BLUE WATER FOOTPRINT BASED ON INDUSTRIAL ACTIVITIES IN KUANTAN RIVER BASIN

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ABSTRAK

Di seluruh pelosok dunia, jutaan manusia adalah di dalam bahaya akibat kekurangan bekalan makanan dan air, melemahkan asas kestabilan tempatan, nasional dan global. Persaingan bagi sumber-sumber terhad – terutamanya air- semakin meningkat, menyulitkan dilema keselamatan terdahulu dan menghasilkan dilema yang baharu. Oleh itu, kajian ini bertujuan untuk menentukan “blue water footprint” bagi aktiviti perindustrian di Lembangan Sungai Kuantan serta untuk mengenalpasti kesan pembangunan penggunaan tanah kepada “blue water footprint accounting” dari tahun 2015 sehingga 2017. Seterusnya adalah untuk meramal kelangsungan Loji Rawatan Bekalan Air di Lembagan Sungai Kuantan. Oleh itu, bagi mencapai objektif yang telah dinyatakan, jumlah bagi “water footprint” dari setiap loji rawatan air akan dikira dan pengagihan pembangunan penggunaan tanah akan dikaji. Satu siri pemodelan akan dibuat dengan menggunakan ANN – sejenis tol aplikasi “Artificial Intelligence” (AI) di Matlab. Oleh itu, hasil dari jumlah “water footprint”, kesan pembangunan penggunaan tanah dan nilai ramalan bagi “water footprint” pada masa akan datang akan ditentukan.

ABSTRACT

Around the globe, millions of people are greatly in danger of not having enough food and water supply, weakening the very basic foundation of local, national and global stability. Competition for scarce resources – especially water- is increasing, aggravate the old security dilemmas and creating new ones. Thus, this study aimed to determine the blue water footprint for industrial activities in Kuantan River Basin and to identify the effect of land use development to the accounting of blue water footprint from 2015 until 2017. Next, to forecast the sustainability of Water Supply Treatment Process in Kuantan River Basin. Therefore, in order to achieve the stated objectives, total water footprint from each water treatment plant will be counted and the distribution of land use development will be analysed. A series of modelling using ANN – an Artificial Intelligence (AI) application tolls in Matlab. Hence, the results of amount blue water footprint, effect of land use development and the future value of predicted water footprint shall be determined.

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LIST OF ABBREVIATIONS

AI	Water Foo
WTP	Water Treatment Plant
WSTP	Water Supply Treatment Plant
A	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DOE	Department of Environment
EC	Electrical Conductivity
FE	Iron
HACH DR 5000	Spectrophotometer Procedures Manual
H_2SO_4	Sulphuric Acid
K	Potassium
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
Mg	Magnesium
Mg/L	Milligram per litre
Na	Sodium
NH3-N	Ammoniacal Nitrogen
NO^{-3}	Nitrate
NTU	Nephelometric Turbidity Units
NWQS	National Water Quality Standard
pH	Potential Hydrogen
$PO\ ^{3}-_{4}$	Phosphate
SI	Sub-indices
TSS	Total Suspended Solid
μs/cm	Microsiemens per centimetre
WQI	Water Quality Index

CHAPTER 1

INTRODUCTION

1.1 Background of Study

In a world where populated by almost eight billion of people, the discussion on the access to the clean water has been the major topic discussed globally. The major problem that is faced by the developing countries is the availability of clean water to be supplied to the rural areas. Competition for scarce resources – especially water – is increasing, exacerbating old security dilemmas and creating new ones (Ban Ki-moon, 2011). According to World Health Organization (WHO), over 1 billion people outside the United States of America do not have access to clean and safe drinking water where 3.4 million people die each year from scarce and contaminated water sources. It can be said that, half of the world's hospital beds are occupied by patients that suffer from Deceases related to lack of access to clean water.

Back in Malaysia, the issue that arises regarding the water is high rates of water wastage. Domestic, industrial and agricultural use has become the top sectors in producing the water wastage. High rates of Non-revenue Water (NRW) is listed as the contributor to the problem that were faced by this country wholly. The rates of NRW in Malaysia has a national average of 40% which equals to a loss of 40 liters out of every 100 liters of treated water. Other than that, changing in weather patterns has affected the water resources. For example, in 1997 and 1998, the El Nino brought severe drought resulting in water crises in many regions of Malaysia. The prediction of water availability in future shall be carried efficiently to ensure the sustainability of water resources.

