4 am. MNF consists of two components which are Legitimate Night Flow (LNF) and Net Night Flow (NNF) (PAIP, 2018).

2.10.2.2 Legitimate Night Flow (LNF)

Legitimate Night Flow (LNF) is the estimated volume of water consumption in the early morning. Total water flow can be obtained from the meter reading at the consumer house. Typically, the meter reading for 10% of house in a particular area are taken to obtain the average hourly flow. The result of this calculation can be used to calculate the Net Night Flow (NNF) (PAIP, 2018).

2.11 Controlling NRW

There are a few methods that need to implement in order to control the rate of NRW (PAIP, 2018):

i. Mapping
ii. Comprehensive Leakage Maintenance Works
iii. Replacement of Meter Production
iv. Replacement of Old Pipe
v. Water Pressure Management
vi. Hot Tapping
vii. District Metering Area (DMA)
viii. District Metering Area (DMA) management

2.11.1 Mapping

Mapping is the creation of maps, a graphic symbolic representation of the significant features of a part of the surface of the Earth. Basic maps and schematic plans together with complete distribution system data and information such as water tanks, pump houses, pipelines, types and sizes of pipe, valves locations, fire hydrant, illustration levels and total connection to users are important in dealing with loss of water. Previously, maps and plans were drawn on paper, now in line with technological advances, a computerized mapping software system has been created. The software is known as the Geographic Information System (GIS) which comes with satellite imagery. GIS used to mark the location of the leak on the plan. It is a user-friendly software that provides easy interaction with other database systems such as financial system, billing, telecommunication and Supervisory Control and Data Acquisition (SCADA) systems, complaint handling and daily handling records. The Global Positioning System (GPS) is used to track and record the location for components of distribution system components accurately based on coordinates. GPS and GIS systems are used together to identify the location of water supply system components in digital maps.

2.11.2 Comprehensive Leakage Maintenance Works

In order to improve the quality of water supply services and restore the consumer confidence level, it is crucial to have The frequently of repair works can be achieved through the following method (SPAN):

i. Increase of manpower for the maintenance work.
ii. Improve on supervision and monitoring work to make sure all the maintenance work will be done properly according to Standard Operating Procedure (SOP).
iii. Accurate information and comprehensive reports.

2.11.3 Replacement of Meter Production

Meter production or also known as output meter is very important in the effort of controlling NRW. It is because the meter production is the main reference to calculate the rate of NRW that occur around that distribution area. A proper monitoring, service and maintenance are needed to make sure this meter always in a good condition and function well.

2.11.4 Replacement of Old Pipe

Leakage along pipeline system contribute a large amount of losses. It is not easy to control and replace all of the old pipe system because it will take a huge amount of cost. In Malaysia, AC pipe has been widely used. The expected remaining service life predictions made using data collected on AC pipes from several utilities vary significantly from utility to utility and even within utilities, depending on the water quality and soil environments. AC pipes in some regions were subjected to aggressive water quality and soil environments and their expected remaining lives ranged from imminent failure to 50 years. In regions with less aggressive water quality and dry soil conditions, AC pipes might be expected to serve for another 100 to 150 years. However, active soil movement can cause premature failure of an AC pipe, substantially reducing its expected remaining service life (Yafei Hu, 2013). According to that situation, the replacement AC pipe to PVC-O pipe has been made due to that oriented unplasticised polyvinyl chloride (PVC-O) pipes were more suitable for the existing water supply system as it was cost effective. Other than that, it could help to minimise the leakage and had longer durability (The Star Online, 2019).

2.11.5 Water Pressure Management

Water pressure management is an important step in managing leakages. Leakage in the mains system occurs due to gravity pressure or pump. The best method of pressure management for the mains system can be determined with some initial step such as:

i. Identify the appropriate zones for the installation of pressure control valve which are Pressure Reducing Valve (PRV).
ii. Identify the supply category and pressure control level through water requirement analysis.
iii. Collect the data for pressure and current flow for that area.
iv. Use the appropriate and specific pressure control design models.
v. Improve the quality of equipment and control valve.
vi. Analyze costs and benefits.

There are various methods used to control the pressure in the mains system. However, the use of PRV with the joint installation of the short-circuit system is more effective. PRV works to maintain the pressure at the specified level. Usually PRV is installed at the downstream of flow meter for each DMA to make sure that the turbulent flow disturbance from the valve does not occur and does not affect the flow meter accuracy.

2.11.6 Hot Tapping

Hot tapping is one of under pressure tapping where the tee is connected to the pipeline using a special tool. The hot tapping method is better than conventional connecting tee because:

i. Connection work can be done at any time because it does not interfere with the water supply to consumers.
ii. The water loss will not occur because the pipeline does not need to be emptied during tee connection work.
iii. There is no need for water supply closure.
iv. Can save the time of work.

2.11.7 District Metering Area (DMA)

Many water utilities operate their pipe networks as an open system where water is fed from more than one WTP into an inter-connected pipe network. Generally, NRW management in an open system is undertaken in a passive manner where NRW reduction activities are initiated only when the loss becomes visible or is reported. A more effective approach is to move towards active NRW management where dedicated teams are established and sent out to look for water losses or other causes of the NRW such as reservoir overflows and illegal connections. Based on the sources of the NRW, its show that leakage contributes to the higher percentage compare than others. Due to such situation, an active NRW management was established.

Active NRW Management is more cost effective when using zones to measure the NRW, where the system as a whole is divided into a series of smaller sub-systems for which NRW can be calculated individually. These smaller sub-systems, often referred to as district meter area (DMA) should be hydraulically isolated so that we are able to calculate the volume of water lost. When a supply system is divided into a smaller area, the utility can better target the NRW reduction activities, isolate water quality problems and better manage overall system pressure to allow for continuous and smooth water supply throughout the network.

Each DMA has its own flow meter that works to record the water flow while each flow meter is equipped with a logger that works to record the reading of the flow meter every fifteen minutes. To get the complete data, the logger will be connected with the server Pmax serve to generate the flow graph. A software known as Nettbase is used to analyse the data from Pmax serve in order to produce a complete data that comprise of volume, MNF, T-factor and others. Based on the data, the percentage of leakage can be calculated as equation 2.14.

$$\% \text{ Leakage} = \text{Total Leakage} / \text{Volume} \qquad 2.14$$

2.11.7.1 Establishing DMA

There are a few criteria to create a preliminary DMA design. They must be tested either in the field or using a network model. In order to establish the DMA, identification of the size of DMA, number of valves that should be closed to isolate the DMA, number of the flow meter to measure the water inflow and outflow, ground level variation, pressure and also the topographic features need to be determined. For the size of DMA, mostly the number of connections is between 1000 to 2500. It is depending on the location itself (PAIP, 2018).

In order to divide a large open system into a series of DMA, the valve needs to be closed to isolate a certain before the flow meter be installed (PAIP, 2018). The flow meter is used to measure the volume of water that flows in into that particular area. However, at least, this process can affect the pressure system for both areas either that particular DMA and its surrounding areas. The water utility therefore must ensure that the water supply to all customers is not compromised in terms of quality, pressure and supply hours. In establishing a DMA, the water utility should limit the number of inflows, which if kept to one meter enables the accurate measurement of water metering into the DMA, it also helps to reduce the cost of design, setup and installation.

If the budget is limited, the water utility should initially establish larger zones of 5,000 or more connections. It can subsequently subdivide them into DMA and sub-DMA of 1,000 or fewer connections for those DMA with high NRW and long lengths of pipework (PAIP, 2018).

For each DMA, a detailed operations manual is needed to assist future teams in managing the water supply. The operations manual includes a schematic of the pipe network, location of the flow meters, pressure control valves, boundary valves, and a copy of the billing database for the DMA. The manual is a working document and operational data should be continually updated.

2.11.8 DMA Management

The implementation district metered areas is not a quick fix, but requires long-term commitment on the part of a water utility management and operations staff. Once the NRW is reduced to an acceptable level, the staff should set up a monitoring regime for DMA inflows. In its simplest form, this consists of a monthly reading of the flow meter totaliser. The installation of a data logger to record flows will however reveal more detailed data including the daily NNF, which enables more precise corrections to the system. The NNF effectively becomes NRW with minimal levels of commercial loss. The daily NNFs can be plotted on a graph against time, to monitor NRW levels in the DMA.

Some time, the rate of NRW is still increasing. The rate of increase depends on a number of issues, including pipe networks age and condition, system pressure, number of illegal connection and tampered meters. It is usually inefficient for leakage detection and customer survey teams to work in the DMA continually. The monitoring team should therefore set an intervention limit or the level at which NRW becomes unacceptable. Once the intervention limit is reached, the teams should be sent in to detect and resolve losses. Generally, they can reduce the NRW level within two to four weeks. Afterwards, they should ensure that the NRW level is monitored until the intervention level is reached again. This process is the optimal management cycle of an established DMA.

CHAPTER 3

RESULTS AND DISCUSSION

3.1 Introduction

The aim of this chapter is to outline on how the condition of NRW rate at this study area was conducted. The summary of the research methodology consists of:

i. Research Planning
ii. Study Area
iii. Data Collection
iv. Data Analysis

3.2 Research Planning

To achieve the objectives of this study, certain method and procedure are used to get all information needed for this research. Research planning is necessary in order to make sure that all work can be done smoothly. The flow of research comprises of several stage starting from the problem statement, objectives, data collection, data analysis, result and discussion. Finally, a conclusion and recommendations were made based on the result and information obtained. Figure 3.1 summarises the methodology used in order to achieve the objective of this research.

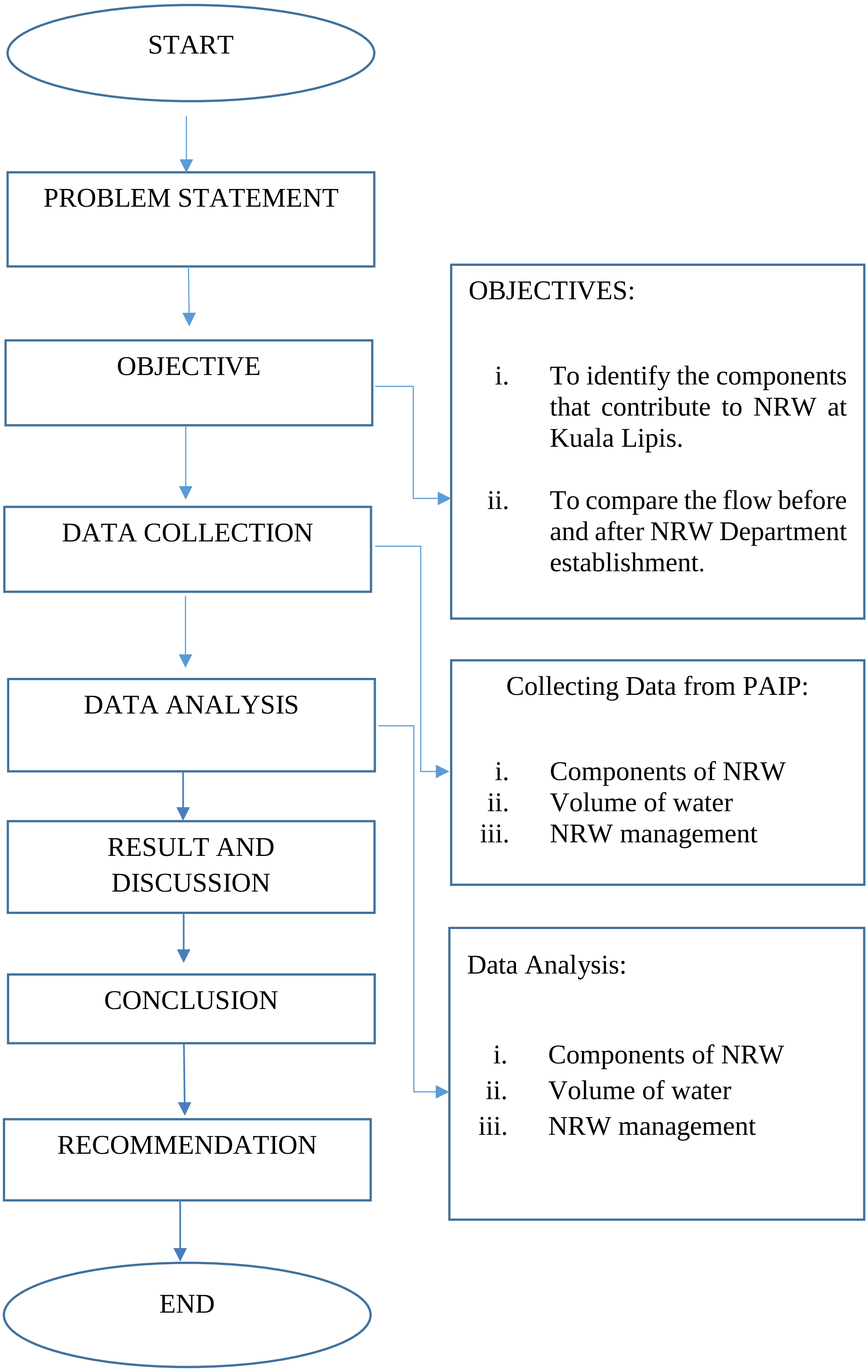

Figure 3.1 Summary of Research Methodology

3.3 Study Area

In Malaysia, the national average of NRW rate is around 35% to 36%, while the rate of NRW in Pahang is 48% (Anon., 2017). The rate of NRW in Pahang is quite high compare than a few districts. Therefore, holistic NRW management has been conducted in Pahang state. There are three districts around Pahang that were chosen to perform NRW management which are Kuantan, Kuala Lipis and Pekan. The establishment of NRW unit in these areas is intended to control the rate of NRW that contributed to the losses to the PAIP.

However, this case study only focuses on the NRW at Kuala Lipis. Kuala Lipis is divided into ten Mukim with the total area of 5198.28 km^2 and an estimated population of over 80,000 peoples (JPS Lipis, 2012). Map of Kuala Lipis are shown in Figure 3.2. There are nine WTP around Kuala Lipis districts that function to provide clean and safe water to residents around this area. That nine WTP consists of Jelai WTP, Benta WTP, Bukit Betong WTP, Kechau WTP, Kuala Medang WTP, Mela WTP, Merapoh WTP, Sungai Temau WTP and Batu 9 WTP. All these WTP were equipped with the total of 52 DMA. The establishment of DMA started on 2014 and completed on 2015 before the management of NRW was handed by NRW unit on 2016. Therefore, this case study consists of three year durations (2016 until 2018).

Figure 3.2 Map of Kuala Lipis

The analysis of production, billing and NRW were carried out based on nine WTP around Kuala Lipis area. Table 3.1 shows the list of WTP that were arranged based on design capacity while the locations for each WTP are as shown in Figure 3.3.

Table 3.1 List of WTP

No.	**WTP**	**Design Capacity (m^3/hour)**
1	Jelai	1,200
2	Benta	526
3	Bukit Betong	500
4	Kechau	450
5	Kuala Medang	430
6	Mela	200
7	Merapoh	148
8	Sungai Temau	78
9	Batu 9	20

Figure 3.3 Location of WTP

3.4 Data Collection

In this case study, the data has been collected from NRW unit of PAIP Kuala Lipis (PAIP Lipis, 2016) (PAIP Lipis, 2017) (PAIP Lipis, 2018). The data consists of the volume of water production, the volume of water billed and the rate of NRW for all water treatment starting from the year of DMA establishment until 2018. Since there were certain DMA that completed in 2014 and others in 2015, the analysis focused data from the year of 2016 after the DMA establishment for all nine WTP. Other than that, the information of the components of NRW and the NRW management were gathered in order to identify the largest factor that contribute to NRW and analyse the methods execute to reduce the NRW.

3.5 Data Analysis

Based on the data that collected from PAIP, there were three types of data that need to analyse:

i. Components of NRW
ii. Volume of water
iii. NRW management

3.5.1 Components of NRW

There are two main items under the components of NRW which are water losses and unbilled authorized consumption. For the first component which is the water losses, its divides into two types of losses which are physical and commercial. The data obtained from NRW department were used to analyse the volume of water that loss due to physical losses, commercial losses and unbilled authorised consumption, in order to prove that it contributed to the incremental rate of the NRW.

3.5.2 Volume of Water

There were three types of data collected for the volume of water; production, billing and NRW for each WTP. The data for production were obtained from the output meter located nearby the WTP itself while the data for billing were obtained from the report that produced by meter reader unit and revenue unit. For NRW, the data were obtained from the difference of the volume of water production and billing.

3.5.3 NRW Management

There are a few methods that need to implement in order to control the rate of NRW which are comprehensive leakage maintenance works, replacement of meter production, replacement of old pipe, establishing of district metering area (DMA) and DMA management. The most important step in managing NRW is by establishing DMA for that particular area. In order to establish a DMA, there are several steps that need to be taken that comprise of:

i. Review
ii. Zero pressure test (ZPT)
iii. DMA meter installation
iv. Data logger installation
v. A complete report of leakage percentage

3.5.3.1 Review

First of all, that pressure and boundary of that area should be identified before the next steps can be proceed. Other than that, all the valve around that area which are sluice valve, hydrant valve, water valve and scour valve should be checked to ensure that all of them are in good condition and can function as well.

3.5.3.2 Zero Pressure Test (ZPT)

Zero pressure test is a training method for validating the zone either the zone is supplied from one inlet or more and also to check the status of boundary valve either it is open or closed. There are several steps to handle the ZPT and its steps are as follows:

i. Install the pressure logger at three points which are at the highest pressure, the lowest and the average pressure to check the pressure.
ii. Make sure that the boundary valve is completely closed and there is no water entered into DMA by using sounding stick.
iii. Calculate the total laps that needed to make sure that the valve is fully closed by using sounding stick.
iv. Check the pressure inside and outside of the DMA to make sure the pressure bar shows the 0 reading.

3.5.3.3 DMA Meter Installation

The installation of DMA meter must be on feeder DMA or at the inlet of each DMA such as at the main pipe supplying water on DMA clearance. The installation of DMA meter must not at the electrostatic area because the electrostatic area may interfere with the meter operation. In order to allow the meter working properly, make sure that the water is properly flowing into the pipe. Lastly, make sure there is no obstacle at the upstream and downstream of the meter pipes when installing meters in the ground because it would disturb the flow of water that would flow through the water.

