IDENTIFICATION OF EFFECTIVE TECHNIQUE TO ESTIMATE WATER LOSS IN WATER SUPPLY SCHEME: A CASE STUDY OF USM ENGINEERING CAMPUS

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SCHOOL OF CIVIL ENGINEERING
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by

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LIST OF ABBREVIATIONS

IWA	International Water Association
JPPA	Jabatan Pembangunan dan Pengurusan Aset
MWA	Malaysian Water Association
NRW	Non-Revenue Water
NRWL	Non-Revenue Water Level
PBAPP	Perbadanan Bekalan Air Pulau Pinang
SPAN	Suruhanjaya Perkhidmatan Air Negara
USM	Universiti Sains Malaysia

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ABSTRAK

Rangkaian pengagihan air mungkin melihat penjimatan yang ketara daripada mengurangkan air tidak terhasil (NRW). Majoriti cenderung untuk menumpukan pada aspek reka bentuk dan pelaksanaan untuk mengurangkan kehilangan NRW dengan mengawal kebocoran, limpahan takungan dan kecurian air dengan lebih baik. Sebaliknya, pilihan mengenai pembaikan atau pemodenan rangkaian air harus dibuat selepas meneliti kehilangan air. Kajian ini bertujuan untuk mengenal pasti kemungkinan punca kehilangan air dan membandingkan kehilangan air dalam sistem bil air dalam tempoh lima tahun. Rangkaian yang dibandingkan berkongsi beberapa ciri, seperti nilai penunjuk keamatan air. Keputusan analisis dilakukan untuk menentukan kadar peratusan kehilangan air dalam tempoh lima tahun. Analisis dilakukan menggunakan indeks kehilangan air yang disyorkan oleh IWA, seperti Paras Air Bukan Hasil (NRWL); Kaedah Pertambahan Geometri telah digunakan untuk menentukan pertambahan penduduk pada masa hadapan dan meramalkan kehilangan air pada masa hadapan. Di banyak negara, termasuk Malaysia, pendekatan yang disyorkan IWA semakin popular. Mengikut keputusan, kehilangan air dalam kedua-dua sistem adalah kurang daripada yang terdapat dalam data untuk rangkaian lain yang mempunyai jenis yang sama dalam literatur.

ABSTRACT

Water distribution networks may see significant savings from reducing non-revenue water (NRW). The majority tends to concentrate on the design and implementation aspects of reducing NRW loss by better controlling leaks, reservoir overflows, and water theft. In contrast, choices about repairing or modernisation a water network should be made after examining water losses. The study aims to identify the possible cause of water loss and compare water losses in water bill systems over five years. The compared networks share several characteristics, such as the water intensity indicator value. The analysis results were performed to determine the percentage rate of water loss in five years. Analysis was done using IWA-recommended water losses indices, such as Non-Revenue Water Level (NRWL); Geometrical Increase Method was used to determine the future increment in population and predict the water loss in the future. In many countries, including Malaysia, the IWA-recommended approach is becoming increasingly popular. According to the results, water losses in both systems are less than those found in the data for other networks of a similar type in the literature.

CHAPTER 1

INTRODUCTION

1.1 Background

Many countries around the world are concerned about Non-Revenue Water (NRW) (Jabari, et al., 2017). Due to the high NRW loss, the amount spent on operating and maintenance costs to provide uninterrupted water delivery to end-users has increased significantly. The "difference between the volume of water distributed by the system and the volume billed to customers" is defined as NRW. High NRW could imply a significant quantity of water loss before it reaches end-users, resulting in higher financial losses. According to the International Water Association (IWA), poor water resource management is one of the reasons for NRW rates.

Physical (or real) losses, commercial (or apparent) losses, and unbilled allowed usage are all components of NRW. Physical water losses from leaks in areas of the distribution system or overflow at storage tanks are reflected in real losses. Poor operations and maintenance, a lack of active leak management, and the degradation of subsurface assets are all major causes of leaks and overflows. Water/drainage/sewerage, electricity, gas, and communications are examples of subsurface assets (NSW et al., 2007). Water metering mistakes, billing irregularities, and unlawful consumption, such as water theft, are examples of commercial losses, sometimes known as apparent losses. Water metering errors account for a significant share of commercial losses (Criminisi, et al., 2009). Furthermore, unbilled approved consumption refers to valid water use that is neither billed nor metered. Water usage for firefighting, flushing of mains and sewers, street cleaning, frost protection, and supply of discounted water due to government policy are all examples of legitimate consumption.