1.2 Problem Statement

The development of industrial activities in Kuantan Industrial Area has increased gradually from 2015 to 2016. The significant increment in percentage of land use will definitely affect the usage of fresh water since there will also be an increment in the population of Kuantan residents. Therefore, an assessment on the water availability is very important in determining the future water resources. To overcome problems such as unnecessary water shortage that usually strike Kuantan’s residents, the accounting of Blue Water Footprint (BWF) in future using Artificial Neural Network (ANN) will give an exact figure of how long the water could be supply in a period of time.

1.3 Research Objectives

The objectives are as the followings:

i. To determine Blue Water Footprint for industrial activities in Kuantan River Basin
ii. To study the effect of land use development to the Blue Water Footprint accounting
iii. To predict the sustainability of WSTP at Kuantan River Basin.

1.4 Scope of Study

This study focusses on the sustainability of Kuantan River Basin in coming years to become the main source of water in Kuantan district. The evaluation of BWF in all five Water Treatment Plant (WTP); Semambu WTP, Panching WTP, Sungai Lembing WTP, Bukit Ubi WTP and Bukit Sagu WTP will provide an amount of treated water to be distributed to their respective area of supply. The source of water intake for all five WTP is Sungai Kuantan. The secondary data for parameters involved such as rainfall intensity in the accounting of BWF is obtained from the local authority, Pengurusan Air Pahang Berhad (PAIP) and others.

1.5 Significance of Study

From this study, the determination of Blue Water Footprint for industrial activities in Kuantan River Basin can be determined from the accounting of water footprint at five Water Treatment Plant. The increasing in overall percentage of industrial zone analysis for Kuantan district will be study whether it effects the accounting of BWF in future. For prediction of sustainability of WSTP in future coming can be made by using a series of modelling by using normalised water footprint data. Hence, the beneficial results of well management of land use is expected to be produced for future wellness.

CHAPTER 2

LITERATURE REVIEW

2.1 Water Resources

Water is a basic life-supporting asset whose presence and accessibility for individual cannot be overestimated (Lomsadze, Makharadze, Tsitskishvili, & Pirtskhalava, 2017). Only 2.5% of water on earth comes from fresh water, and over two thirds of this is frozen in a form of glaciers and polar ice caps. Water resources can be define as sources of fresh water that are useful, or potentially useful, to society that can be used for agricultural, industrial or recreational usage. It can be the groundwater, rivers, lakes and reservoirs. The importance of water resources is very high especially in agricultural sector where it is estimated that, almost 70% of world-wide water are being used for irrigation in agriculture. The advance development of socio-economic over the past several decades, adverse effects of human exercise on natural ecosystems, seriously threaten fragile landscape ecology and water resources (Lomsadze et al., 2017).

In addition, the uncertainty concepts play a prominent role in global environmental change research, including climate change science and climate change impact science, with hydrology and water resources research in particular (Kundzewicz et al., 2018). (Zolghadr-Asli, Bozorg-Haddad, & Loáiciga, 2018) reported that, the performance assessment of water resources systems is vital step in achieving a sustainable development. The issues of global warming and the movement of the desertification process will adding up a bigger hole on the fresh water problem and it is presumed that a number of people who is affected by the problem will migrate out from the area (Bolashvili et al., 2015).

2.1.1 Water Resources Management

Nowadays, most countries are placing unparalleled pressure on water resources. The world's population is growing fast and estimates show that with current situation happening, the world will face a 40% shortfall between forecast demand and available supply of water by 2030. This is can be worsen by the chronic water scarcity, uncertainties in hydrological events and an extreme floods and droughts are targeted to be some of the biggest threats to international prosperity. Thus, it is very crucial to ensure that all those available water is being well managed. The application of Integrated Water Resources Management (IWRM) in Malaysia can be classified as the best move to cater the management issues of water resources. The average annual rainfall of 2940mm and the surface runoff is 1500mm with groundwater recharge of 192mm has been recorded in the data of hydrological balance in Malaysia. Through the implementation of IWRM, there are 189 delineated river basins with 80 sq.km in size. Plus, the total coastline of 4809km has been classified into management units for the purposes of monitoring and management