3.5.3.4 Data Logger Installation

Data logger was installed at the highest and the lowest areas. The data logger would be placed for a certain period as already set on the system. After that period, the logger would be collected and would be connected to computer to get any relevant data. There are two types of data logger which are:

i. Pressure Data Logger
ii. Flow Data Logger.

The pressure data logger would be installed at the highest and the lowest areas. The data from this logger were used to calculate the T factor. The common logger used is logger Lolog 450 as shown in Figure 3.4.

Figure 3.4 Pressure Data Logger; Lolog 450

Flow data logger would be installed on DMA meter. It consists of two channel which are flow and pressure. The function of this logger is to analyse the reading of minimum night flow and total daily flow. The common logger used is logger Cello 4 and Cello 4s as shown in figure 3.5.

Figure 3.5 Flow Data Logger; Cello 4

3.5.3.5 A Complete Report of Leakage Percentage

A complete report of leakage percentage would be obtained from the MNF report. Besides the high percentage of leakage, NNF that exceeds 10 l/s indicates a high leakage occur on that DMA. The rate of NNF would be obtained using Equation 2.13 and the proses for obtaining all the value for that equation has been described in topic 2.10. The calculation for percentage leakage also can be calculated using equation 2.14. Based on the percentage leakage and NNF obtained, the NRW unit can identify the area of high leakage base on the DMA since the calculation would be made by DMAs. Figure 3.6 shows an example of MNF report that used by PAIP Kuala Lipis to identify the leakage based on DMA. DMA helps a lot in managing NRW since it would help the unit to find the location of leakage on the small area only.

				Established					Jan-18						
No.	DMA Code	DMA	WTP	Pipe Length (KM)	Connection (conn)	LNF (l/s)	BNC (l/s)	T-Factor	MNF (m^3/hr)	Volume (m^3/day)	Total Leakage (m^3/day)	% Leakage	NNF (l/s)	NNF l/km/hr	NNF l/conn/hr
28	06 04 003	DMA.LPS.MERAPOH-Kg Kubang Rusa	MERAPOH	19.62	348	6.48	1.40	14.10	33.16	883.61	67.51	8%	1.33	244	14
29	06 02 001	DMA.LPS.BENTA-Kemahang	BENTA	40.80	588	4.84	5.00	23.50	39.24	1362.09	89.68	7%	1.06	94	6
30	06 02 002	DMA.LPS.BENTA-Budu	BENTA	24.63	338	3.66	0.00	22.75	34.16	1014.40	477.48	47%	5.83	852	62
31	06 02 003	DMA.LPS.BENTA-Benta	BENTA	14.72	749	2.46	0.00	23.90	26.10	1115.20	412.13	37%	4.79	1,171	23
32	06 02 004	DMA.LPS.BENTA-Kg Peruang	BENTA	5.70	194	0.37	0.00	23.27	2.92	196.81	36.86	19%	0.44	278	8
33	06 02 005	DMA.LPS.BENTA-Kg Jerkoh	BENTA	17.36	669	1.41	4.17	17.76	23.94	1025.00	68.41	7%	1.07	222	6
34	06 02 006	DMA.LPS.BENTA-Benta JPJ	BENTA	24.50	467	1.83	10.56	22.12	71.24	2035.13	589.28	29%	7.40	1,087	57
35	06 02 007	DMA.LPS.BENTA-Kg Tualang Padang	BENTA	5.30	77	0.70	0.00	22.95	8.35	239.19	133.84	56%	1.62	1,100	76
36	06 11 001	DMA.LPS.MELA-Kg Limau Purut	MELA	6.30	50	0.23	0.46	24.96	3.24	113.90	18.87	17%	0.21	120	15
37	06 11 002	DMA.LPS.MELA-Kg Jeram Landak	MELA	37.10	593	3.14	8.10	24.92	0.00	887.46	-1008.36	-114%	-11.24	-1,091	-68
38	06 11 003	DMA.LPS.MELA-Kg Mela	MELA	37.10	533	0.73	4.70	19.79	40.90	1266.69	422.48	33%	5.93	575	40
39	06 11 004	DMA.LPS.MELA-Kg Serdang	MELA	10.00	64	0.30	0.00	22.23	31.61	767.68	678.64	88%	8.48	3,053	477
40	06 01 001	DMA.LPS.SG JELAI-Jalan Lipis Benta	JELAI	39.90	929	0.95	4.50	13.91	88.24	2334.20	954.45	41%	19.06	1,720	74
41	06 01 002	DMA.LPS.SG JELAI-Kg Tempoyang	JELAI	19.06	1096	4.86	17.10	17.22	27.83	1073.30	-882.15	-82%	-14.23	-2,688	-47
42	06 01 003	DMA.LPS.SG JELAI-Batu 2	JELAI	5.49	493	1.49	5.50	17.70	81.40	1322.07	995.31	75%	15.62	10,243	114

Figure 3.6 Sample of MNF Report

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

In order to analyse the effectiveness of the NRW management in Kuala Lipis district, the components of NRW were identified. Then, the discussion focused on the existing condition, production, billing and NRW for each of the nine WTP and arranged according to WTP design capacities. Lastly, comparison for all the WTP was made to access the overall performance of the NRW management.

4.2 Components of NRW

The NRW components are the factor that contribute to the occurrence of NRW in an area. The NRW unit of Kuala Lipis had classified that the use of meters bills, non-meter bills, meters without bills, use without meter and bills, unauthorized consumption, inaccurate meters and physical loss were the components of the NRW. This is according to the IWA Standard Water Balance discussed in chapter 2.9.1. Figure 4.1 shows the sample of components on NRW prepared by the NRW unit.

BORANG WATER BALANCE NRW - BWBNRW 2018

DAERAH: LIPIS
BULAN: OGOS

PERKARA	NAMA DAN KOD LOJI									JUMLAH
	JELAI	BENTA	BATU 9	MERAPOH	SUNGAI TEMAU	BUKIT BETONG	KECHAU	MELA	KUALA MEDANG	
	0601	0602	0603	0604	0605	0606	0607	0611	0509	
Pengeluaran (m3)										0.00
1.0 PENGGUNAAN DENGAN METER DENGAN BIL										
Semua Akaun Berdaftar (m3)										0.00
2.0 PENGGUNAAN TANPA METER DENGAN BIL										
a) Penggunaan Bil Anggaran										0.00
b) Meter Pengguna Yang Rosak										0.00
c) Penjualan Air Melalui Tanker										0.00
d) Penjualan Air Kepada Kontraktor										0.00
3.0 PENGGUNAAN DENGAN METER TANPA BIL										
a) Pemberian Air Percuma Kepada Intitusi										0.00
b) Penghantaran Air Percuma Melalui Tanker	466.00						392.00			858.00
4.0 PENGGUNAAN TANPA METER TANPA BIL										
a) Kegunaan Semasa Kebakaran										0.00
b) Kegunaan Untuk Kerja Amal										0.00
c) Penggunaan Tanker Semasa Krisis										0.00
d) Aktiviti Scouring / Flushing							6764.00			6764.00
e) Aktiviti Pembersihan Tangki										0.00
5.0 PENGGUNAAN TANPA KEBENARAN										
a) Penyambungan Haram										0.00
b) Penggunaan Hidrant Tanpa Kebenaran										0.00
c) Penggunaan Air Dari Tempered Meter										0.00
6.0 KETIDAKTEPATAN METER PENGGUNA										
a) Kehilangan Air Akibat Ketidaktepatan Meter										0.00
b) Kesilapan Data Kawalan										0.00
7.0 REAL LOSSES / KEHILANGAN FIZIKAL										
a) Kebocoran Paip / Paip Pecah	9360.00	15077.00	254.00	1043.00		1367	1473.00	756.00	2439.00	31769.00
b) Tangki Bocor / Overflow										0.00
JUMLAH	9826.00	15077.00	254.00	1043.00	0.00	1367.00	8629.00	756.00	2439.00	39391.00

Figure 4.1 Components of NRW

Sources: (PAIP, 2018)

From the data collection, it was recorded that the use of meter bill comprised of the registered account. The use of non-meter bills is comprised of the estimated bills, meter error, sales of water through tankers and sales of water to contractors. The use of meters without bills comprise of free water grant to institutions and free water delivery by tankers. The use without meter and bills is the use of water for firefighting, charity work, the use of tankers during water crisis, tank cleaning, scouring and flushing activities. The unauthorized consumptions were the illegal connection, unauthorized use of hydrant and water use from tempered meters while the inaccuracy of user meters is the loss of water due to inaccuracy of meters as well and also error in controlling data. Lastly, physical loss occurs due to leakage of pipes, broken pipes, leaky tanks and overflow tanks.

Normally, there are only certain data can be recorded as components of the NRW which were free water delivery by tankers, scouring and flushing activities, leakage of pipes, broken pipes, leaky tanks and overflow tanks. The data for free water delivery by tanker were recorded based on the capacity of tanker itself. There were two capacity of tanker used which are 6m^3 and 8m^3. Meanwhile, data for scouring and flushing activities were obtained based on the current pressure of that area as well as the duration of that activity. Lastly, the data for overflow tank was calculated based on the overflow duration while the data for leakage tank was obtained from the result of drop test.

4.3 Water Treatment Plant

Table 4.1 shows the design capacity for nine WTP around the study area. The list of WTP was arranged according to its plant design capacity.

Table 4.1 Design Capacity

No.	WTP	Design Capacity (m^3/hr)	DMA (No.)	Pipe Length (km)	Connection (nos)
1	Jelai	1,200	13	139.31	5,571
2	Benta	526	7	133.01	3,082
3	Bukit Betong	500	7	182.04	3,153
4	Kechau	450	9	150.66	2,395
5	Kuala Medang	430	7	98.25	2,319
6	Mela	200	4	90.50	1,240
7	Merapoh	148	3	43.27	1,023
8	Sungai Temau	78	1	14.83	416
9	Batu 9	20	1	9.50	112

4.3.1 Jelai WTP

4.3.1.1 Existing Condition

The Jelai WTP is the main treatment plant in the area as it has the largest production account compared to other water treatment plants. The plant works to provide clean water for residents around the city center and nearby areas. The raw water source for this plant is obtained from the nearby river known as Sungai Jelai. The design capacity of the water treatment plant is 1,200 m^3 per hour and operates 24 hours daily. However, due to the age and size of the raw water pump used, the plant only processes 850 m^3 per hour of raw water.

4.3.1.2 District Metering Area (DMA)

There are thirteen DMA branches that serve to distribute water from this water treatment plant to consumers. The DMA for this plant was fully completed in November 2015. However, the complete recorded data has begun from year 2016. The total length of the pipeline for the entire DMA is 139.31 kilometers and connected by 5,571 connectors. The lists of DMA for this WTP are shown in Table 4.2.

Table 4.2 DMA of Jelai WTP

No.	DMA CODE	DMA LOCATION	PIPE LENGTH (km)	CONNECTION (nos)
1	06 01 001	Jalan Lipis Benta	39.90	929
2	06 01 002	Kg. Tempoyang	19.06	1096
3	06 01 003	Batu 2	5.49	493
4	06 01 004	Taman Emas	2.61	248
5	06 01 005	Kg. Kuala Lanar	21.70	264
6	06 01 006	Hospital Kuala Lipis	13.00	562
7	06 01 007	Sg. Kerpan	9.10	203
8	06 01 008	Taman Bukit Bius	0.50	22
9	06 01 009	Bandar Lama Lipis	1.20	246
10	06 01 010	Bukit Kerani A	8.70	690
11	06 01 011	Bukit Kerai B	5.25	310
12	06 01 012	Taman Lipis Baru	3.60	394
13	06 01 013	Bukit Sarang	9.20	114
TOTAL			139.31	5,571

4.3.1.3 Production

Figure 4.2 shows clean water production records from 2016 to 2018. The baseline production for Jelai WTP is 487,122 m^3 per month. Based on this figure, it showed that the water production rate for this water treatment plant changed throughout the year with the amount of 5,353,485 m^3 on 2016, 4,825,525 m^3 on 2017 and 4,437,524 m^3 on 2018. However, it shows that a sudden drop of 27.56% occurred in April 2016. It is occurred due to drought season. It was recorded that the percent of production reduce from year to year starting from 9.86% on 2017 and 8.04% on 2018. With the establishment of NRW units, most of the pipe leakage can be detected and repairs work can be done immediately. Therefore, the amount of production can be reduced according to consumer needs due to the lack of water loss rate.

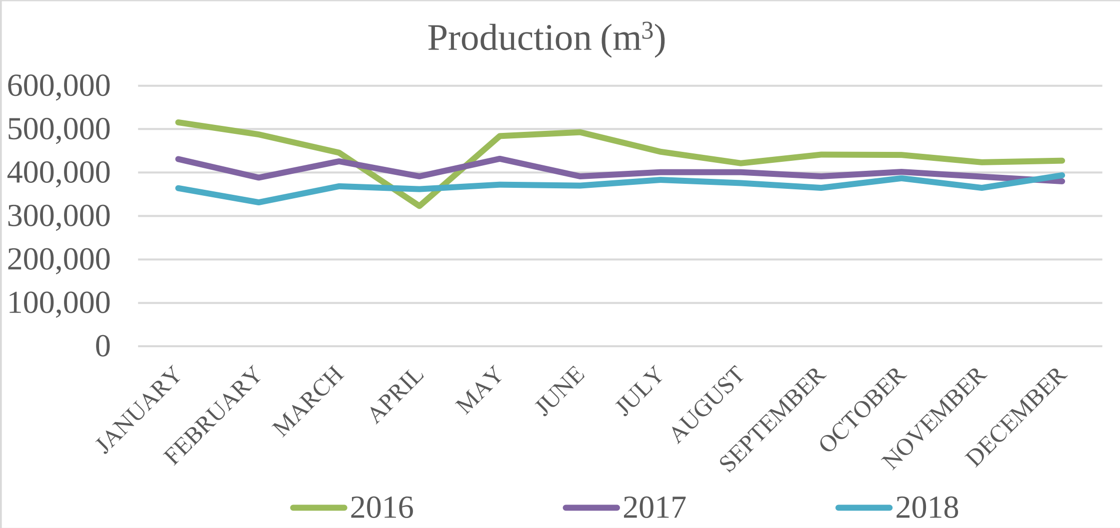

Figure 4.2 Production of Jelai WTP

4.3.1.4 Billing

Figure 4.3 shows the amount of water billed for year of 2016 to 2018. The baseline for billing of this WTP is 232,695 m^3 per month. In 2016, the amount of water billed was 3,119,146 m^3, while 3,076,720 m^3 on 2017 and 3,115,882 m^3 on 2018. Referring to the amount of water billed in 2016, a decrease of 1.36% had occurred on 2017 while there was an increase of 1.27% in 2018. Based on that situation, it indicates that the NRW unit is monitoring the current situation and take appropriate and prompt action to overcome the losses.

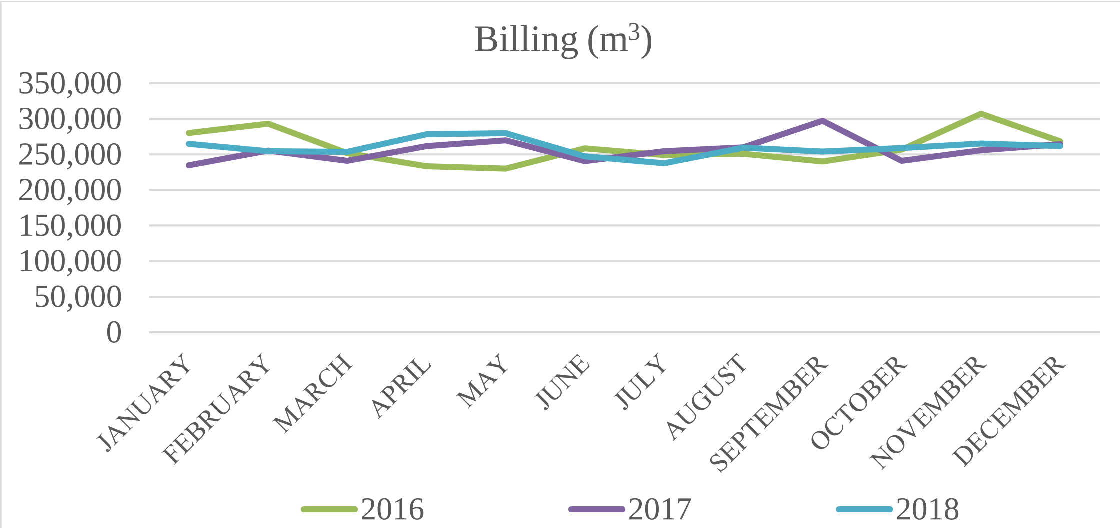

Figure 4.3 Billing of Jelai WTP

4.3.1.5 Non-Revenue Water

Referring to the NRW baseline for this WTP which are 50.23%, it shows that the rate of NRW has been reduced starting from 50.23% to 45.71% on January 2016 after the establishment of DMA. Figure 4.4 shows the rate of NRW was 41.17% on 2016, then it decreased to 36.08% in 2017 and subsequently decreased to 29.65% in 2018. It shows a very good achievement for the early years of the establishment of the NRW unit since the national rate of the NRW are between 30% and 35%. Table 4.3 summarises the losses for each kilometer pipeline for Jelai WTP starting from 2016 until 2018. It shows that the rate decrease from year to year starting with 937 m^3/day/km on 2016, 733 m^3/day/km on 2017 and 554 m^3/day/km on 2018. Based on that figure, it shows that DMA Bandar Lama Kuala Lipis contributed the highest losses in each kilometer pipe for three consecutive years when compare to other DMAs.