Through sophisticated water management systems, countries like Singapore and Japan have been able to drastically reduce their NRW rates (Kangangi, et al., 2015). Other research has found that good water management is critical to reducing NRW losses (Murugan, et al., 2019). However, due to the technical difficulties and complexities of NRW management, ongoing improvement of NRW loss remains a challenge in many countries. NRW continues to be a problem, particularly in Malaysia. One of the key contributors to this problem is a lack of public knowledge of the severity of the NRW problem, as well as a belief that such a situation is solely the responsibility of the water authorities (Chan, et al., 2017). Furthermore, the lack of a unified government policy on water security, as well as funding constraints, stymie the implementation of NRW reduction projects (Chan, et al., 2020).

This research focuses on the calibration of various water leakage variables at USM's engineering campus, including quantification, addressing water loss components, and potential for both water loss and revenue loss in the study area using calculations based on Real Loss Performance Indicators that were recognized by the IWA and AWWA (Lambert, A. et al., 2003). Additionally, certain suggestions and solutions could help to reduce water leakage in order to conserve natural resources and energy, which would benefit the government, organizations, and ecology. This study also provides a pathway for a second research goal with distinct factors for a different form of institution or organization in developing nations dealing with a comparable circumstance.

1.2 Problem Statements

According to Penang Water Supply Corporation (PBAPP), and the National Water Services Commission (SPAN), there are 14 areas in Nibong Tebal involving a total of 6,612 accounts, and over 33,000 residents were identified including Engineering Campus, USM as locations that often experience water supply disruption and low water pressure problems with most of them being at high elevation or at the end of the distribution pipes (Bernama et al., 2022)

There are some possible factors that may cause the water loss such as high leakage and pipe failure (due to unmaintained maximum pressure) as well as provision of insufficient supply (due to unmaintained minimum pressure) are scenarios that spread water deficit within the distribution system (Abera, et al., 2018).

Additionally, in order for the relevant action to be done, it was necessary to determine the different methods for estimating non-revenue water by utilizing an appropriate indication (Van Beek, et al., 2017). The other methods were approached due to a lack of specialized measurement equipment and funding for installing sensors that can detect and quantify the water loss at a particular place (Bhagat, et al., 2019).

Assessment of future water demand is a vital and critical element in any water resources study, therefore determining current water and fire demand projections at engineering campus is necessary. The current water supply system must be evaluated, as well as the pipeline networks so that the results of this study can identify whether the water distribution system is efficient or not.

1.3 Objectives

The objectives of this study are:

1. To identify the possible causes of water losses and solution in engineering campus, USM.
2. To assess different method to estimate non-revenue water.
3. To evaluate current water supply demand and pipeline system in engineering campus, USM.

1.4 Scope of Work

In this project, the main goal of this study was to figure out what was causing the water losses and what might be done about it by comparing water bills and estimating physical losses. The examination was conducted throughout the USM Engineering campus area, and the volume of water delivered and the percentage of losses were calculated by using utilizing an appropriate indication.

The next step is to use the Water demand and Consumption approach to determine the population of the area and usage of water that the consumers used. This method can be used to determine how the water flows in the distribution system and water consumption during the 5 years.

Finally, using the modelling software Bentley Water CAD V8i, assess the current water supply system of pipeline networks. This software was made with the purpose of establishing a pressure regime for customer demand, velocity, and head loss, as well as systematically studding and better understanding network operation.

1.5 Dissertation Outline

The dissertation for this project consist of 5 chapters, namely Introduction, Literature Review, Methodology, Results and Discussion, and Conclusion. Chapter 1 of this dissertation provide an insight on the background of study, problem statements, objectives, scope of work as well as dissertation outline.

While Chapter 2 compiles the literature review, and breakdowns the research topic into several components while past study and research findings related to each component are discussed.