(J. Y. Huang, Lou, & Li, 2016) said that, Integrated Urban Water Management is an effective way to be used to reduce water resource shortages in a developing regions where the majority of raw water comes from other part. While, the involvement of stakeholders and the interactions between the river committees are playing a big role for the effective IWRM (Barbosa, Mushtaq, & Alam, 2017). The importance of water resources management had been studied by (Friesen, Rodriguez Sinobas, Foglia, & Ludwig, 2017) where the holistic approach of IWRM is vital in order to develop appropriate management measures to mitigate or adapt the environment to scarcity and drought conditions

2.1.2 Water Supply

Looking back to the history recorded on the development of water supply in Malaysia or more likely to be known as Federated Malay State (FMS) at particular time. The water supply system first started to be administered in this country is at the early of 19th century where the implementation covers two parts; FMS and in the Straits Settlement where Pulau Pinang is said to be the first state to have a formal arrangement for a water supply system with a population of 10,000 people. The conventional method of supplying the water was being used which the fresh water from the hills was grasped to the town by a brickwork channel while earthen pipe and tin pipes being laid through the streets and houses respectively. Only 30 years later a modern rapid gravity filtration plant or Water Treatment Plant(s) were being introduced.

The development of treatment plants were meant to serve the large town where the populations of people are high compared to any other part of the region. The capability of the plants to cater the demand of water are efficiently conducted; due to the low demand of water and a slow growth of population. Department of Health become the only responsible authority in ensuring the water quality always in a safe range by conducting the chemical and bacteriological analysis. Noted there, almost all major towns in FMS had their own treated water supply before the Second World War take place. The dark side history of development water supply system has taken place during the intrusion of Japanese between 1941 and 1945, where no more extension in the construction of water treatment plant and the worst case happened when the existing water supply installation become progressively become worst due to little monitoring activities to the water supply system.

Crucial advancement era took a turn when the British agreed on the independence of Federated Malay State in 1957. The first scheme developed was the Klang Gates Dam and the Bukit Nanas treatment plant, purposely to supply the capital city of Kuala Lumpur completed in 1959. More treatment plants comes after the establishment of National Five Year Development Plans (1966-1970, 1971-1975, 1976-1980, 1981-1985, 1986-1990 and 1991-1995) which includes all more sectors involved such as Water Supply, Roads, Health and Education which play an important roles towards a developed nation.

An unavoidable relations between the supply of fresh and clean water with the treatment that must be performed before the water being distributed is something that should not be neglected. Study on the steps of prevention the any water source from being contaminated has been deeply explored by (Wisner & Adams, 2003) where he suggested a few fundamental changes such as raising the wall of dug well and providing a cover will helps from any contamination due to events like floods run-off into the open hole. This is due to the fact that Deceases such as waterborne germs could be founded if the water has been contaminated. Thus the unit processes of water treatment should be conducted efficiently to circumvent any possible threats to the quality of water. Such unit processes included are screening, aeration, flocculation, sedimentation and filtration (Hendricks, 2010). Each processes shall carries a different character of tasks in cleaning the water up and it may varies differently according to the availability technology and the water it needs to process.

The typical and commonly used of water treatment process can identified below with a brief and details explanations for the general unit processes according to the practiced in Malaysia Water Treatment Plant:

I. Screening

Screening is the retention of particles either by a network or longitudinal bars with openings littler than the particles to be expelled where it is classified as a method to separate the particles according to their respective size. Under this process, two fractions will be produced; (1) underflow - particles that pass through the screen and (2) overflow - particles that is rejected by the screen (Hendricks, 2010).

II. Coagulation/Flocculation

Coagulation can be defined as the process in which reaction is produced from the contacts between a chemical and colloidal particle where the products are known as *microfloc* (Hendricks, 2010). In this process, two stages will take places: (1) choosing the suitable chemicals, a sufficient dosage and a perfect pH for the best reaction to happen, and (2) triggering contacts between the chemical (coagulant) and the colloidal particle.

III. Sedimentation

It is also known as gravity settling. The flocs that were produced in the previous stage will eventually settle to the bottom of the water due to its heavy in weight and will be channeled out to the drying lagoons.