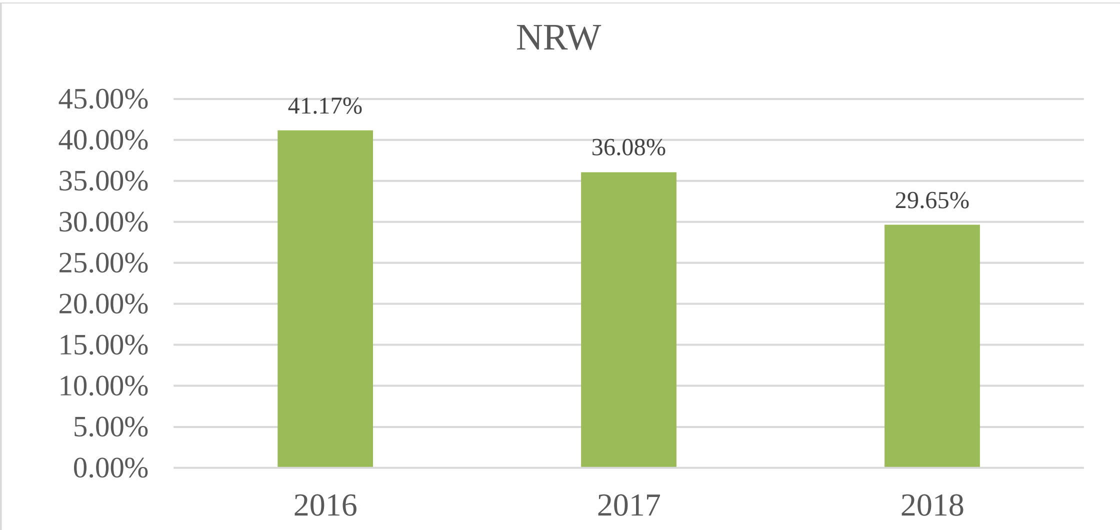

Figure 4.4 NRW of Jelai WTP

Table 4.3 Water Losses (m^3/day/km) for Jelai WTP

				2016			2017			2018		
No	**DMA LOCATION**	**LENTGH**	**CONNECTION**	**PRODUCTION**	**BILLING**	**LOSSES**	**PRODUCTION**	**BILLING**	**LOSSES**	**PRODUCTION**	**BILLING**	**LOSSES**
		(km)	**(nos)**	**(m^3/year)**	**(m^3/year)**	**(m^3/day/km)**	**(m^3/year)**	**(m^3/year)**	**(m^3/day/km)**	**(m^3/year)**	**(m^3/year)**	**(m^3/day/km)**
				5,353,485	**3,119,146**		**4,825,525**	**3,076,720**		**4,437,524**	**3,115,882**	
1	Jalan Lipis Benta	39.90	929	892,728	520,138	26	804,687	513,063	20	739,986	519,593	15
2	Kg Tempoyang	19.06	1096	1,053,208	613,639	63	949,340	605,293	49	873,008	612,997	37
3	Batu 2	5.49	493	473,751	276,026	99	427,030	272,271	77	392,694	275,737	58
4	Taman Emas	2.61	248	238,317	138,853	104	214,814	136,964	82	197,542	138,707	62
5	Kg Kuala Lanar	21.70	264	253,692	147,811	13	228,673	145,800	10	210,287	147,656	8
6	Hospital Lipis	13.00	562	540,057	314,658	48	486,797	310,378	37	447,655	314,329	28
7	Sg Kerpan	9.10	203	195,074	113,658	25	175,836	112,112	19	161,698	113,539	14
8	Taman Bukit Bius	0.50	22	21,141	12,318	48	19,056	12,150	38	17,524	12,305	29
9	Bandar Lama Lipis	1.20	246	236,395	137,733	225	213,082	135,859	176	195,949	137,589	133
10	Bukit Kerani A	8.70	690	663,060	386,324	87	597,669	381,069	68	549,613	385,920	52
11	Bukit Kerani B	5.25	310	297,896	173,566	65	268,518	171,205	51	246,927	173,384	38
12	Taman Lipis Baru	3.60	394	378,617	220,597	120	341,277	217,596	94	313,837	220,366	71
13	Bukit Sarang	9.20	114	109,549	63,827	14	98,745	62,959	11	90,806	63,761	8
	TOTAL	139.31	5,571			937			733			554

4.3.2 Benta WTP

4.3.2.1 Existing Condition

Benta WTP is built to process and supply clean water for residents around the town and some adjacent areas. The raw water source for this plant is obtained from the river located next to the plant. The short distance between the water treatment plant and the intake can facilitate treatment work evenly in reducing the cost for the pipeline. The design capacity of this WTP is 300 m^3 per hour but due to plant upgrades and pump conversion, the raw water treated by the plant has increased to 526 m^3 per hour.

4.3.2.2 District Metering Area

There are seven DMA branches for this plant that was fully completed in November 2014. The total pipe length around the DMA is 133.01 kilometers with 3,082 connectors. The list of DMA for this WTP are shown in Table 4.4.

Table 4.4 DMA of Benta WTP

No.	DMA CODE	DMA LOCATION	PIPE LENGTH (km)	CONNECTION (nos)
1	06 02 001	Kemahang	40.80	588
2	06 02 002	Budu	24.63	338
3	06 02 003	Benta	14.72	749
4	06 02 004	Kg. Peruang	5.70	194
5	06 02 005	Kg. Jerkoh	17.36	669
6	06 02 006	Benta JPJ	24.50	467
7	06 02 007	Kg. Tualang Padang	5.30	77
TOTAL			133.01	3,082

4.3.2.3 Production

The production baseline for Benta WTP is 322,383 m^3 per month. Figure 4.5 shows the production rate for the Benta WTP for year of 2016 until 2018. Based on this figure, it shows that the production rate for these WTP decreases year by year. Starting with 3,477,786 m^3 for year of 2016, it has decreased by 14.47% in 2017 become 2,974,637 m^3 per year. For the following year, the production rate decreased by 6.04% to 2, 795, 085 m^3 in 2018.

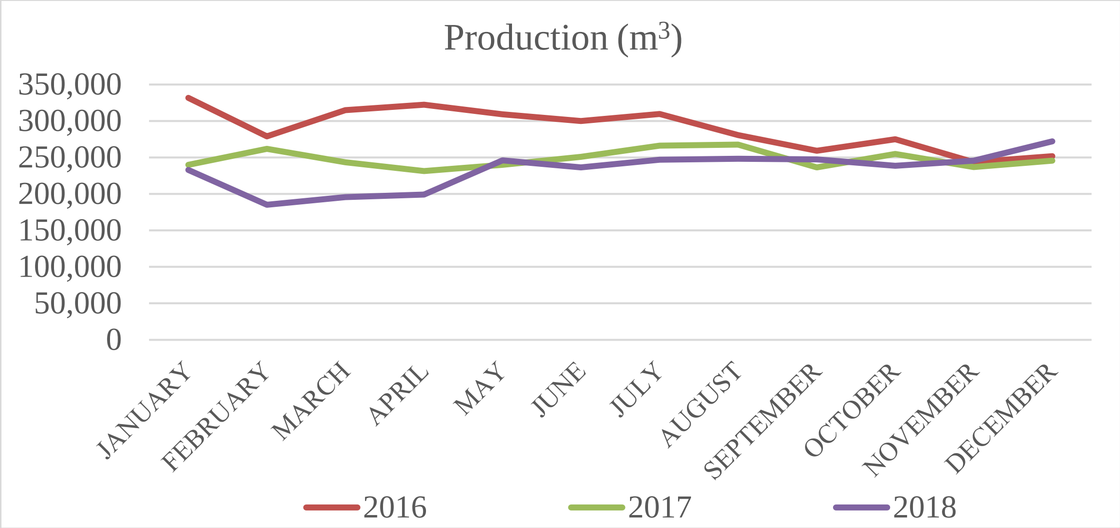

Figure 4.5 Production of Benta WTP

4.3.2.4 Billing

Figure 4.6 shows a record of billing for the year of 2016 up to 2018. Based on the figure, it can be seen that billing rates often change significantly for each month. Referring to the amount of 116,347 m^3 billing baseline for these WTP, it showed that there was an increasing rate in the first month after the NRW unit was establish with the rise of 7.87% on January 2016. The billing of this WTP for year 2016 was 1,471,803 m^3. However, due to several factors such as high leakage rates and delays in repair work, billing rates already decline from year to year until 1, 238, 395 m^3 on 2018.

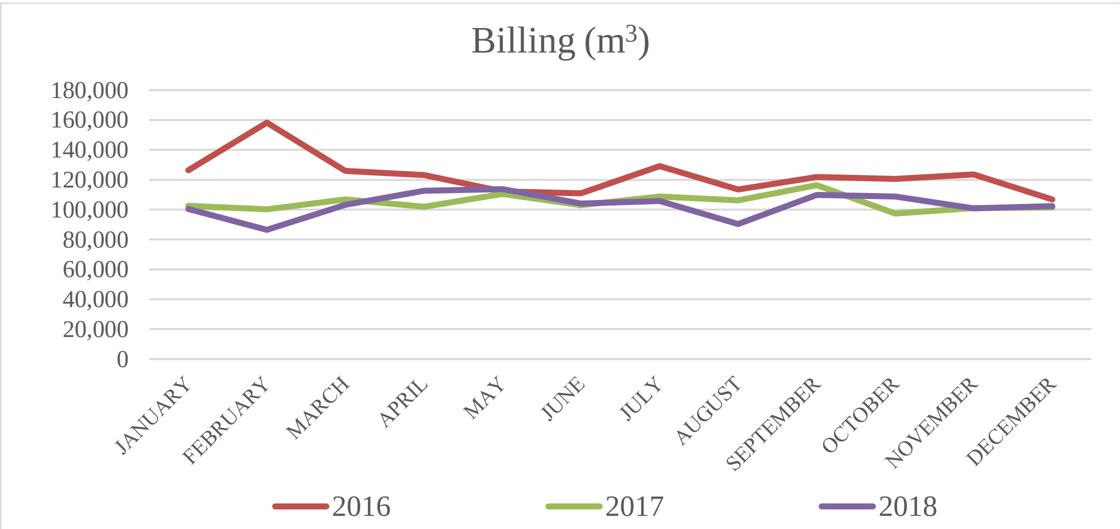

Figure 4.6 Billing of Benta WTP

4.3.2.5 Non-Revenue Water

Figure 4.7 shows the NRW rate for three consecutive years, 2016, 2017 and 2018 for the Benta WTP. The NRW baseline for this WTP is 63.91%. Referring to the baseline rate and information from this figure, it shows a decrease of 6.59% for the first year but suddenly increase with the amount of 0.33% in the second year after the establishment of the NRW unit. It occurred due to time constraints for repairing work. As a result of teamwork and effective action in overcoming water loss problems, the NRW rate was lowered in 2018 to 55.24%. Table 4.5 summarise the losses for each kilometer pipeline for Benta WTP starting from 2016 until 2018. Similarly, for DMA, the rate of losses for each kilometer pipe in this DMA also decreased year by year. Based on that figure, it shows that DMA Benta provide the highest losses for the three consecutive years. The total pipe length for this DMA is the fourth longest among seven DMA but this DMA has the highest total connection since it is the small town for this area.

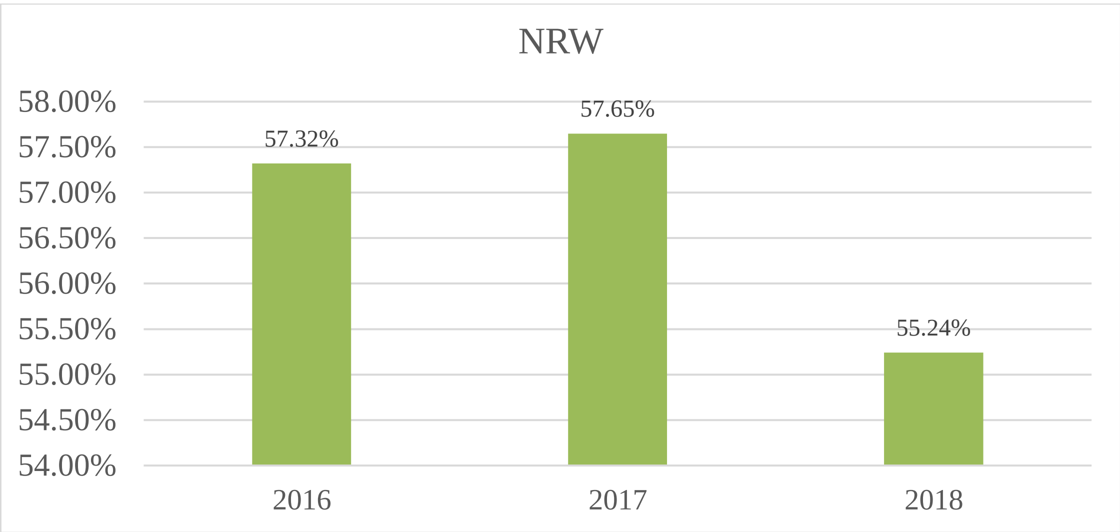

Figure 4.7 NRW of Benta WTP

Table 4.5 Water Losses (m^3/day/km) for Benta WTP

No.	DMA LOCATION	LENTGH (km)	CONNECTION (nos)	2016 PRODUCTION (m^3/year)	2016 BILLING (m^3/year)	2016 LOSSES (m^3/day/km)	2017 PRODUCTION (m^3/year)	2017 BILLING (m^3/year)	2017 LOSSES (m^3/day/km)	2018 PRODUCTION (m^3/year)	2018 BILLING (m^3/year)	2018 LOSSES (m^3/day/km)
				3,477,786	**1,471,803**		**2,974,637**	**1,256,593**		**2,795,082**	**1,238,395**	
1	Kemahang	40.80	588	663,510	280,798	26	567,517	239,739	22	533,260	236,267	20
2	Budu	24.63	338	381,405	161,411	24	326,226	137,809	21	306,534	135,814	19
3	Benta	14.72	749	845,185	357,683	91	722,908	305,382	78	679,272	300,960	70
4	Kg Peruang	5.70	194	218,913	92,644	61	187,242	79,098	52	175,940	77,952	47
5	Kg Jerkoh	17.36	669	754,912	319,480	69	645,695	272,765	59	606,720	268,814	53
6	Benta JPJ	24.50	467	526,971	223,015	34	450,732	190,405	29	423,525	187,648	26
7	Kg Tualang Padang	5.30	77	86,888	36,771	26	74,318	31,394	22	69,832	30,940	20
	TOTAL	133.01	3,082			330			283			256

4.3.3 Bukit Betong WTP

4.3.3.1 Existing Condition

Bukit Betong WTP is built to process clean and safe water for residents around that area. The raw water source for this WTP is obtained from the nearby river that located next to the WTP itself. The short distance between the water treatment plant and the intake can facilitate treatment work evenly in reducing the cost for the pipeline. The design capacity of this WTP is 500 m^3 per hour but due to plant upgrades and pump conversion, the raw water treated by the plant has increased to 526 m^3 per hour daily. However, due to the current demand, this WTP only need to process 470 m^3 of raw water per hour.

4.3.3.2 District Metering Area

Bukit Betong WTP has only seven DMA branch involving 182.04 kilometer of pipes line and 3,153 connectors that used to provide clean water to consumers. The DMA for this area was completed in November 2014 and the complete recorded data has begun from year 2015 onwards.

Table 4.6 DMA of Bukit Betong WTP

No.	DMA CODE	DMA LOCATION	PIPE LENGTH (km)	CONNECTION (nos)
1	06 06 001	Kg Bkt Betong	33.3	381
2	06 06 002	Kg Lubuk Kulit	29.95	378
3	06 06 003	Kg Gua	18.8	426
4	06 06 004	Padang Tengku	22.15	781
5	06 06 005	Kg Relong	42.36	712
6	06 06 006	Kg Keledek	26.28	361
7	06 06 007	Kg Bapong	9.2	114
TOTAL			182.04	3,153

4.3.3.3 Production

Production baseline for Bukit Betong WTP is 279,840m^3. Figure 4.8 shows the production rate for this WTP for three years from 2016 until 2018. The production rate for this WTP is variable over the years. In 2016, its production rate is 3,472,351m^3, then the rate slowly decreased year by year to 3,304,730m^3 on 2017 and 2,858,524m^3 on 2018. It shows a good progress since even the production decreased year by year, consumers were still able to get the water supply due to the percentage of leakage slowly had been tackled.

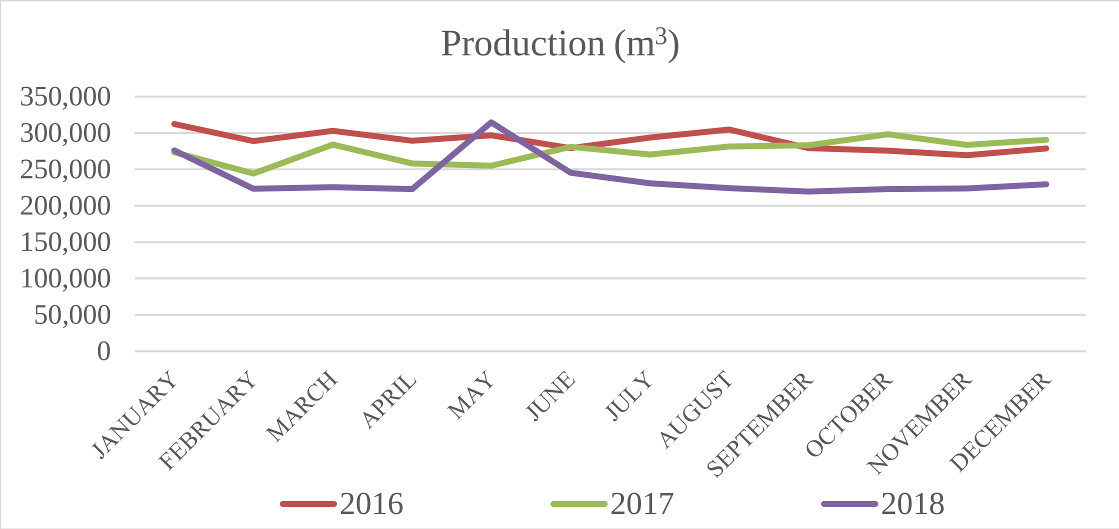

Figure 4.8 Production of Bukit Betong WTP

4.3.3.4 Billing

The baseline rate for Bukit Betong WTP is 110,885 m^3. Figure 4.9 shows the billing rate from 2016 until 2018. According to this figure, the billing rates were not consistent: 1,789,495 m^3 in 2016, 1,561,287m^3 in 2017 and 1,655,585 m^3 in 2018. On 2016, the billing rates showed an inclining trend but decline in 2017 by 12.75%. However, in 2018, the rate inclined by 6.04%.