Next, the methods used to carry out this project are then detailed in detail in Chapter 3. All of the changes made to the methodology method are documented with suitable explanations, and the flow of data collection, analysis, and presentation is also covered.

Followed by Chapter 4, all of the study findings are reviewed, and a discussion is held to discover relevant trends, patterns, and explanation behind this effort.

Finally, Chapter 5 summarizes the overall success of this initiative in terms of its basic goals. For those who want to improve this study further, suggestions and recommendations are provided as a guide

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The flow of literature in this chapter reflects the objectives of the study directly. As this research deals with over all coverage of water supply and water losses in distribution systems, issues related to water loss and pipe leakage. This chapter also critically discussed different method to estimate NRW which emphasis on current and future demand during pandemic.

2.2 Water Loss and Leakage

The phrase "water loss" is typically used to describe the difference between the total volume of water delivered to the network and the total volume of water used by customers as measured by flow meters (Lambert et al., 2009). Water loss is seen as a major issue in water management and a global concern that necessitates a strong and effective management strategy based on a deeper comprehension of its causes and the variables that affect it (Koelbl et al., 2009). A third of the total water abstracted for urban applications is either lost due to water distribution system (WDS) leaks and pipe bursts, or it is not taken into account in revenue and financing systems (Nazif et al., 2010). Worldwide, both developed and poor nations experience water losses (Thornton et al. 2008). Estimated non-revenue water (NRW) levels were 15 and 35 percent of the yearly system input volume for industrialized and developing countries, respectively (Kanakoudis et al., 2012). According to the Global Water Supply and Sanitation Assessment 2000 Report, NRW levels are 39 percent, 42 percent, 42 percent, and 15 percent, respectively, in Africa, Asia, Latin America and the Caribbean, and North America (WHO-UNICEF; Islam et al., 2011). In addition, while several nations have water loss levels below 10%, the average water loss level in European Union (EU) nations is over 20% (ztürk et al., 2007).

Leakage can be defined as unintentional or accidental loss of water from the pipe distribution network. Leaking pipes are a primary concern for water utilities constituting a large portion of water losses. Leakage rates are also related to the length of pipes and the number of connections. Improper connections can sometimes result in the continuous escape of water from the distribution pipes. These water losses can be divided into two groups: commercial (apparent) losses, which consist of water volumes consumed but not accounted for, and physical (real) losses, which are caused by large damages that may have occurred to the network pipes or by the deterioration of the pipe junctions or the hydraulic devices (Malcolm, 2008).

2.2.1 Commercial Losses

Water that is consumed but not purchased by the consumer is included in commercial losses, also known as apparent losses. Most of the time, reliable records of water flow through meters are inaccurate. Since lost water is invisible, unlike leaks or reservoir overflows, many water companies ignore commercial losses and focus only on physical losses. Since lowering commercial losses increases income and reducing physical losses lowers production costs, commercial losses can sometimes be larger in volume and value than physical losses. Commercial losses can be divided into four basic categories: (1) inaccurate client meters; (2) unlawful usage; (3) meter reading problems; and (4) faults in data handling and accounting (Malcolm et al., 2008).

2.2.1(a) Customer meter inaccuracy

Inaccurate meters frequently underreport water consumption, which lowers sales and, consequently, lowers revenue. Meters over report consumption only very infrequently. Since they use more water and frequently pay higher rates, utilities should first concentrate on large clients like industrial or commercial users. Customers are billed based on their actual consumption, which encourages them to save water, when accurate meters are used, as opposed to charging them on an assumed per capita basis (Malcolm, et al., 2008). The sentences that follow go over common issues with consumer meter accuracy and utilities' responses. The following list describes some typical approaches to dealing with inaccurate consumer meters:

i. Installing meters properly

According to the manufacturer's instructions, meters should be fitted correctly. For instance, certain meters need a certain length of straight pipe both upstream and downstream of the meter. As a result, a typical meter stand should be created on site. To ensure that only standardized, high-quality meters are utilized, utilities should buy the meters on behalf of the customers. Meters should be placed so that readers can quickly read them and so that it is simple to distinguish which meter belongs to which property.