IV. Filtration

Water flows through a channel intended to evacuate particles in the water. The channels are made of layers of sand and rock, and now and again, smashed anthracite. Filtration gathers the suspended polluting influences in water and upgrades the viability of cleansing. The channels are routinely cleaned by backwashing.

V. Disinfection

Water is disinfected before it enters the conveyance framework to guarantee that any sickness-causing microbes, viruses, and parasites are annihilated. Chlorine is utilized in light of the fact that it is an extremely successful disinfectant, and residual concentration can be kept up to against conceivable biological contamination in the water conveyance framework.

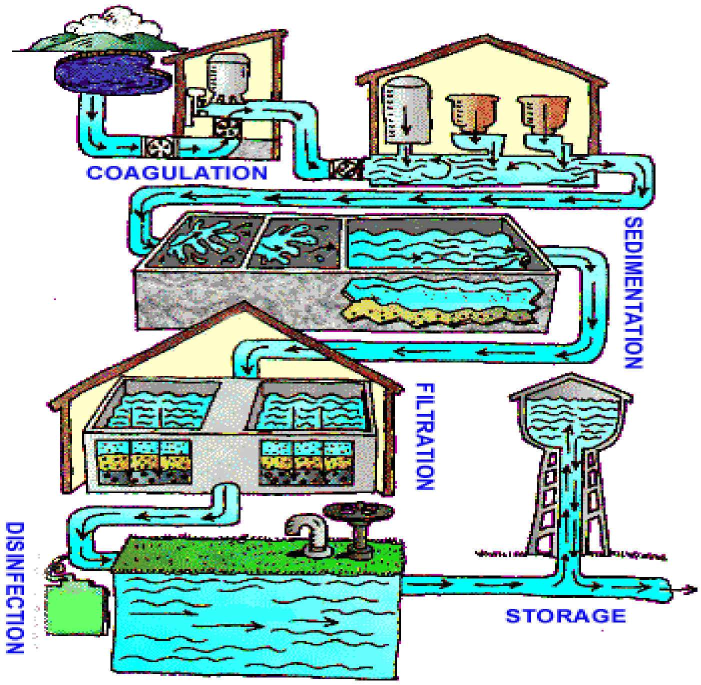

Figure 2.1 Water Treatment Process

(Source: https://www.cdc.gov/healthywater/drinking/public/water_treatment.html)

2.1.3 Sustainability Management of Water Supply

Water supply system is defined as a flow of water to consumers in various ways (Dilday & Rock, 1971). A minimum access of 20 litres per capita per day of acceptable quality water must be accommodated to consumers as a basic service of water supply (Kuhlman & Farrington, 2010). Consequently, in order to manage the supply of water, it is essential for the management to ensure that basic water requirements are provided; abating the risk of water losses and pollution; conserving environmental resources; conveying water from flood to drought; minimizing cost of supply; supplying water from wet to dry area; creating water awareness among consumer and sustaining water supply (Stephenson, 1998).

Malaysia has an advantage of having an abundance quantity of water. The level of safety of water to be supplied are measured by referring to the Water Quality Index (WQI), based on these parameters; Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Ammoniacal Nitrogen, Dissolved Oxygen (DO), pH and Total Suspended Solid (TSS)(“National Water Quality Standards,” 2014). Water with WQI more than 81 is safe for supply, but need to undergo a series of treatment process. Therefore, sustainable water supply depends strongly on water quality and quantity.

There are many literature definitions of the word “sustainability”, but it is mainly defined as maintaining well-being for current and future (Kuhlman & Farrington, 2010). Sustainable development is the ability of humanity to ensure that development meets the current demand, without compromising the ability of future generation to meet their own needs (Brundtland, 1987). In the context of water management, sustainable management is pertinent in response to the requirement of managing resources, so that the availability of resources for current and future generations will be ensured (Bureau & Dep, 1993).

Moreover, the sustainability of water resources is believed to be dependent on availability of water resources from the intake (Arjen Y Hoekstra, Chapagain, & Zhang, 2016). However, changes of global climate and socio-economic have caused uncertainties which have further complicated the management of water resources towards sustainability (Pahl-Wostl, 2007). Hence, the study of water improvement in term of water resources, quality and supply is crucial in order to ensure the sustainability of water. Since all services and productions are all towards sustainability globally (Starik & Kanashiro, 2013), water supply should not be diverged. The sustainability criteria of water supply can be divided into 3 categories, which are; social, economic and environment.