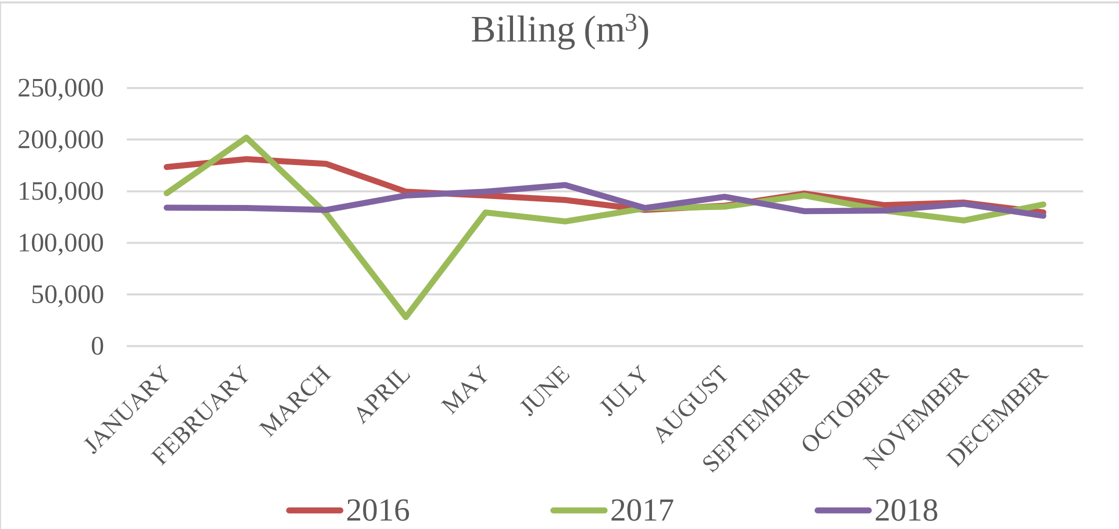

Figure 4.9 Billing of Bukit Betong WTP

4.3.3.5 Non-Revenue Water

Figure 4.10 shows the NRW rate of Bukit Betong WTP for three consecutive years of 2016, 2017 and 2018. Based on this figure, it shows that the rate of NRW for this plant varies from year to year starting with 48.49%, 52.55% and 41.59%. Although the rate is still high, it shows a good achievement as the baseline rate was at 60.38%. The trend of the NRW of this WTP corresponded to the varies billing recorded. Table 4.7 summarise the losses for each kilometer pipeline for Bukit Betong WTP starting from 2016 until 2018. Based on that figure, it shows that the rate of losses for each kilometer pipe increased in 2017 then decreased in 2018. It had a similar as the NRW since the losses are a part of NRW. DMA Padang Tengku shows the highest rate of losses with the highest numbers of connection.

Figure 4.10 NRW of Bukit Betong WTP

Table 4.7 Water Losses (m^3/day/km) fot Bukit Betong WTP

				2016			2017			2018		
No.	**DMA LOCATION**	**LENTGH**	**CONNECTION**	**PRODUCTION**	**BILLING**	**LOSSES**	**PRODUCTION**	**BILLING**	**LOSSES**	**PRODUCTION**	**BILLING**	**LOSSES**
		(km)	**(nos)**	**(m^3/year)**	**(m^3/year)**	**(m^3/day/km)**	**(m^3/year)**	**(m^3/year)**	**(m^3/day/km)**	**(m^3/year)**	**(m^3/year)**	**(m^3/day/km)**
				3,472,351	**1,789,495**		**3,304,730**	**1,561,287**		**2,858,524**	**1,655,585**	
1	Kg Bkt Betong	33.30	381	419,589	216,238	17	399,335	188,662	17	345,416	200,056	12
2	Kg Lubuk Kulit	29.95	378	416,286	214,535	18	396,190	187,176	19	342,696	198,481	13
3	Kg Gua	18.80	426	469,147	241,778	33	446,500	210,945	34	386,213	223,685	24
4	Padang Tengku	22.15	781	860,103	443,259	52	818,584	386,732	53	708,058	410,089	37
5	Kg Relong	42.36	712	784,115	404,098	25	746,263	352,565	25	645,502	373,859	18
6	Kg Keledek	26.28	361	397,564	204,887	20	378,372	178,758	21	327,284	189,555	14
7	Kg Bapong	9.20	114	125,546	64,701	18	119,486	56,450	19	103,353	59,859	13
	TOTAL	182.04	3,153			183			189			131

4.3.4 Kechau WTP

4.3.4.1 Existing Condition

Kechau WTP provides and clean water for residents around that its water sources obtain from the nearby river that also located nearby the WTP. The design capacity of the WTP is 400 m^3 per hour and operates 12 hours daily. However, due to plant upgrades and pump conversion, the raw water treated by the plant has increased to 450 m^3 per hour.

4.3.4.2 District Metering Area.

Kechau WTP has nine DMA branch involving 150.66 kilometer of pipes line and 2,395 connectors that used to provide clean water to consumers. The DMA for this area was completed in February 2015, however, the complete recorded data begun from year of 2016 onwards.

Table 4.8 DMA of Kechau WTP

No.	DMA CODE	DMA LOCATION	PIPE LENGTH (km)	CONNECTION (nos)
1	06 07 001	Bandar Baru Lipis	42.22	906
2	06 07 002	Kg Melaka	30.45	419
3	06 07 003	Kechau 1 & 2	24.8	361
4	06 07 004	Kechau 7	9.1	58
5	06 07 005	Kechau 3	5.1	44
6	06 07 006	Kechau 6	2.14	144
7	06 07 007	Kechau 11	4.5	44
8	06 07 008	Kechau Tui	18.2	249
9	06 07 009	Pagar Sasak	14.15	170
TOTAL			150.66	2,395

4.3.4.3 Production

The baseline rate for this plant is 195,181 m^3. Figure 4.11 shows the production rate for three consecutive years for these WTP starting from 2016 to 2018. Based on this figure, it shows that the production rate for 2016 is 2,254,400 m^3, production for 2017 is 2,384,092 m^3 and production for 2018 is 2,364,434 m^3. The first three months, the production rate was static due to the meter problem.

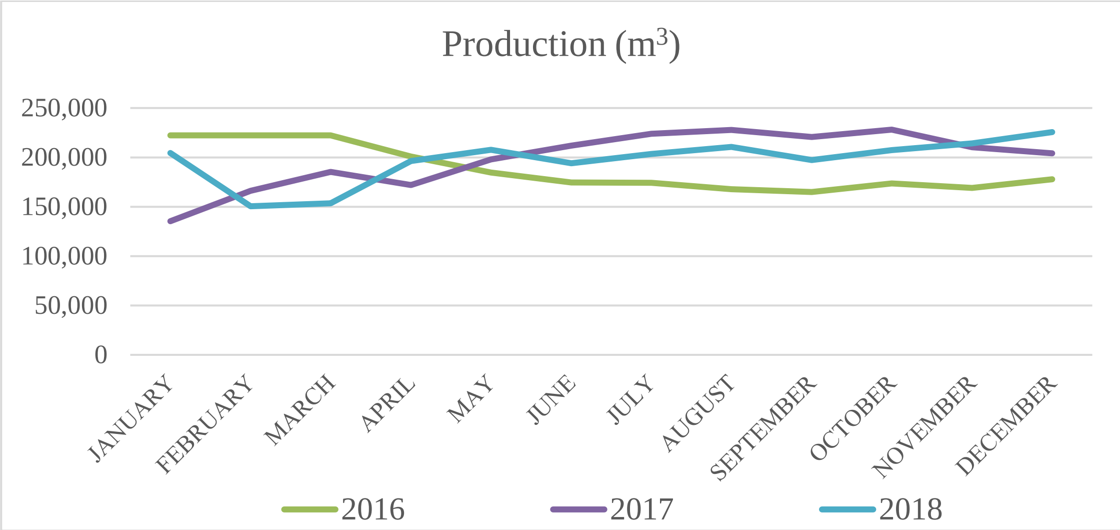

Figure 4.11 Production of Kechau WTP

4.3.4.4 Billing

Figure 4.12 shows the billing rates for Kechau WTP for year of 2016, 2017 and 2018. The baseline rate for this plant is 106,241 m^3. Based on this figure, the billing rate is changing from year to year, similar trends recorded at other WTP. In 2016, the billing rate is 1,740,235 m^3, in 2017 the rate has decreased by 13.96% to 1,497,304 m^3 per year. However, the rate increased again in 2018 with its current volume of 1,585,522 m^3 per year.

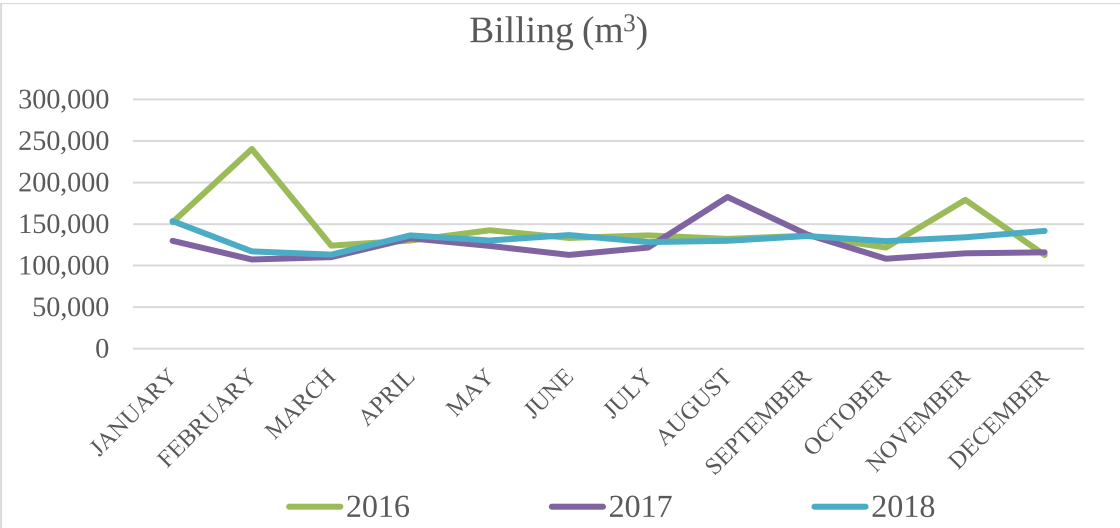

Figure 4.12 Billing of Kechau WTP

4.3.4.5 Non-Revenue Water

NRW baseline for this plant is 45.57%. Figure 4.13 shows the rate of NRW for 2016, 2017 and 2018 for Kechau WTP. Based on the figure, it shows that the NRW rate is 22.54%, 35.97% and 32.46% for these three years. These rates changed particularly from year to year corresponding to the rate of water loss that occurred during that year. Table 4.9 summarise the losses for each kilometer pipeline for Kechau WTP starting from 2016 until 2018. Similar to the rate of NRW, the losses for each kilometer pipe also increased in 2017 and decreased in 2018. Based on this figure, DMA Kechau 6 shows the highest rate of losses among the nine DMA despite having the shortest pipe length. It shows that there are many water losses that occur due to broken pipe, leakage pipe and also due to commercial losses. There is another factor that contributes to higher losses which are due to inaccurate meter tagging. This problem may affect the billing rate for that DMA but still able to give the revenue to PAIP since the billing will be recorded in another DMA.

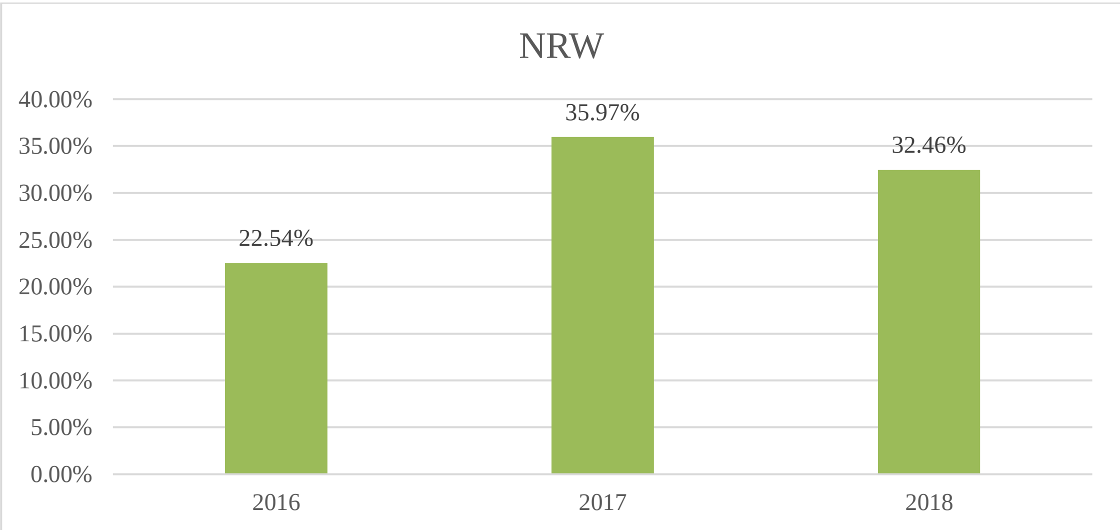

Figure 4.13 NRW of Kechau WTP

Table 4.9 Water Losses (m^3/day/km) for Kechau WTP

				2016			2017			2018		
No.	**DMA LOCATION**	**LENTGH**	**CONNECTION**	**PRODUCTION**	**BILLING**	**LOSSES**	**PRODUCTION**	**BILLING**	**LOSSES**	**PRODUCTION**	**BILLING**	**LOSSES**
		(km)	**(nos)**	**(m^3/year)**	**(m^3/year)**	**(m^3/day/km)**	**(m^3/year)**	**(m^3/year)**	**(m^3/day/km)**	**(m^3/year)**	**(m^3/year)**	**(m^3/day/km)**
				2,254,400	**1,740,235**		**2,384,092**	**1,497,304**		**2,364,434**	**1,585,522**	
1	Bandar Baru Lipis	42.22	906	852,813	658,310	13	901,874	566,412	22	894,437	599,784	19
2	Kg Melaka	30.45	419	394,402	304,450	8	417,092	261,950	14	413,653	277,384	12
3	Kechau 1 & 2	24.80	361	339,807	262,307	9	359,356	225,690	15	356,393	238,987	13
4	Kechau 7	9.10	58	54,595	42,143	4	57,736	36,260	6	57,260	38,397	6
5	Kechau 3	5.10	44	41,417	31,971	5	43,800	27,508	9	43,438	29,129	8
6	Kechau 6	2.14	144	135,546	104,632	40	143,344	90,026	68	142,162	95,330	60
7	Kechau 11	4.50	44	41,417	31,971	6	43,800	27,508	10	43,438	29,129	9
8	Kechau Tui	18.20	249	234,382	180,926	8	247,866	155,670	14	245,822	164,841	12
9	Pagar Sasak	14.15	170	160,020	123,524	7	169,226	106,280	12	167,830	112,542	11
	TOTAL	150.66	2,395			99			170			149

4.3.5 Kuala Medang WTP

4.3.5.1 Existing Condition

Kuala Medang WTP obtained its raw water source from the nearby river that also located nearby the WTP. The design capacity of the water treatment plant is 326 m^3 per hour and operates 12 hours daily. However, due to plant upgrading and pump conversion, the raw water treated by the plant has increased to 430 m^3 per hour.

4.3.5.2 District Metering Area

This WTP has seven DMA branches that fully completed in February 2015 with 98.25 kilometer of pipeline involving 2,319 connectors. However, the complete recorded data has begun from year of 2016 onwards.

Table 4.10 DMA of Kuala Medang WTP

No.	DMA CODE	DMA LOCATION	PIPE LENGTH (km)	CONNECTION (nos)
1	06 12 001	Kg Serau	12.3	66
2	06 12 002	Tg Gahai	24.35	215
3	06 12 003	Felda Sg Koyan 3	11.45	596
4	06 12 004	Felda Sg Koyan 1 & 2	13.8	736
5	06 12 005	Kg Kuala Medang	8.3	302
6	06 12 006	Pos Pantos	3.7	189
7	06 12 007	Kuala Koyan	24.35	215
TOTAL			98.25	2,319

4.3.5.3 Production

The baseline production for this plant is 144,030 m^3 per month. Figure 4.14 shows the record for clean water production from 2016 to 2018. The three-year production volume for this plant showed a reduction starting from 1,758,277 m^3 in the first year, 1,605,913 m^3 in the second year and 1,415,630 m^3 in the third year. Based on this figure, production for the first five months of 2016 was high compared to the following years. This is due to the occurrence of undetectable loss.

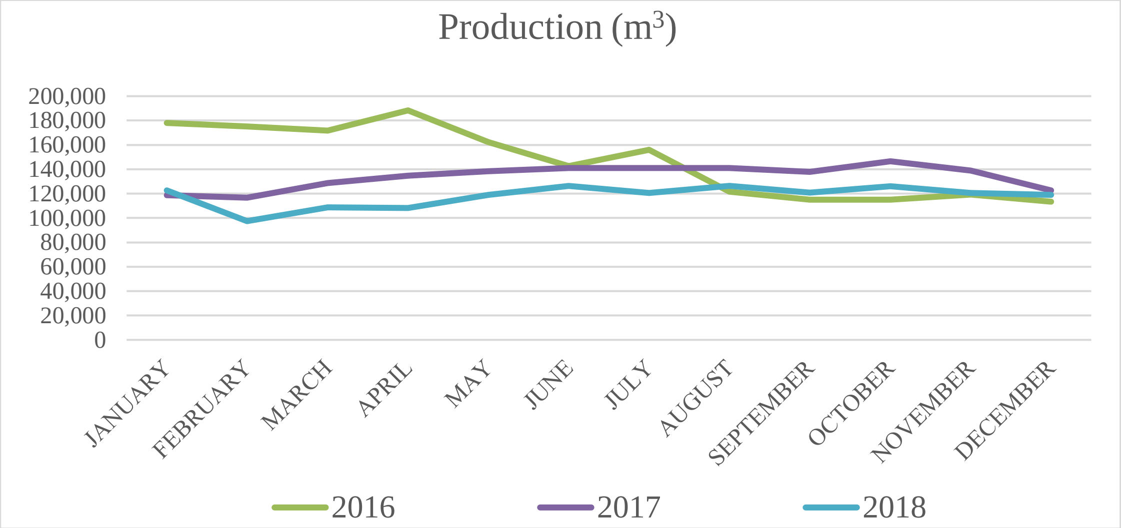

Figure 4.14 Production of Kuala Medang WTP

4.3.5.4 Billing

The billing baseline for Kuala Medang WTP is 76,776 m^3 per month. Figure 4.15 shows the total billing for three consecutive years from the year of 2016 to 2018. The three-year billing rate were 1,176,510 m^3, 1,090,449 m^3 and 1,120,567 m^3 respectively. Billing rates were varied for each year beginning with a decrease of 7.31% in the second year and an increase of 2.76% in the third year. Based on Figure 4.15, it can be seen that the billing rate for February 2016 has increased dramatically to 34.03% due to the data handling error.