ii. Sizing meters properly

Customer meters operate within a defined flow range, with each manufacturer defining the maximum and minimum flows. When the flow rate falls below the specified minimum, large meters won't detect low flows. In order to understand the nature of each customer's water demand and their likely use, utilities should undertake customer surveys. The suitable meter size for residences and businesses can be determined using this information. Checking the flow pattern and the recently placed meter determines whether the proper meter size is utilized for customers with high demand. When a storage tank is erected on the customer's property and the water flow is managed by a ball or float valve, problems with low flows may arise. As the water level in the tank rises, these valves gradually close, which reduces the flow through the meter and frequently falls below the minimum flow specification. If the storage tank is larger than the customer's consumption, the issue is exacerbated because the ball or float valve won't ever fully open, resulting in a constant low flow through the meter.

iii. Using the appropriate class and type of meter

Data on consumer consumption is more accurate when the right meter is selected. Where water quality is poor, Class B meters are an excellent option because the meter won't be significantly impacted by the sediments. Where roof tanks are employed and the water quality is good, Class D meters are preferred since they have a lower minimum flow specification and will more precisely measure the input into the roof tank. Since Class C meters can monitor low flows better than Class B meters and are less expensive than Class D meters, they are a good compromise in the majority of cases. Positive displacement (PD), multi-jet, single-jet, turbine, and electromagnetic meters are examples of common types of meters. The 15 mm and 20 mm PD meters are the most popular types of meters for residential and small commercial applications. For modest commercial and industrial systems that require 20 mm to 50 mm diameters, single-jet and multi-jet meters are more accurate. For sizes 100 mm and greater, electromagnetic meters are the ideal option.

iv. Maintaining and replacing meters properly

All meters should be installed above ground and put in a convenient spot for auditing, such as where meter readers may visit them on their regular tours. The utility should replace the meters in a systematic manner, starting with the earliest and worstmaintained ones. Poor upkeep may diminish the meter's lifespan in addition to encouraging inaccuracy. In places with poor water quality, meter maintenance is extremely important. Mechanical meters lose accuracy over time as the mechanical bearings deteriorate, increasing friction and causing the meters to under-register. Depending on the manufacturing quality, these changes will take place over a period of years. Using a calibrated meter test bench, the water utility should routinely test a sample of its customers' meters, including a variety of meter brands and ages. The ideal age at which customer meters should be replaced will be determined by this testing.

2.2.2 Physical Losses

The total volume of water losses minus the commercial losses constitutes physical losses, often known as actual losses or leakage. The calculated leakage volume, however, could be inaccurate because the water balance method shows that commercial losses are estimated (Malcolm et al., 2008).

The three main components of physical losses include:

- Leakage from transmission and distribution mains.
- Leakage and overflows from the utility’s reservoirs and storage tanks.
- Leakage on service connections up to the customer’s meter.

2.2.2(a) Leakage from Transmission and Distribution Mains

The total volume of water losses minus the commercial losses equals physical losses, often known as actual losses or leakage. The calculated leakage volume, however, could be inaccurate because the water balance method shows that commercial losses are estimated (Malcolm et al., 2008). Transmission and distribution main leakages are typically large-scale, even catastrophic events that result in harm to both automobiles and highway infrastructure. Even though they disrupt supply, the bulk of these bursts are typically not extremely severe. The bursts are rapidly reported and rectified or turned off as a result of their size and visibility.

Utility managers can determine the number of leaks on mains repaired throughout the reporting period (often 12 months) and estimate an average leak flow rate by using information from repair records. This results in the following total annual volume of mains leakage:

$$Total\ annual\ vol.of\ leakage\ from\ = \frac{No.of\ reported\ burst\ x\ Average\ leak}{Flow\ rate\ x\ Average\ leak\ duration} \tag{2.1}$$

2.2.2(b) Leakage and overflows from the utility's reservoirs and storage tanks

Reservoir leakage and overflows from storage tanks may be easily measured. Utility management should keep an eye out for overflows before estimating their usual duration and flow rate. It is crucial to regularly conduct nightly monitoring of each reservoir because the majority of overflows happen at night when demand is low. These measurements can be made directly or by installing a data logger, which will then automatically record reservoir levels at predetermined intervals.