Firstly, social sustainability of water supply is defined as the quality and availability of water to meet human needs. Ensuring efficient use of water is the economical sustainability of water supply, while environmental sustainability is to assure the protection of natural resources (Pires et al., 2016). To meet the demand, the supply of water must be continuous in order to meet the social sustainability. The quality of water supply must also comply with the standard water quality.

To improve the social sustainability of water supply in term of availability and quality, some studies have been conducted. Among the studies to ensure the availability of water supply are; China's Water Resources Vulnerability: A Spatio-temporal Analysis during 2003–2013 (J. Cai, Varis, & Yin, 2017), Urban Water Conservation Through Customised Water and End-Use Information (Liu, Giurco, & Mukheibir, 2016), Determinants of Domestic Water Consumption in Hermosillo, Sonora, Mexico (Ojeda, Álvarez, Ramos, & Soto, 2016), and The Research of Water Use in Spain Francisco (Montoya, Baños, Meroño, & Manzano-Agugliaro, 2016).

For the water quality of water supply, the studies to improve water quality are; rural household water treatment and drinking water quality assessment of Balaka district in Malawi (Mkwate, Chidya, & Wanda, 2016), the effects of water body classification to water quality prediction (Barclay, Tripp, Bellucci, Warner, & Helton, 2016), a review on land uses and water quality in twenty century (Giri & Qiu, 2016), developing a surface water quality standards in China (Su et al., 2017) and strategies to monitor water quality (Behmel, Damour, Ludwig, & Rodriguez, 2016). Despite conserving water resources and enhancing water quality, the prime reason of conducting these studies is to ensure the continuous and better supply to consumer for consumption.

Secondly, economical sustainability of water supply is measured on the efficiency of the treatment process in supplying treated water to consumer. Thus, it is necessary to know the exact value of total water consumption to assess the sustainability of our water service in term of economic sustainability. However, although the water intake value and water supply to consumer have been recorded, they do not include all utilized water consumption to produce treated water.

Finally, based on environmental sustainability, the protection of water supply is done by protecting the water intake resources. Water resources are part of the ecosystem, and sustainability of ecosystem is defined when the ecosystem is able to meet human needs without causing any harm (Morelli, 2011). In response to that, there are many studies conducted which are related to environmental sustainability of water supply. Among them are sustainable urban water resources management by considering the Life Cycle Assessment (LCA) in term of uncertain water utilization (Y. Cai, Yue, Xu, Yang, & Rong, 2016), the effects of human intervention and climate change to water resources (Haddeland et al., 2014), the effects of climate change to the water resources in Yellow River Basin in China (Zhu, Lin, Wang, Zhao, & He, 2016). Therefore, the sustainability of water supply will be maintained if all the sustainability criteria have been fulfilled, which are social, economic and environment. Management of water supply needs to be enhanced in order to meet the criteria.

2.2 Factors Affecting Water Footprint

According to Oxford, urbanization is defined as the increase in the proportion of a population living in urban areas and the process by which an area loses its rural character and way of life (Oxford Reference, 2018). The process of (mega) urbanization shifted from industrial to newly-industrialized and developing countries in the 1950s. Urbanization strongly affects the quality of water resources and its management, albeit the differences in these countries – water sector infrastructure and gradual growth as realized in the industrial nations over about a century enabled a systematic planning of land use. On the other hand, the newly-industrialized and developing countries had caused uncontrollable development over a short period, which in turn caused tremendous land use changes and created informal living conditions due to insufficient living room and water supply capacities (Kraas & Sterly, 2009).

There are four immediate consequences on the hydrological cycle which are caused by urbanization; changes in the river and groundwater management, flooding occurrence as a result of increased soil sealing, water shortage due to rising consumption and water contamination (Rogers, 1994). The urban water resources are put under severe pressure with the occurrence of changes in natural drainage and the discharge of pollutants into groundwater and surface water. Surface run-off is increased by extensive soil sealing, which result in the reduction of natural groundwater recharge (Goudie, 1990). Contrary to the reduction of groundwater, the urban groundwater recharge is increased by leaking water mains and sewerage canals (Lerner, 1990; Foster *et al.*, 1999; Welty, 2009). As a result, the leaching out of contaminants occurs (Morris *et al.*, 1994; Klinger, 2007). The interaction of ground, surface and wastewater systems causes the entry of pollutants into the urban water system to increase – substantially in cities that have no adequate wastewater system (Strauch *et al.*, 2009; Putra & Baier, 2009).