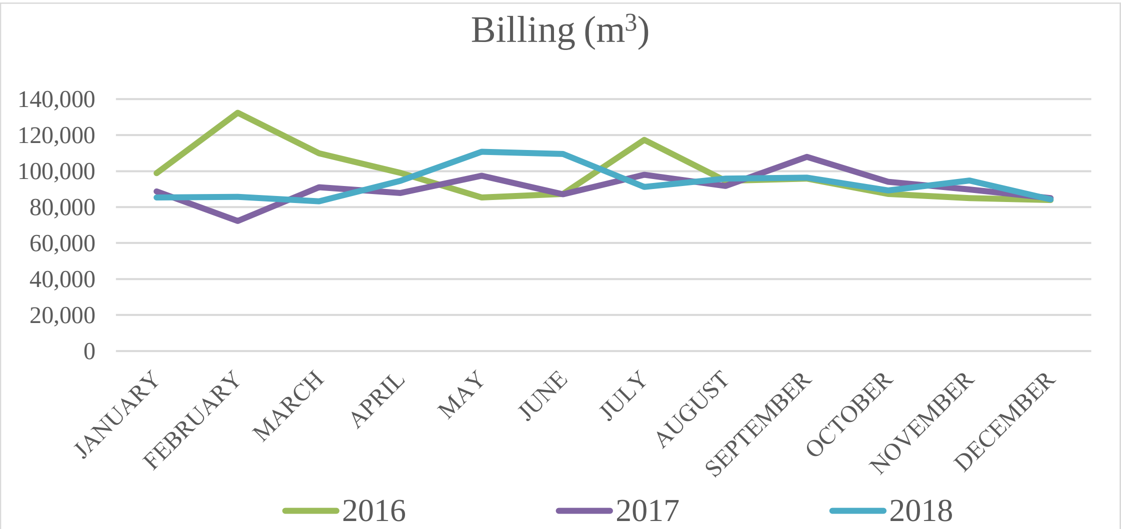

Figure 4.15 Billing of Kuala Medang WTP

4.3.5.5 Non-Revenue Water

The NRW baseline for Kuala Medang WTP is 46.69%. Based on NRW baseline, it shows that the rate of NRW has been reduced starting from 46.69% to 44.52% in January 2016 after the establishment of DMA. Figure 4.16 shown that the rate of NRW was 31.76% in 2016, then it decreased to 32.04% in 2017 and subsequently decreased to 20.62% in 2018. It shows a very good achievement for the early years of the establishment of the NRW unit since the normal rate of the NRW are between 30% and 35%. Table 4.11 summarises the losses for each kilometer pipeline for Kuala Medang WTP starting from 2016 until 2018. It shows that the rate of losses decreases year by year. The rate of losses for each kilometer pipe for this DMA already decrease by 11.49% on the second year and continuously to decrease by 42.75% to 75 m^3/day/km on 2018. Based on this figure, the losses for DMA Sungai Koyan 3 and DMA Sungai Koyan 1 and 2 had almost similar in value and are highest among others.

Figure 4.16 NRW of Kuala Medang WTP

Table 4.11 Water Losses (m^3/day/km) for Kuala Medang WTP

				2016			2017			2018		
No.	**DMA LOCATION**	**LENTGH (km)**	**CON (nos)**	**PRODUCTION (m^3/year)**	**BILLING (m^3/year)**	**LOSSES (m^3/day/km)**	**PRODUCTION (m^3/year)**	**BILLING (m^3/year)**	**LOSSES (m^3/day/km)**	**PRODUCTION (m^3/year)**	**BILLING (m^3/year)**	**LOSSES (m^3/day/km)**
				1,758,227	**1,176,510**		**1,605,913**	**1,090,449**		**1,415,630**	**1,120,567**	
1	Kg Serau	12.30	66	50,040	33,484	4	45,705	31,035	3	40,290	31,892	2
2	Tg Gahai	24.35	215	163,009	109,077	6	148,888	101,098	5	131,246	103,890	3
3	Felda Sg Koyan 3	11.45	596	451,877	302,372	36	412,731	280,253	32	363,827	287,994	18
4	Felda Sg Koyan 1 & 2	13.80	736	558,023	373,399	37	509,682	346,085	32	449,290	355,644	19
5	Kg Kuala Medang	8.30	302	228,971	153,215	25	209,136	142,008	22	184,355	145,930	13
6	Pos Pantos	3.70	189	143,297	95,886	35	130,883	88,872	31	115,375	91,327	18
7	Kuala Koyan	24.35	215	163,009	109,077	6	148,888	101,098	5	131,246	103,890	3
	TOTAL	98.25	2,319			148			131			75

4.3.6 Mela WTP

4.3.6.1 Existing Condition

Mela WTP provides clean water for residents around the nearby areas and obtained its raw water sources from the nearby river that located next to the WTP. The design capacity of the water treatment plant is 200 m^3 per hour and operates 12 to 18 hours daily depend on the residents need. However, due to the age and size of the raw water pump used, the plant only processes 195 m^3 per hour of raw water.

4.3.6.2 District Metering Area

Mela WTP only has four DMA branch involving 90.50 kilometer of pipes line and 1,240 connectors that used to provide clean water to consumers. The DMA for this area was also completed in March 2015, however the complete recorded data has begun from year of 2016 onwards.

Table 4.12 DMA of Mela WTP

No.	DMA CODE	DMA LOCATION	PIPE LENGTH (km)	CONNECTION (nos)
1	06 11 001	Kg Limau Purut	6.3	50
2	06 11 002	Kg Jeram Landak	37.1	593
3	06 11 003	Kg Mela	37.1	533
4	06 11 004	Kg Serdang	10	64
TOTAL			90.5	1,240

4.3.6.3 Production

The production baseline for this plant is 94,435 m^3 per month. Based on Figure 4.17, the production rate for this plant changed from year to year starting from 2016 until 2018. In 2016, the production rate was 1,238,887 m^3 and it increased by 17.34% in 2017. In 2018, the production rate for this plant decreased by 8.56% to 1,329,332 m^3.

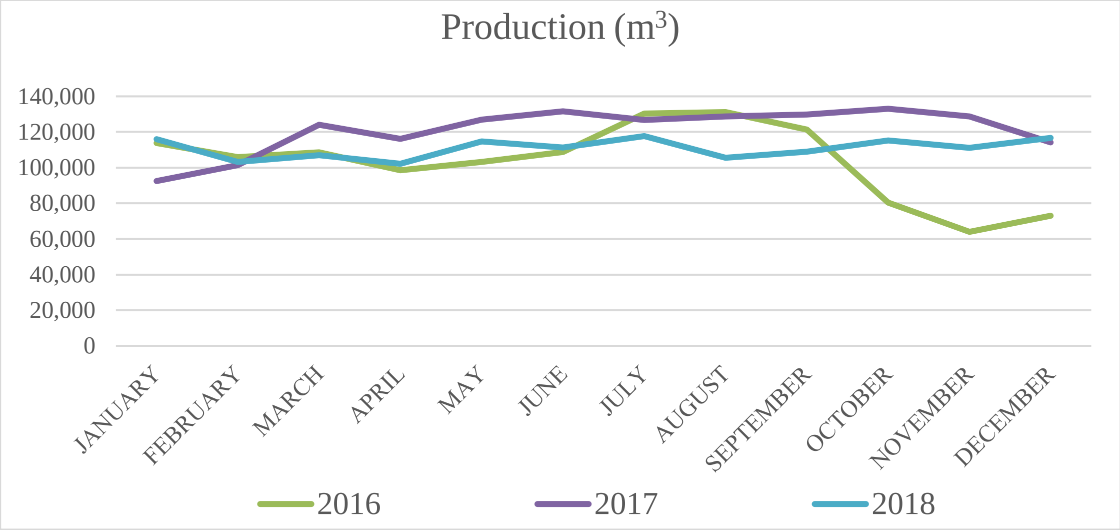

Figure 4.17 Production of Mela WTP

4.3.6.4 Billing

The baseline rate for Mela WTP is 32,194 m^3. Figure 4.18 shows the amount of billing for the Mela WTP from 2016 to 2018. Based on this figure, it shows that the billing rate for this plant increased annually over the three years starting from 484, 817 m^3 in the first year, 530,381 m^3 in the second year and 541,748 m^3 in the third year. The billing increasing rates did not correspond to the production volume. This showed that there are a lot of losses occur that lead to the large different between production and billing.

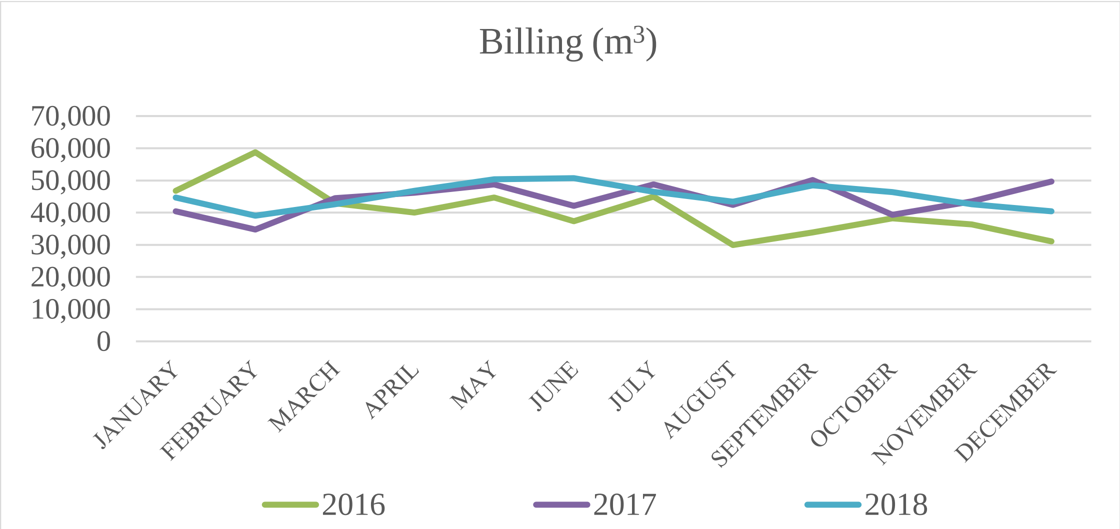

Figure 4.18 Billing of Mela WTP

4.3.6.5 Non-Revenue Water

The NRW baseline for this WTP is 65.91%. Figure 4.19 shows the NRW rate for the Mela WTP from 2016 to 2018. Based on this figure, the NRW rate in 2016 was 59.47%, then the rate increased to 63.26% for the following year before returning to 59.19% in 2018. Despite the billing rate increased over the three-year period, the NRW rate did not show a steady decline. This was due to increase of production and water loss. Although the rate was still high, but it was reduced to 6.72% when compared to the baseline rate. Table 4.13 summarises the losses for each kilometer pipeline for Mela WTP starting from 2016 until 2018. Similar to the rate of NRW, the losses increased in 2017 and decreased in 2018. The sharp increase in 2017 was due to the meter problem and also the losses in the water distribution system. From Table 4.13, the rate of water losses for DMA Kampung Jeram Landak and DMA Kampung Mela was almost similar. This is due to both DMAs had the same total pipe length, but a different number of connections.

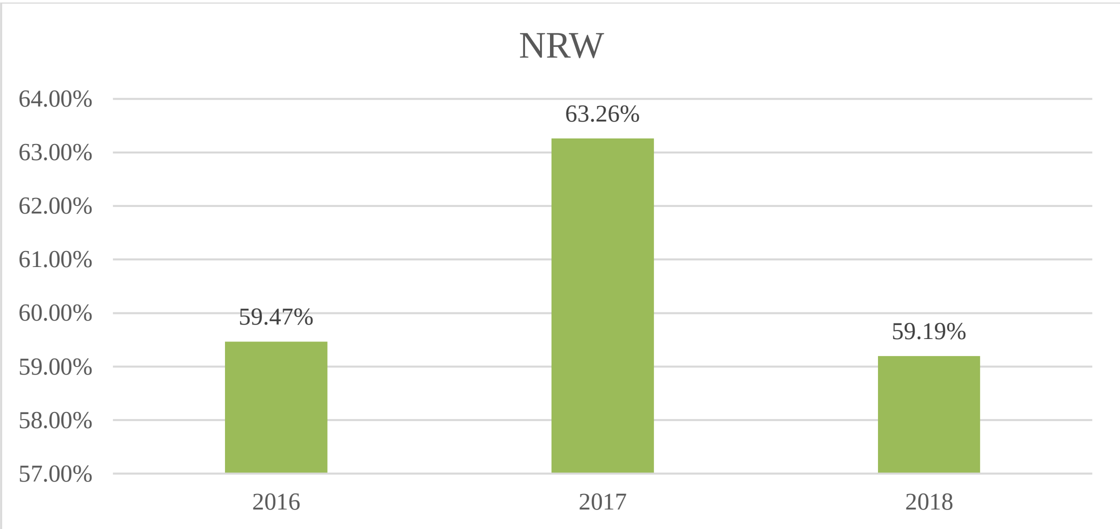

Figure 4.19 NRW of Mela WTP

Table 4.13 Water Losses (m^3/day/km) for Mela WTP

No.	DMA LOCATION	LENTGH (km)	CONNECTION (nos)	2016 PRODUCTION (m^3/year)	2016 BILLING (m^3/year)	2016 LOSSES (m^3/day/km)	2017 PRODUCTION (m^3/year)	2017 BILLING (m^3/year)	2017 LOSSES (m^3/day/km)	2018 PRODUCTION (m^3/year)	2018 BILLING (m^3/year)	2018 LOSSES (m^3/day/km)
				1238887	**484817**		**1453716**	**530381**		**1329332**	**541748**	
1	Kg Limau Purut	6.30	50	49955	19549	13	58618	21386	16	53602	21845	14
2	Kg Jeram Landak	37.10	593	592468	231852	27	695205	253642	33	635721	259078	28
3	Kg Mela	37.10	533	532522	208393	24	624863	227978	29	571398	232864	25
4	Kg Serdang	10.00	64	63943	25023	11	75031	27375	13	68611	27961	11
	TOTAL	90.50	1,240			74			91			78

4.3.7 Merapoh WTP

4.3.7.1 Existing Condition

The Merapoh WTP was built to process and supply clean water for residents around the town. Similar to other plants, this plant also sources its supply from the nearby river. However, the water source for this plant is quite far because there was no suitable area that meets the criteria for placing the WTP. Basically, WTP should be at the high places to allow water to be distributed to consumers by gravity without relying entirely on pumps. The design capacity of this WTP is 120 m^3 per hour but due to plant upgrades and pump conversion, the raw water treated by the plant has increased to 148 m^3 per hour to accommodate the increasing needs of the surrounding population.

4.3.7.2 District Metering Area

This WTP has three DMA branches that fully completed in November 2014 with a 43,270 meter of pipeline involving a 1,023 connector. However, the complete recorded data has begun from year of 2015 onwards. But, in order to standardise the analysis work with other WTP, the analysis was made for three consecutive years, 2016, 2017 and 2018.

Table 4.14 DMA of Merapoh WTP

No.	DMA CODE	DMA LOCATION	PIPE LENGTH (km)	CONNECTION (nos)
1	06 04 001	Pekan Merapoh	18.25	344
2	06 04 002	RPS Merapoh	5.40	331
3	06 04 003	Kg Kubang Rusa	19.62	348
TOTAL			43.27	1,023

4.3.7.3 Production

The production baseline for this plant is 83,161 m^3 per month. Based on Figure 4.20, it shows that production rates in 2018 were lower than in previous years. Based on production baseline and production in January 2016, it showed an increase of 0.19%. The production rate for 2016 was 1,016,183 m^3 in the first year and increased to 1,042,801 m^3 in the second year. After implementing some measures such as pressure control, detecting leakage and pipe repairs, production rates had decreased by 15.38% in 2018.

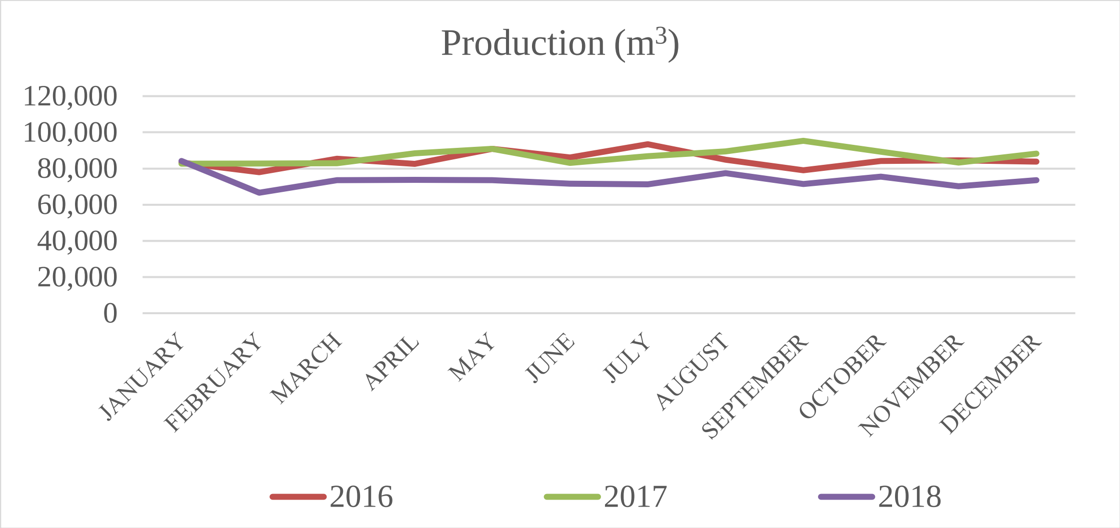

Figure 4.20 Production of Merapoh WTP

4.3.7.4 Billing

The billing baseline for this WTP is 31,516 m^3. Referring to Figure 4.21, the billing rate decreases during the first two years after the establishment of the NRW unit starting with 505,528 m^3 in 2016 and 436,352 m^3 in 2017. After some action taken such as replacement of aging pipeline and pressure management, the rate again rose 2.24%.