The utility does a drop test to determine the amount of water lost from tank leaks. During this test, all inflow and outflow valves are closed. The utility then analyzes how quickly the water level drops. However, fixing these leaks requires draining the reservoir and organizing a backup supply, which is a significant effort.

2.2.2(c) Leakage on service connections up to the customer’s meter

This kind of leakage typically causes the most physical losses and is difficult to detect. By deducting the mains leakage and storage tank leakage from the total volume of physical losses, utility managers can determine the approximate volume of leakage from service connections.

2.3 Type of Water Pipes

Old or poorly built pipelines, insufficient corrosion protection, poorly maintained valves, defective materials, improper installation, excessive water pressure, water hammer, ground movement due to drought or frost, extreme loads, and vibration from traffic are all contributing factors (Hunaidi et al., 2000). A problem that is frequently mentioned, in addition to reservoir overflow and losses, is the impact of old, corroded subsurface assets on NRW rates. The "wrong quality selection of pipes and devices" can lead to high NRW rates, according to (Tabesh et al., 2018). As a result, it is essential to evaluate the piping materials before utilizing them in the water distribution system.

It was stated that pipes made of asbestos-cement accounted for around half of all pipe breaks each year (Rishyakaran et al., 2016). The Malaysian government has invested in NRW reduction contracts and replacement projects, like pipe replacement and water meter replacement, to address the NRW issue (Bernama et al., 2017). The suggested long-term solution includes replacing the current asbestos-cement pipes with new pipes made of ductile iron, mild steel, polyethylene, and modified unplasticized polyvinyl chloride (UPVC) as part of the replacement project (Tan et al., 2017). Despite having fulfilled their purpose in the past, asbestos-cement pipes are no longer a viable alternative because the material is hazardous to health (Luus et al., 2007). Initiatives are made in Malaysia to lessen the usage of asbestos (Safitri Zen et al., 2013).

2.4 Measuring Water Losses

The most commonly used techniques for calculating losses are the minimum night flow (MNF) per connection and the unaccounted-for water (UFW) reported as a percentage of total consumption. MNF is a prediction of the likely rate of losses at a specific time, whereas UFW is a measure of losses over a period as the difference between the amount of water provided into a system and the metered or projected quantity of water consumed by consumers. For detecting the presence of current undetected leaks and bursts as well as the onset of new ones, night flow measurements in moderately sized sectors (up to about 3000 service connections) are very helpful. Continuous night flows, however, can also be employed to calculate annual real average losses (Farley et al., 2003). Water that has not been accounted for is a helpful indicator of potential losses, but it may overestimate those losses because supply meters frequently show usage below what is really used. Unaccounted for water is influenced by a variety of elements that vary depending on the project, including housing standards, occupancy rates, main age and length per serviced population of 1000, trade and bulk supply percentages, ground quality, etc (Twort et al., 2004).

2.4.1 Calculating Real Loss Performance Indicators

One would suppose that accurate performance indicators are utilized for benchmarking, cross-national performance comparison, or target setting as a high level of water losses, both real and apparent, is a very serious efficiency issue. Unfortunately, this is not generally the case; water losses are still reported as a percentage of system input, with the exception of the UK water industry. The serious issues with this indicator have been brought up at numerous conferences around the world, most recently at the IWA leakage conference in Cyprus (Liemberger et al., 2006). The Non-Revenue Water Level (NRWL), which was determined as a percentage of total water produced using the following formula, is the newest and most accurate real loss indicator (approved by the IWA and AWWA).

$$NRWL = \left(\frac{SIV - BAC}{SIV}\right) x\ 100\% \tag{2.2}$$

where SIV (System Input Volume) is the water supplied to the network (m^3/year), and BAC (Billed Authorised Consumption) is the water sold (m^3/year).

2.5 Urban Water Demand

The amount of water that consumers need to meet their demands is known as their water demand. Although conceptually the two terms do not have the same meaning, it is frequently equated simply to water consumption. Theoretical water demand typically exceeds actual consumptive water consumption in the majority of developing nations. Domestic water demands, comprising in-house use and out-of-house use, are among the numerous kinds of urban water demand. The needs for culinary sanitation, household cleaning, laundry, and car washing go under the category of in-house use, whereas the needs for watering gardens, swimming pools, public standpipes for public usage, and fountains fall under out-of-house use.

One liter per capita per day (liter/capita/day) is the standard unit of measurement for urban water demand. The different indoor water use components (kitchen, bathroom, laundry, and toilet) and home occupancy can be used to create a typical pattern (referred to as the water use profile), which can be used to provide a reasonable picture of indoor water usage (Kanakoudis et al., 2011). Due to the wide range of service levels that occur within a single urban region, urban water demands are frequently homogenous in many Malaysian cities. Household connections, standpipes, and even no service are all possible service levels (Welday et al., 2005).

2.5.1 Water demand and Consumption

One of the challenges the water authority faces is estimating the sub- city's water demand because the consumption over the past few years that should have served as a baseline is significantly lower than the actual need because of the water deficit. Therefore, rather than using real demand, the sub-water city's consumption is predicted using the amount given. For these reasons, the sub-estimated city's current water supply is determined by studying the authority's customer billing information. The following summarizes the current condition as provided by the water authority (AAWSA et al., 2006)

The estimated 4% of the population who use in-house services use between 80 and 100 liters of water per person per day, whereas the other 94% of the population who has access to clean drinking water is served by yard connections and uses between 15 and 30 liters per person per day.

Water is used for non-domestic purposes, excluding industrial and industry, at a rate of around 25 and 7 liters per person per day, respectively. About 40% of the water needed by industry is provided by the water authority, with the remaining 60% coming from deep wells operated by the enterprises themselves (SEURECA et al., 2007).

2.5.2 Water Demand Management

The amount of water that consumers need to meet their demands is known as their water demand. Although technically the two terms do not have the same meaning, it is sometimes equated to water usage in a simple way (Wallingford., 2003). Theoretical water demand typically surpasses actual consumptive water usage in the majority of developing nations. Any socially advantageous measure that lowers average or peak water withdrawals or consumption from either surface or groundwater, along with the preservation or improvement of water quality, is referred to as water demand management (Thomas et al., 2003). An institution's adaptation and implementation of a strategy to affect water demand and usage in order to achieve any of the following goals: economic efficiency, social development, and social equality is known as water demand management (Mckenzie et al., 2013).

Domestic water demands, including in-house use and out-of-house use, are among the numerous kinds of urban water demand. The needs for culinary sanitation, household cleaning, laundry, and car washing go under the category of in-house use, whereas the needs for watering gardens, swimming pools, public standpipes for public usage, and fountains belong under out-of-house use.

2.6 Geometrical Increase Method

This approach makes the assumption that the population growth rate will be constant from decade to decade. The future population growth is estimated using the geometric mean increase. Since this strategy produces higher values, it should only be used for the first few decades of the development of a new industrial town. It is possible to estimate the population at the end of the nth decade, "Pn," by using this method.

2.7 Water Performance of Distribution Networks

A water distribution model must incorporate the idea of a network. The network holds all of the system's various parts and specifies how they are linked together. Nodes, which represent features at particular locations within the system, and links, which specify relationships between nodes, make up networks.

There are many different kinds of nodal elements in water distribution models, such as the nodes at pipe junctions, the nodes at reservoirs and storage tanks, the nodes at pumps, and the nodes at control valves. To describe the pipes linking these nodes, models use link elements. Additionally, components like pumps and valves are sometimes categorized as connections rather than nodes. Users can query tabular displays of model data with filtering and sorting instructions considerably more easily if element labeling is used properly. It is better to begin pipe labeling at the water source and count outward along each pipeline rather than beginning at a random node (Amdework et al., 2012). Additionally, a pipe-labeling system should be created to represent the fact that pipe components were not laid out randomly.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discusses the overall flow of research, from the site selection to data collection and analysis, in detail. Besides, the chapter will introduce primary considerations on site selection and some basic information about the chosen area of study. Lastly, the approaches involved in data collection and analysis are explained. The flowchart for this project is shown in Figure 3.1.