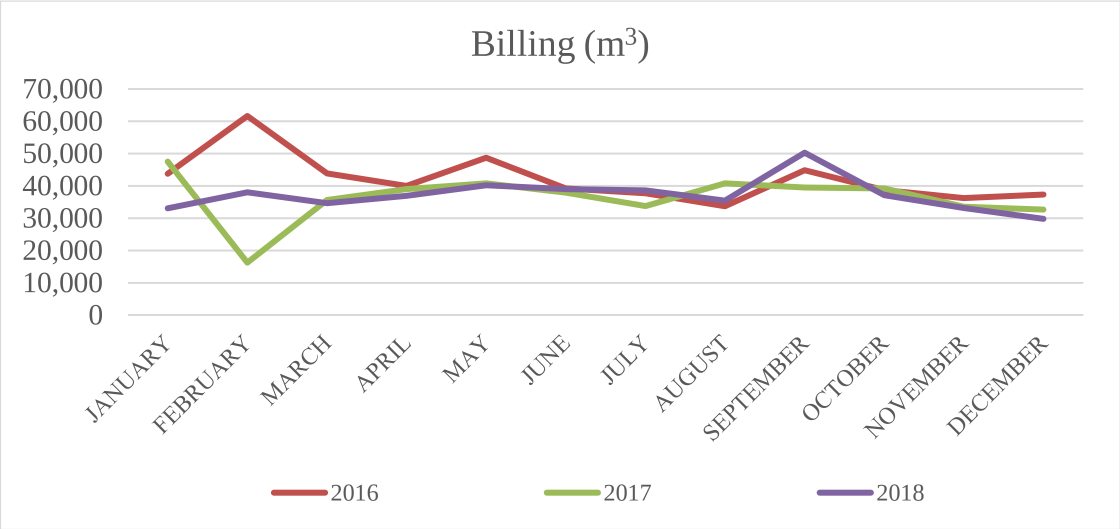

Figure 4.21 Billing of Merapoh WTP

4.3.7.5 Non-Revenue Water

NRW baseline for this WTP is 62.10%. Figure 4.22 shows the rate of NRW for Merapoh WTP over a three-year period from 2016 until 2018. According to the reduction of the billing rate for the first two years, the NRW rate already affected with increasing rate starting with 49.96% in 2016 to 58.19 % in 2017. In 2018, the NRW rates declined by 9.01% due to the increase of billing rates in 2018. Table 4.15 summarises the losses for each kilometer pipeline for Merapoh WTP starting from 2016 until 2018. Based on the table, it shows that the rate of losses for DMA RPS Merapoh was the highest with 84 m^3/day/km for 2016, 100 m^3/day/km for 2017 and 72 m^3/day/km for 2018. Compare that other DMA, this DMA has the shortest total pipe length and the least number of connections. Based on the information from PAIP, beside the leakage of pipe, the losses of this area also occur due to water theft. After taken a few actions, the rate decreased in 2018.

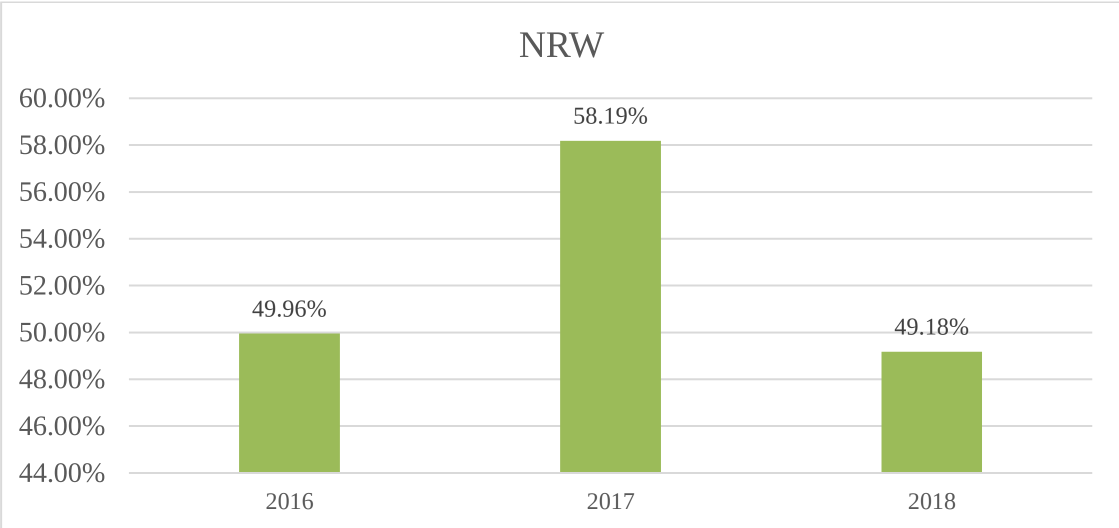

Figure 4.22 NRW of Merapoh WTP

Table 4.15 Water Losses (m^3/day/km) for Merapoh WTP

				2016			2017			2018		
No.	**DMA LOCATION**	**LENTGH**	**CON**	**PRODUCTION**	**BILLING**	**LOSSES**	**PRODUCTION**	**BILLING**	**LOSSES**	**PRODUCTION**	**BILLING**	**LOSSES**
		(km)	**(nos)**	**(m^3/year)**	**(m^3/year)**	**(m^3/day/km)**	**(m^3/year)**	**(m^3/year)**	**(m^3/day/km)**	**(m^3/year)**	**(m^3/year)**	**(m^3/day/km)**
				1,016,183	**505,528**	**m3/day/km**	**1,042,801**	**436,352**	**m3/day/km**	**882,461**	**446,161**	**m3/day/km**
1	Pekan Merapoh	18.25	344	341,708	169,992	26	350,658	146,730	31	296,742	150,029	22
2	RPS Merapoh	5.40	331	328,794	163,568	84	337,407	141,185	100	285,528	144,359	72
3	Kg Kubang Rusa	19.62	348	345,681	171,968	24	354,736	148,436	29	300,192	151,773	21
	TOTAL	43.27	1,023			134			159			114

4.3.8 Sungai Temau

4.3.8.1 Existing Condition

Sungai Temau WTP is the second smallest treatment plant after the Batu 9 plant for this district. The WTP operates to provide clean water to residents around the area. The area is moderately proportionate as it is the FELCRA and FELDA area. Most areas are used for plantation and agricultural activities such as oil palm cultivation. The raw water source for this plant is obtained from the river located behind this plant. Design capacity for this plant is 78 m^3 per hour but the treatment process involves only 60 m^3 per hour depending on the needs of the surrounding population. Due to the small service area and the small population, the plant works only for 12 hours every day.

4.3.8.2 District Metering Area

Sungai Temau WTP only has one DMA branch involving 4,830 meters long pipes line and 416 connectors that used to provide clean water to consumers. Similar to other DMA installed, the DMA for this area was also completed in November 2014 and the complete recorded data also had begun from 2015 onwards.

Table 4.16 DMA of Sungai Temau WTP

No.	DMA CODE	DMA LOCATION	PIPE LENGTH (km)	CONNECTION (nos)
1	06 05 001	Felda Chegar Perah	14.83	416
TOTAL			14.83	416

4.3.8.3 Production

Figure 4.23 shows the three-year production rate for the Sungai Temau WTP starting from 2016 until 2018. The baseline production for this plant is 51,589 m^3. Based on this figure and baseline rate, it shows the production for each year decreased by 12.49% from the first year to the second year. Then, continuously decreased to 4.90% in the third year making the total production of 353,565 m^3 as compared to 370,715 m^3 for the previous year.

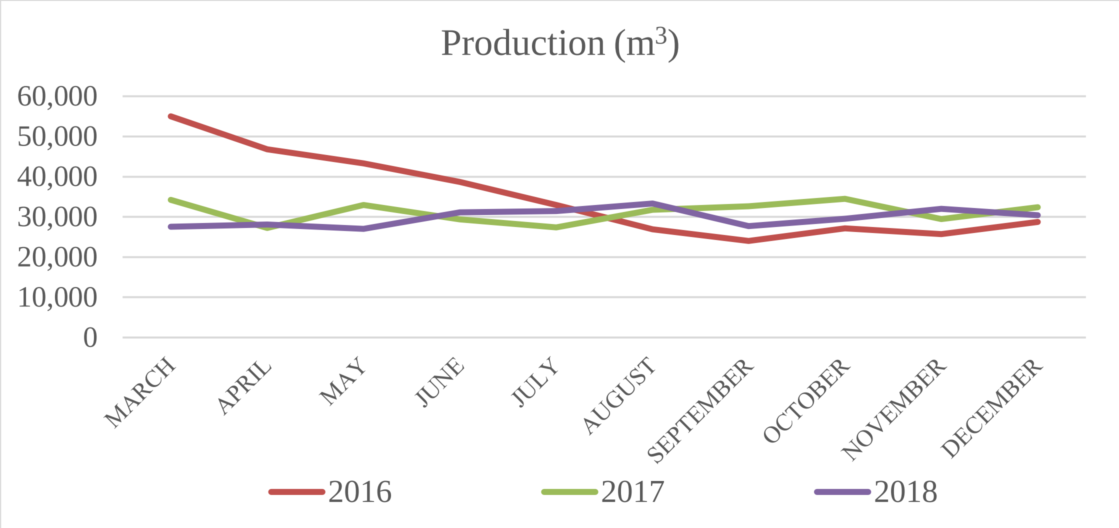

Figure 4.23 Production of Sungai Temau WTP

4.3.8.4 Billing

The billing baseline for Sungai Temau WTP was 11,692 m^3. According to Figure 4.24, it shows that the billing rate was 202,296 m^3 in 2016, 159,779 m^3 in 2017 and 173,326 m^3 in 2018. It showed a decline in the first two years and then increased during the third year. From this figure, it shows that there was a decrease rate of billing in February 2017, the lowest rate of the three years, and this was due to data handling error.

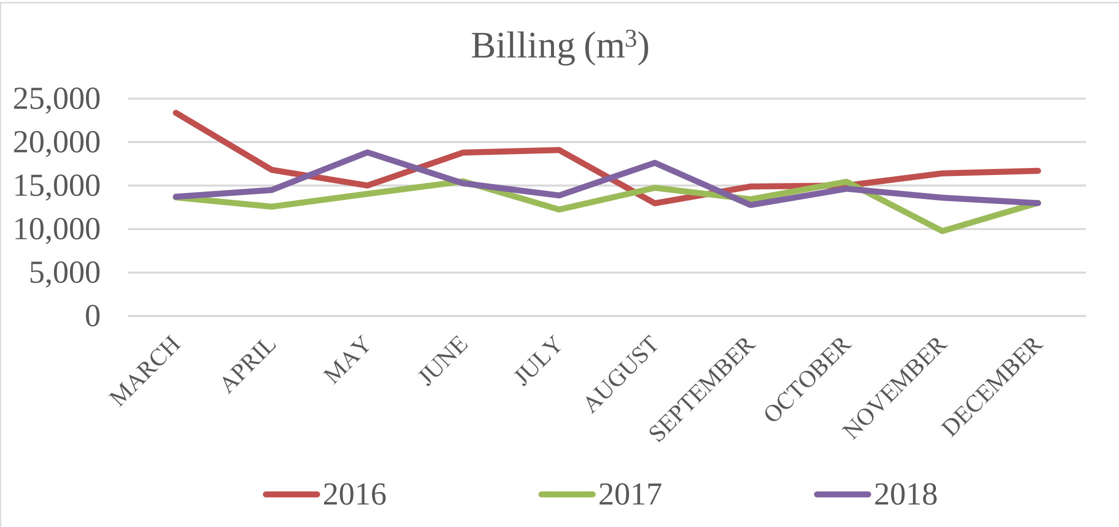

Figure 4.24 Billing of Sungai Temau WTP

4.3.8.5 Non-Revenue Water

NRW baseline for Sungai Temau WTP is 77.34%. Based on Figure 4.25, the rate of NRW for this treatment plant is uneven due to the decline from year to year. In 2016, the NRW rate for this WTP is 50.27% then increased to 56.75% by 2017. However, in 2018 the rate returned decrease to 50.63%. Although the rate is still high, there was a decline in comparison to the baseline rate. Table 4.17 summarises the losses for each kilometer pipeline for Sungai Temau WTP starting from 2016 until 2018. Even this WTP only has one DMA on that of Batu 9 WTP, but the rate of water losses for this DMA still high since the coverage area is wide with 416 accounts of connections.

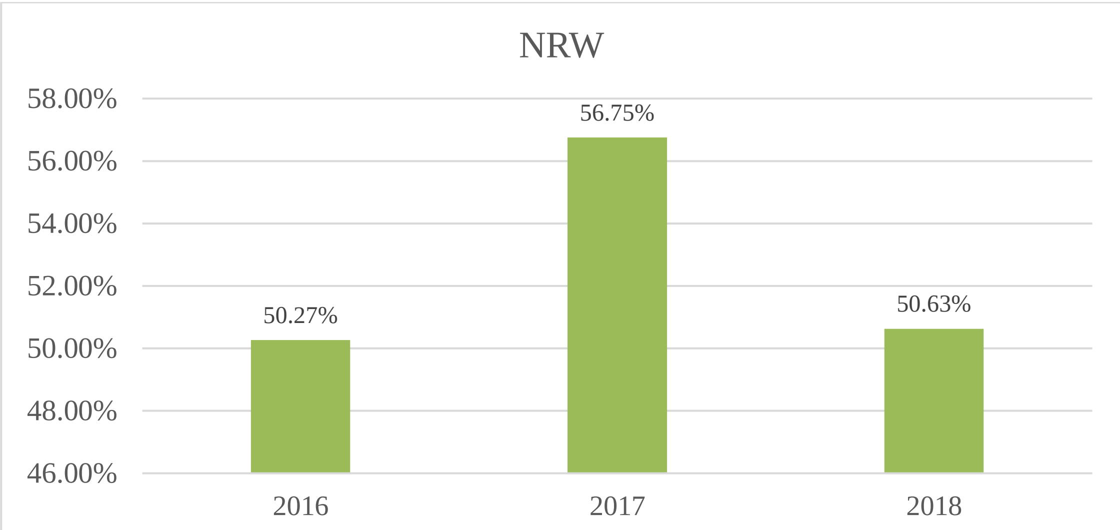

Figure 4.25 NRW of Sungai Temau WTP

Table 4.17 Water Losses (m^3/day/km) for Sungai Temau WTP

				2016			2017			2018		
No.	**DMA LOCATION**	**LENGTH (km)**	**CONNECTION (nos)**	**PRODUCTION (m3/year)**	**BILLING (m3/year)**	**LOSSES (m3/day/km)**	**PRODUCTION (m3/year)**	**BILLING (m3/year)**	**LOSSES (m3/day/km)**	**PRODUCTION (m3/year)**	**BILLING (m3/year)**	**LOSSES (m3/day/km)**
				423,646	**202,296**		**370,715**	**159,779**		**352,565**	**173,326**	
1	Felda Chegar Perah	14.83	416	423,646	202,296	41	370,715	159,779	39	352,565	173,326	33

4.3.9 Batu 9 WTP

4.3.9.1 Existing Condition

The Batu 9 WTP is the smallest plant in the district with a design capacity of only 20 m^3 per hour. However, this plant only processes 12.50 m^3 per hour to provide water to residents around the area with an operating hour of 12 hours daily. The intake of this WTP is also located next to the WTP. Almost all water components for this plant are compacted in a container except for clean water tanks. Although the capacity for this plant is too small, the WTP still needs to operate as no nearby WTP around this area. The hilly physical topography makes it less possible for other WTP to supply water to consumers in that area.

4.3.9.2 District Metering Area

Batu 9 WTP only has a single DMA which was set up in November 2014. The total length of the pipe involved is only 9,500 meters with 112 connectors. However, the complete recorded data had begun from year of 2015.

Table 4.18 DMA of Batu 9 WTP

WTP	DMA CODE	DMA LOCATION	PIPE LENGTH (km)	CONNECTION (nos)
1	06 03 001	Batu 9	9.50	112
TOTAL			9.50	112

4.3.9.3 Production

Figure 4.26 shows the production rate for Batu 9 WTP starting on year of 2016 until 2018. Baseline production for this plant is 5,066 m^3 per month. The average production for each year was different, from 67, 576 m^3 in 2016, 58, 535 m^3 in 2017 and to 66,719 m^3 in2018. The average production for this plant is reduced from the first year to the second year. However, there was an increase of 12.27% in 2018 the cause the rate increase to 66, 719 m^3.

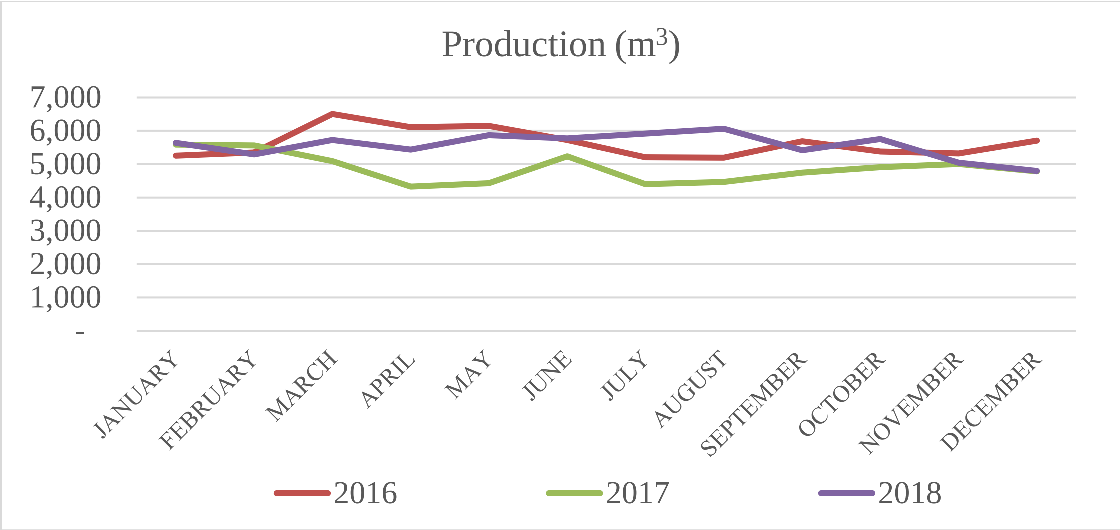

Figure 4.26 Production of Batu 9 WTP

4.3.9.4 Billing

Figure 4.27 shows the billing rate for Batu 9 WTP. Same goes to other WTP, billing rates are constantly changing from month to month. Billing baseline for this WTP is 3,251 m^3. There was an increase of 2.71% when compared to the baseline billing rate and the billing rate for January 2016. The billing rate for this WTP dropped evenly for two consecutive years starting with 45,802 m^3 in 2016 and 42, 852 m^3 in 2017. After two years of decline, the billing rate for this WTP rose 2.93% to 44, 146 m^3 by 2018.