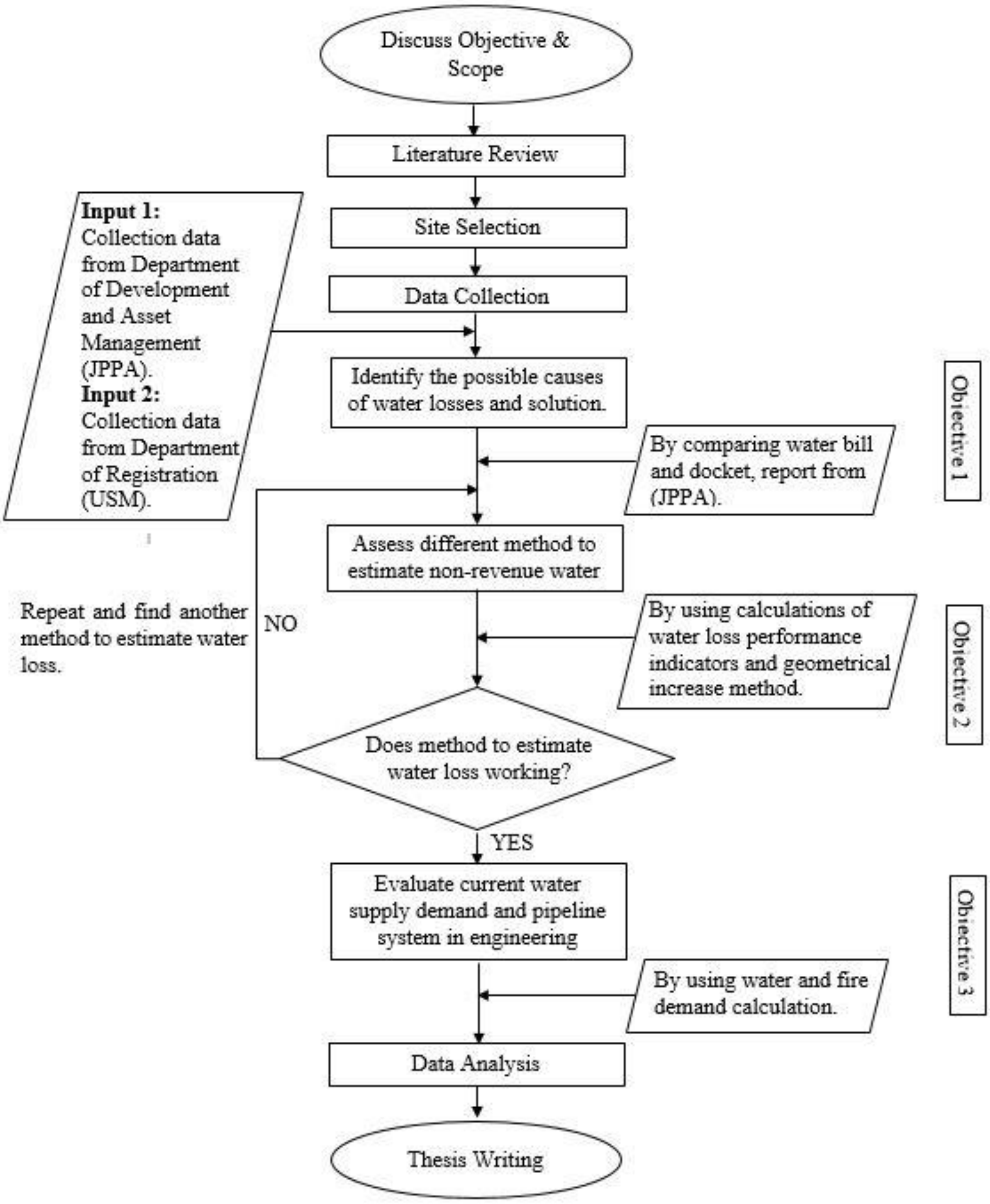

Figure 3.1 Summary of flow chart methodology

3.2 Site Selection

The USM Engineering Campus is located in Transkrian, Nibong Tebal and it was near next to two other minor surrounding towns, Parit Buntar, Perak, and Bandar Baharu, Kedah. On 320 acres of land that was formerly an oil palm plantation, the campus is located. It was developed using an eco-friendly but futuristic approach. The engineering campus is unique because of its heart-shaped layout. At the moment, the campus is home to roughly 3000 undergraduate and graduate students, as well as 1000 staff members, both academic and non-academic.