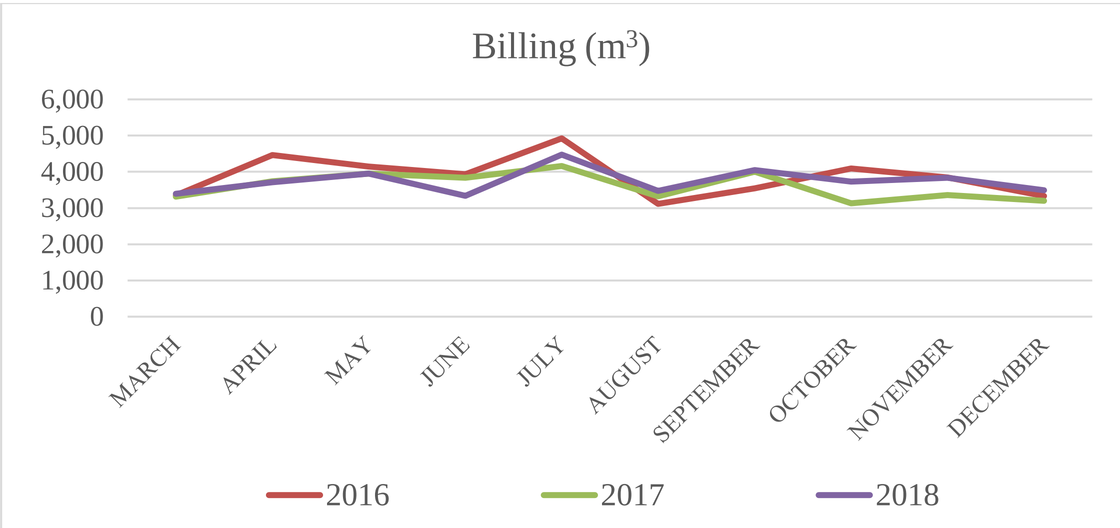

Figure 4.27 Billing of Batu 9 WTP

4.3.9.5 Non-Revenue Water

Figure 4.28 shows the NRW rate for three consecutive years, 2016, 2017 and 2018 for the Batu 9 WTP. The NRW baseline for this WTP was 35.83%. Referring to the baseline rate and information from this figure, it shows a decrease of 3.95% for the first year. Besides that, the rate also decreased for the second year to 26.02%. However, due to leakage problem, the rate of NRW rose to 33.65% in 2018. Table 4.19 summarise the losses for each kilometer pipeline for Batu 9 WTP starting from 2016 until 2018. DMA for Batu 9 WTP shows the lowest water losses per kilometer pipe since this WTP covers the smallest area compare with other WTPs. Therefore, the rate of water losses can easily be controlled.

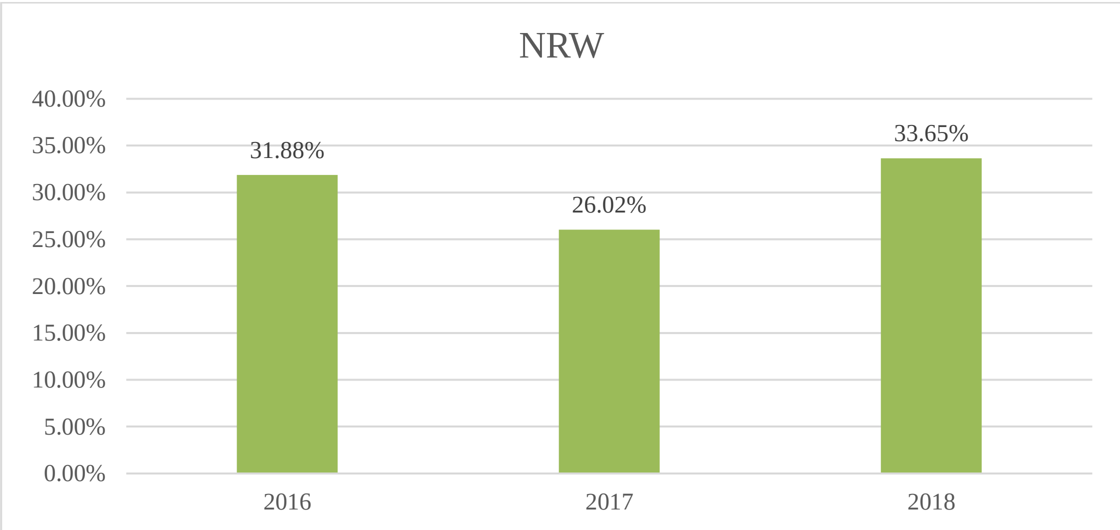

Figure 4.28 NRW of Batu 9 WTP

Table 4.19 Water Losses (m^3/day/km) for Batu 9 WTP

				2016			2017			2018		
No.	**DMA LOCATION**	**LENGTH (km)**	**CONNECTION (nos)**	**PRODUCTION (m^3/year)**	**BILLING (m^3/year)**	**LOSSES (m^3/day/km)**	**PRODUCTION (m^3/year)**	**BILLING (m^3/year)**	**LOSSES (m^3/day/km)**	**PRODUCTION (m^3/year)**	**BILLING (m^3/year)**	**LOSSES (m^3/day/km)**
				67,576	**45,802**		**58,535**	**42,852**		**66,719**	**44,146**	
1	DMA.LPS.BATU 9-Batu 9	9.50	112.00	67,576.35	45,802	6	58,535	42,852	5	66,719	44,146	7

4.4 Summary

Figure 4.29 to Figure 4.37 summarize the production, billing and NRW for all WTP in Kuala Lipis district. The Jelai WTP showed a steady decrease in NRW. It shows that mostly the rate of NRW for 2017 is higher than other years. It is occurred due to the meter problem and data handling error. Compare to other WTP, the Jelai WTP showed the smooth decreasing rate of NRW. The Jelai WTP supplies clean and safe water around the Kuala Lipis city and covered the highest population area. Therefore, this WTP is given priority over other WTPs because high levels of leakage give a significant impact to the consumers which leads to insufficient amount of water supply. Based on the nine WTP, Batu 9 is the smallest WTP with the design capacity of 20 m^3 per hour. Even though this WTP has a small capacity and located at hilly area, the need to establish the water supply is mandatory. If other WTP supply to this area, a long pipe is required but not economical.

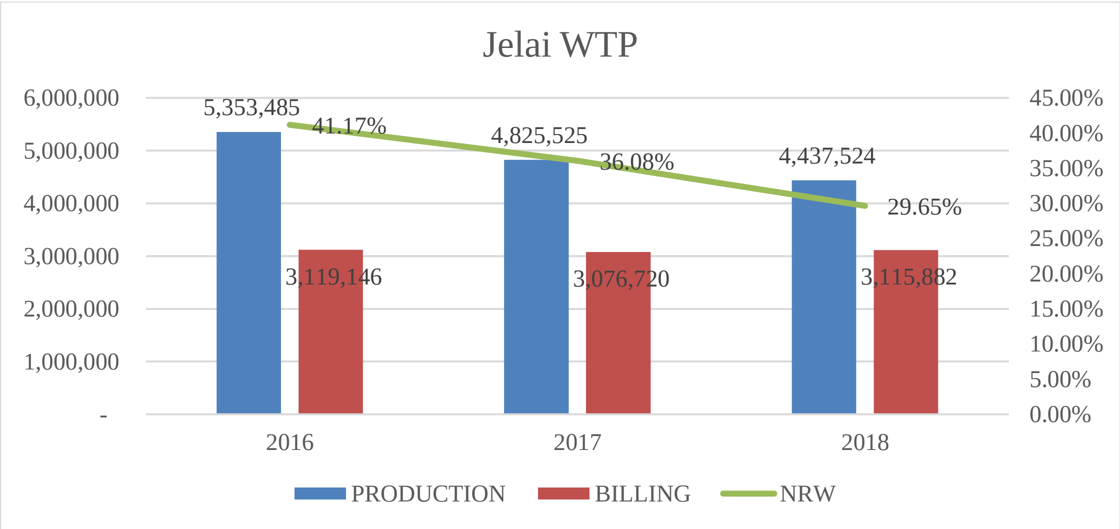

Figure 4.29 Summary of Production, Billing and NRW for Jelai WTP

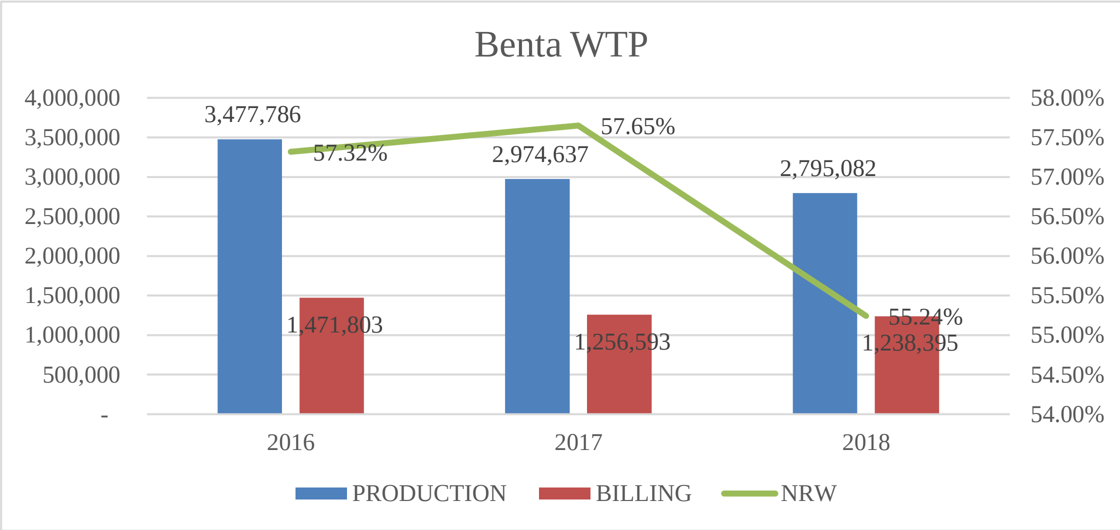

Figure 4.30 Summary of Production, Billing and NRW for Benta WTP

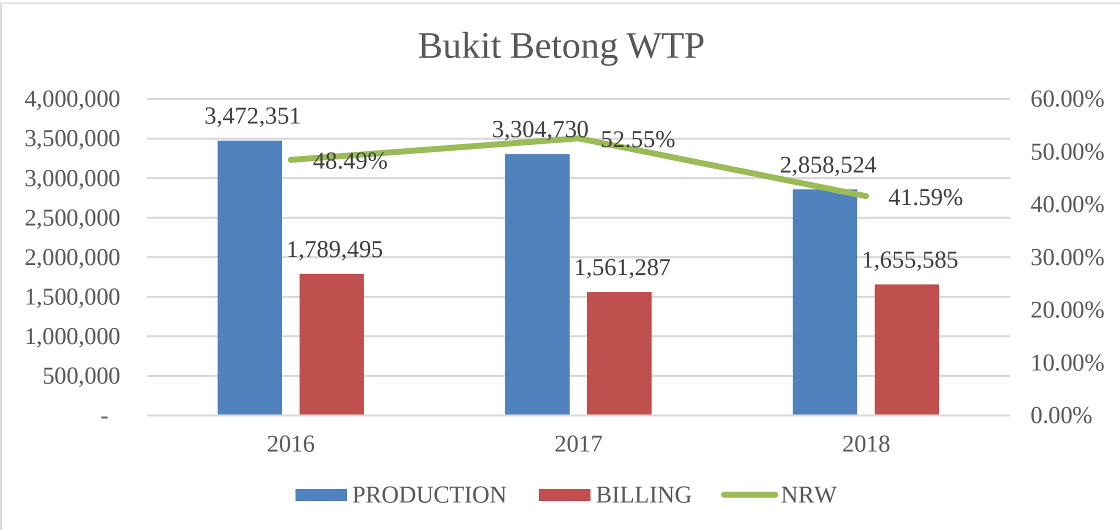

Figure 4.31 Summary of Production, Billing and NRW for Bukit Betong WTP

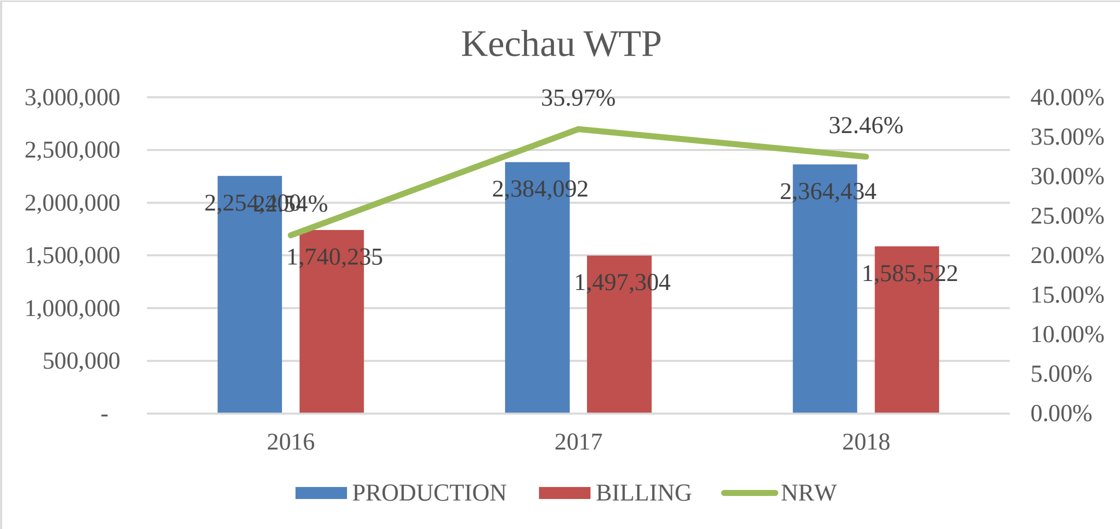

Figure 4.32 Summary of Production, Billing and NRW for Kechau WTP

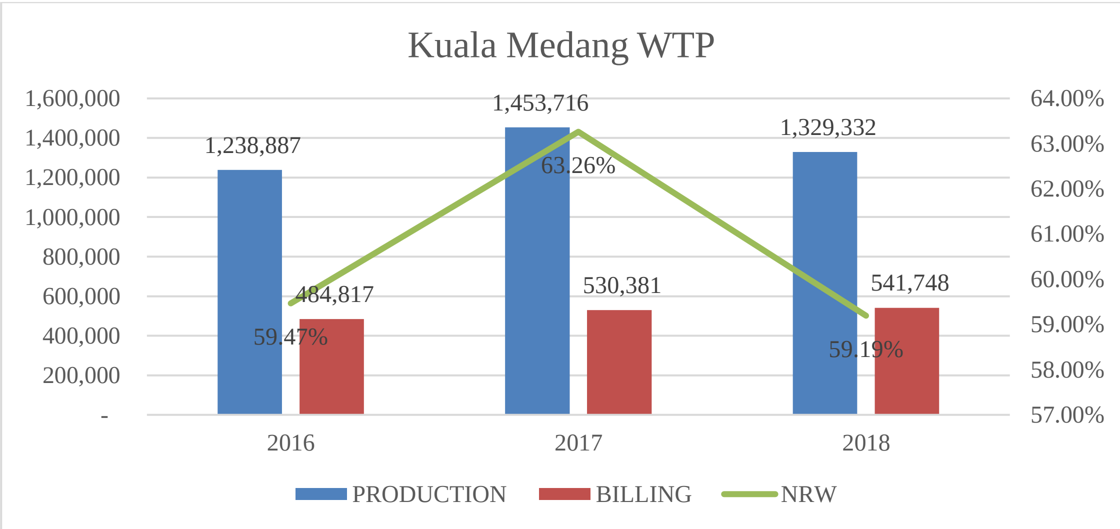

Figure 4.33 Summary of Production, Billing and NRW for Kuala Medang WTP

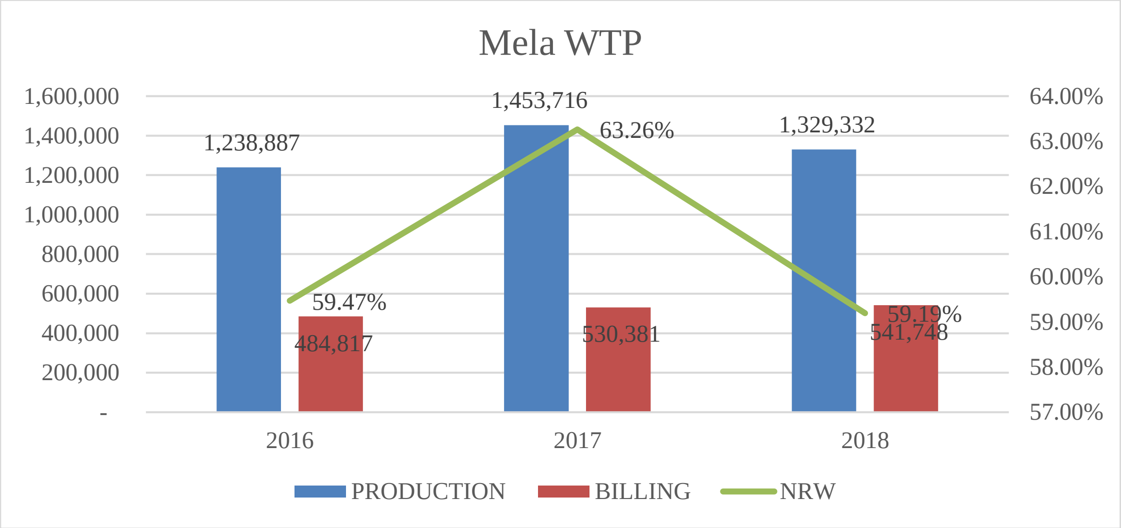

Figure 4.34 Summary of Production, Billing and NRW for Mela WTP

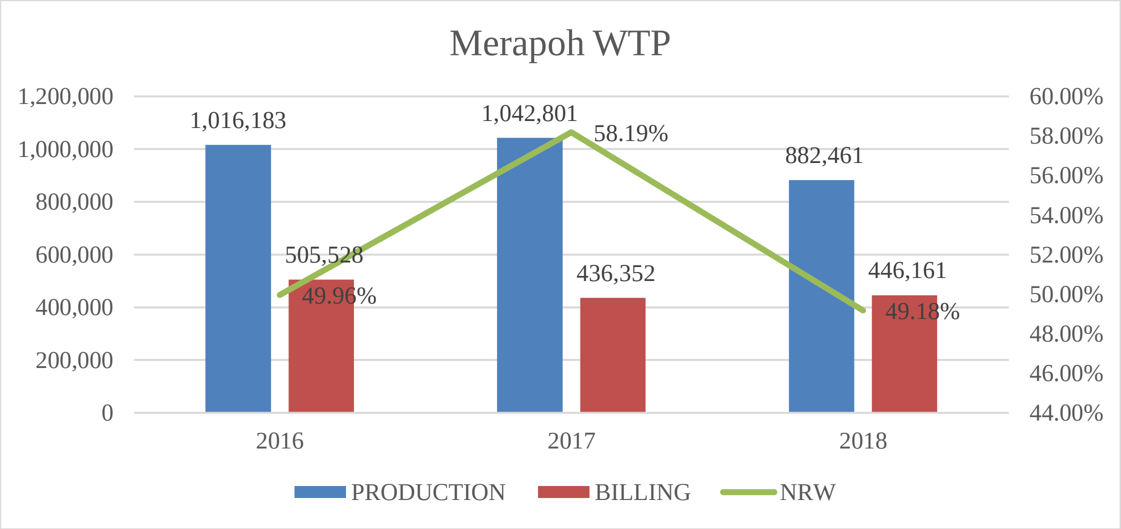

Figure 4.35 Summary of Production, Billing and NRW for Merapoh WTP

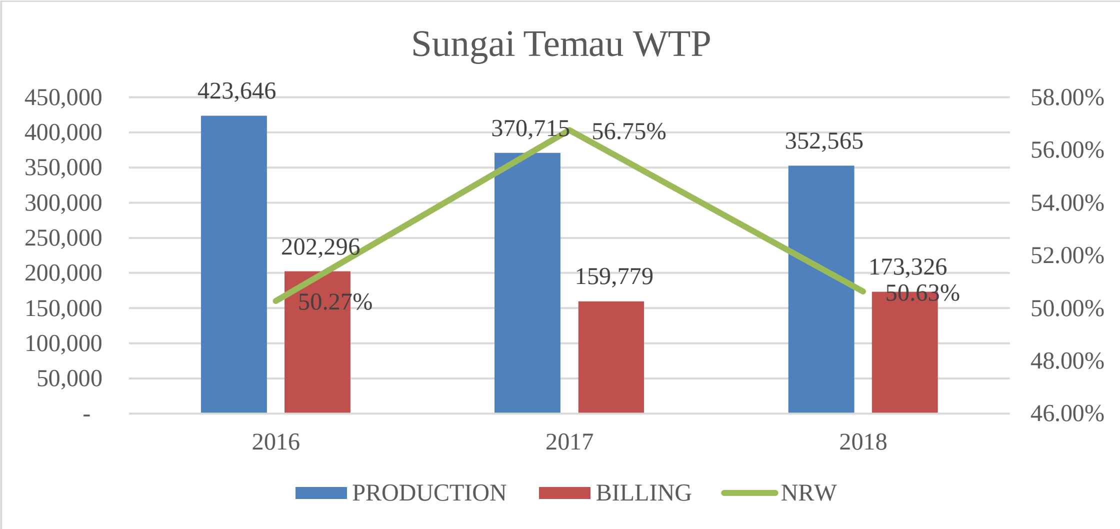

Figure 4.36 Summary of Production, Billing and NRW for Sungai Temau WTP

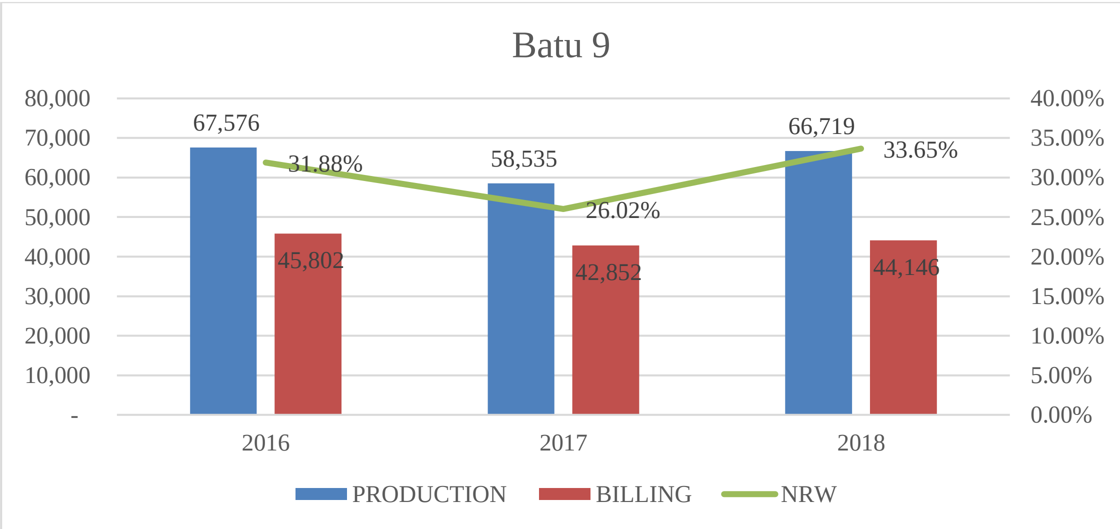

Figure 4.37 Summary of Production, Billing and NRW for Batu 9 WTP

Figure 4.38 summarizes the rate of production versus billing for 2016 until 2018. Even though the productions changed, the billing remain unchanged. These were reflected in the NRW trend for all the WTP as shown in Figure 4.40.

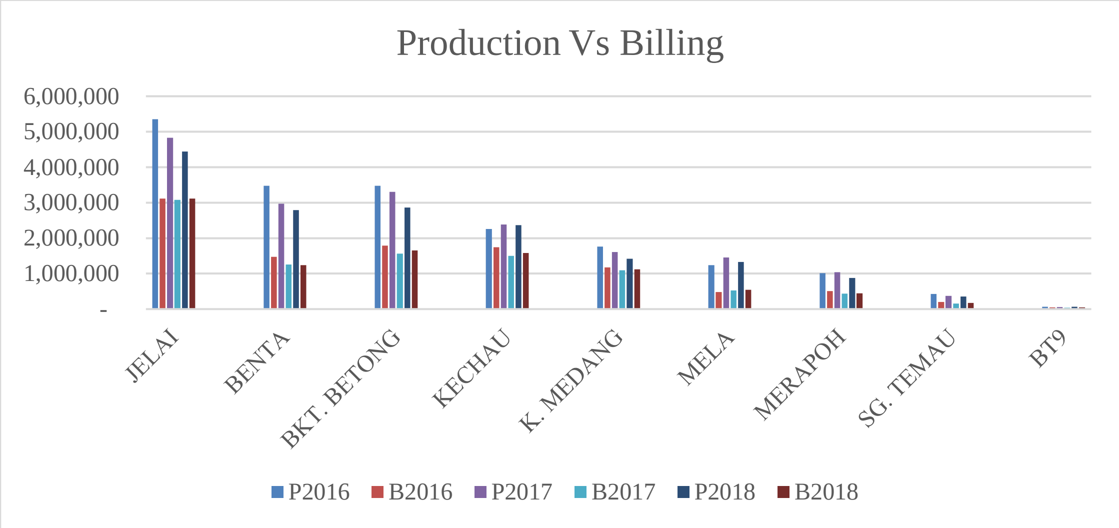

Figure 4.38 Summary of Production and Billing for All WTP

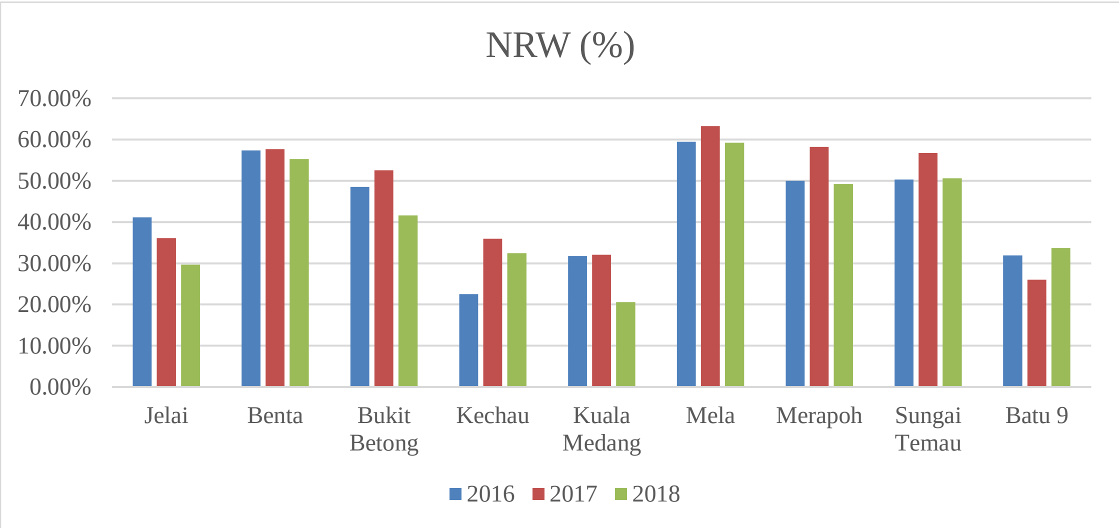

Figure 4.39 Summary of NRW for all WTP

Figure 4.41 shows the summary of water losses for each kilometer pipeline per day for each WTP. Based on that figure, it shows that the amount of water losses in each kilometer pipe is directly proportional to the rate of NRW because it is a part of NRW components

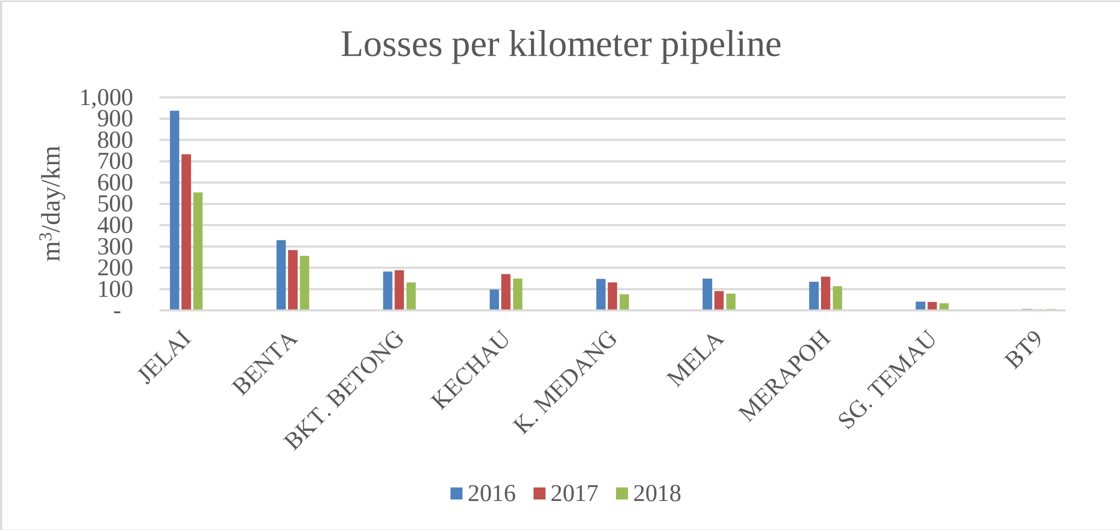

Figure 4.40 Summary of Losses for each Kilometer Pipeline

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The objectives of this study were achieved through the study of NRW at Kuala Lipis, Pahang. The analysis made based on the data and information obtained from PAIP Kuala Lipis, components of NRW, volumes of water and NRW management. The analysis for the volume of water was based on the volume of production, billing and NRW for each nine WTP around Kuala Lipis area for three consecutive years (2016 until 2018) after the establishment of NRW unit.

5.2 Conclusion

The following section summarised the conclusion based on the objectives set earlier.

5.2.1 To Identify the Components that Contribute to NRW at Kuala Lipis

Generally, based on the standard water balance there were three components of NRW that consist of physical losses, commercial losses and unbilled authorised consumption. Based on the analysis made, it shows that the main factor that contributed to water losses is the physical losses as proven by the analysis of water losses for each kilometre pipe of each WTP in the previous chapter. It shows that there was 2,027 m^3 of water losses occur per day for each kilometer pipe for the year of 2016, 1,800 m^3 for the year of 2017 and 1397 m^3 for the year of 2018. It is about 5,224 m^3 of water loss every day in each kilometre pipe along these three consecutive years.

5.2.2 To Compare Flow Before and After NRW Unit Establishment

In order to compare flow before and after NRW unit establishment, the analysis made based on the volume of production, billing and NRW for each WTP for three years (2016 until 2018) after the establishment of NRW unit. The comparison of the flow was made based on the baseline rate before the establishment of NRW management. Referring to trend of NRW for all nine WTP, it shows that the rate of NRW varies from year to year. The rate of NRW are directly proportional to the production and billing rate. There was a lot of difference between the production and billing that occur due to water losses.

From all WTP around Kuala Lipis area, only Jelai WTP shown consistence decrease of NRW. This situation occur due to Jelai WTP is the priority since it functions to supply the clean and safe water to the Kuala Lipis city with the highest population rate when compare than others WTP. The highest rate of water losses may lead to insufficient water supply for surround population. Normally, any improvement of the NRW for certain area would focused the area of large population. Therefore, the overall monitoring and management started at the Jelai WTP which provide supply to the town. For other WTP, the overall monitoring and management would be carried out according to priority due to lack of manpower.

5.3 Recommendations

The study of NRW at Kuala Lipis has provided a clear picture on NRW and the importance of controlling the rate of NRW. Controlling the rate of NRW is the responsibility of all parties and not only for water utilities. Even though a lot of raw water sources are available, the need to reduce the daily rate of wastage is necessary since the entire proses of treating water consumed a lot of money. For the water utilities, even the NRW unit had been established with the establishment of DMA, the NRW unit need to improve their efforts in managing the rate of NRW to ensure the rate of NRW for entire Kuala Lipis area be reduced consistently and able to achieve the national standard of NRW between 30% to 35%. Table 5.1 provides some suggestion that needs to put in place in order to control the rate of NRW.

Table 5. 1 List of Recommendations

No.	Type of Recommendations	Reasons
1	Replacement of aging pipe infrastructure.	Minimize the water losses due to leakage of pipe.
2	Replacement of aging meter consumers.	Avoid the unbilled authorised consumption.
3	Increase manpower for maintenance.	Ensure the pipe leakage can be repaired immediately.
4	Improve recording system management.	Detect any missing data. Update and upgrade data. Facilitate in identifying the root and losses of water.
5	Bulk meter installation.	Help to monitor the flow.
6	Pressure control.	Help to reduce leakage.
7	Leakage monitoring system.	Identify the water losses.
8	Overflow control system.	Avoid tank overflow.
9	Allocate monetary budget for pipe replacement and maintenance.	Replace aging pipe infrastructure.

REFERENCES

Anon., 2017. *KeTTHA to introduce new non-revenue water policy,* Kuala Lumpur: The Mlaysian Reserve.

Dhar, D., 2011. *Fluid Flow,* Indian: s.n.

Farley, M., 2001. *Leakage management and control : a best practice training manual.* s.l.:World Health Organization.

Farok, G., 2017. A case study of Dhaka Water Supply System Management. *Non-Revenue Water (NRW) is a challenge for Global Water Supply System Management.*

Guo, P., 2016. *Major and Minor Losses.* [Online]
Available at: https://studylib.net/doc/10130722/major-and-minor-losses
[Accessed 2018].

JPS Lipis, 2012. *Peta Lokasi Daerah Lipis.* Kuala Lipis: JPS Kominiti.

KDF Fluid Treatment, I., 2018. *POE or POU?.* [Online]
Available at: http://www.kdfft.com/POEorPOU.htm

Lai Chee Hui, C. N. W. a. N. A. Z., 2013. A Review of Selected Water Service Providers in Malaysia. *Non-revenue Water Management in Malaysia,* Volume 1, pp. 7-17.

Liemberger, F. a., 2010. *The Issues and Challenges of Reducing Non-Revenue Water,* s.l.: s.n.

PAIP Lipis, 2016. *Yearly Report,* Kuala Lipis: NRW unit.

PAIP Lipis, 2017. *Yearly Report*, Kuala Lipis: NRW unit.

PAIP Lipis, 2018. *Yearly Report*, Kuala Lipis: NRW unit.

PAIP, 2018. [Interview] 2018.

Simbeye, I., 2010. *Managing Non-Revenue Water,* Germany: Rackwitz.

SPAN, 2018. *Rate of NRW,* Kuantan: s.n.

Spuhler, G. a., 2018. *Water Distribution Pipes,* s.l.: s.n.

The Star Online, 2019. *Minister: NRW rate must be reduced,* Kuantan: The Star Online.

Yafei Hu, D. W. a. R. C., 2013. *Long Term Performance of Asbestos Cement Pipe ,* North America: Water Research Foundation.

Yunus A. Chengel, J. M. C., 2014. *Fluid Mechanics.* Third Edition ed. s.l.:s.n.