Six major schools for undergraduate and graduate study offer programs at the engineering campus, including the schools of civil engineering, electrical and electronic engineering, materials science and engineering, mechanical engineering, aerospace engineering, chemical engineering, and school of language, literacy, and translation. Additionally, there are two research institutions, namely the Science and Engineering Research Center (SECS), and the River and Urban Drainage Engineering Research Center (REDAC).

Several administrative and service centers are also located on the campus, including Desasiswa Jaya Lembaran Utama (JLU), the Student and Alumni Affairs Division (BHEPA), the Registration Department, Treasurer, Asset Development and Management, Security, Library, Islamic Center, Health, Co-Curriculum Plans, and the Office of the Director.

Figure 3.2 Location of study area based on Google Map

3.3 Method and Data Analysis

Before analyzing the water loss, the research area's water supply coverage was assessed. The amount of consumption and the amount of water connection were the main factors considered when assessing the water supply coverage since they have a direct impact on the problem of water loss. For the local level study, data on water production and consumption that had previously been recorded by PBA for monitoring purposes was used instead of the total water generated and the actual water use as aggregated from the individual contracts (customer meters).

3.3.1 Data Collection

To determine the causes of water loss and possible solutions is to acquire data from the Department of Development and Asset Management in terms of yearly reports, total water bills and total water usage from 2017-2021. In addition, discussions with the assistant engineers from JPPA also assisted to discover solutions to the problem of water loss. The department of the registrar provides data on the population of students and employees who are on campus from 2017 to 2021.

3.3.2 Method of Analysis

Due to a lack of specialized measurement equipment and funding for the installation of sensors that can detect and quantify the water loss at a particular place, the top-down method was utilized in this study. Using a top-down methodology, researchers were able to assess each individual system component, such as individual blocks or the entire campus distribution network. The various components of water balance, water consumption, customer count, potential leakage point detection, and source of the loss at the site were then calculated (Puust et al., 2010).

3.4 Possible Cause of Water Loss

There are several factors that cause water leaks to occur. One of the initiatives is using the JPPA docket report. It is possible to pinpoint the incident's location and the different kinds of water leaks that happen on the campus by consulting the report.

3.4.1 Pipe Leakage

Water leak reports have been reported often during the past five years, according to the list of dockets published by JPPA. As a result, the JPPA also noted the report of the leak and decided to fix the water leak. The statistics report on water leakage and the five-year average will be presented in the following chapter.

Old or improperly built pipelines, insufficient corrosion protection, poorly maintained valves, defective materials, improper installation under excessive loads, and vibration from traffic are all factors that contribute to water leaks (Georgia et al., 2007).

A problem that is frequently mentioned, in addition to reservoir overflow and losses, is the impact of old, corroded subsurface infrastructure on NRW rates. To solve this issue, new pipes should be installed in place of the old, corroded ones.

Figure 3.3 Pipe repair work is carried out

3.4.2 Estimating physical losses

Physical losses can be determine by checking leakage pipe in engineering campus, USM. To do this checking must require permission technician from development department. This method can be done by guidance from technician so that can locate the location.

3.5 Measuring Water Loss

In order to estimate the total loss of water in the engineering campus, is by using calculations of water loss performance indicators that can be determined by comparing with water bills from the years 2017 to 2021. In this case, the data were collected from the development department. Although the data has been collected from the development department, the water loss analysis also has been done by estimating physical losses by checking leakage pipes in the engineering campus.

3.5.1 Water Bills

The water bills data from year 2017 to 2021 were collected from development department office and field. Additionally, some supporting data was gathered through conversation and from the different offices' other departments.

Table 3.1 Total Water Bill (RM) that given from Development and Asset Management Department.

Year	Total Water Bill (RM)
2017	473,099.35
2018	586,232.50
2019	576,041.80
2020	485,700.70
2021	550,339.90
Total	2,671,414.25

3.5.2 Water Consumption

Each year from 2017 to 2021, data on each customer's water consumption was gathered in order to assess the water loss in the distribution system. There are 4507 consumers in the Engineering Campus as of the end of December 2021. In this sense, water use includes metered, billed, and unbilled allowed use. Additionally, the following equation was used to calculate the engineering campus USM average daily per capita consumption.