Thus, it can be said that ecological and social vulnerability (cp. Wehrhahn *et al.*, 2008) are increased by spatial changes and the state of water infrastructures. Private use accounts for the largest proportion of total sales volume of tap water, followed by industrial, public and other uses. In Guangzhou, China, water sector structures were surveyed on-site to relate land use and its effects on water resources, as well as to gain knowledge on a micro-scale embedded in the mega- urban context. The potential sources for surface and groundwater contamination were also identified.

It is unquestionable that in almost all parts of the world, the city has become a place for migrants to stay due to number of availability of potential jobs. This leads to a higher degree of surface sealing and decreased infiltration areas due to the need for horizontal construction, rising water consumption, increasing density as a result of vertical development, and sewage production as consequences of population growth and enhanced living conditions. According to (Strohschön, 2012), agricultural activities in Shibi and Yuangangcun, animal husbandry in Shibi and untreated domestic sewage causes surface water contamination by microorganisms and organic pollutants. Depending on the availability of limited technological filtering or treatment resources, other possible surface water contamination and health-risks might also arise.

The hydrological research is made easier by analysing how people value and appraise water quality, as well the effects of water management and the land use change on human performance. Different perceptions by inhabitants of a certain area postulates the level of knowledge on poor water quality and its potential effects on human health and diverse potential risk exposures.

Surface waters are mainly used for construction of roads and buildings. Nowadays, it is used for sewage disposal and integrated in the urban space in form of reservoirs for water storage, flood protection and recreational areas. Artificial surface water bodies such as waterfalls, fountains or lakes are already integrated as modern design elements in the cityscape – currently forming a considerable contrast to severely polluted creeks and ponds. To compare and standardize urban and water planning structures and measures, micro-typology has proven to be a good outset. Reconstruction processes implemented on the Marro-scale also lead to the restructuring of local impacts on the micro-scale. The understanding of the relationship between (changing) landscape patterns and water quality can be improved by embedding the characteristics of the units in the broader context.

All in all, the interdependencies of a rapid population growth and an increasing use of water, land use patterns, peoples’ ways of thinking and responding as well as surface and groundwater systems affects the water footprint.

2.2.1 Land Use Development

Studies on the relation between land-use changes and land policies during the process of industrialization and urbanization has increased attention in the recent years (Wang, Lin, Glendinning, & Xu, 2018). The needs of the community in a city has driven the land use development. The alteration of land usage result in uncontrollable traffic movement which is caused by changing traffic generation or attraction of the new land use (Rahayu, Ahyudanari, & Pratomoadmojo, 2016).

There are multiple challenges in discussing how the land uses affect the water quality in such a high-density stream network area. As the spatial scale increased, the land use effects and hydrological condition on water quality became more diverse (Zhao, Lin, Yang, Liu, & Qian, 2015). The land use within the watershed has great impacts on the water quality of rivers. Due to the changes in the land cover patterns within the watershed that result from increasing human activities, the water quality of rivers may degrade (J. Huang, Zhan, Yan, Wu, & Deng, 2013).In regions where there are no issues on water availability and great land-use pressure, a method to release crop land areas is by yield intensification promoted by subsurface drip irrigation (Scarpare et al., 2016).

Thus, to prevent water stress within watersheds integrating drinking water catchments, it is fundamental to consider the relevance of addressing water quality impact driven from land use within the planning process (Meneses, Reis, Vale, & Saraiva, 2015).

2.3 Water Footprint

Water footprint (WF) is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community (A. Hoekstra & Chapagain, 2007). The concept was introduced in 2002 by the Dr. Arjen Hoekstra at the International Expert Meeting on Virtual Water Trade, which was held in Delft, Netherlands (Hoekstra, 2003). The WF concept is primarily rooted in the search to illustrate the hidden links between human consumption and water use and between global trade and water resources management (A Y Hoekstra, 2009).

There are three different types of WF in an individual or community, which are blue, green and grey WF. The blue WF is defined as the volume of freshwater that evaporated from the global blue water resources (surface water and ground water) to produce the goods and services consumed by the individual or community. The green WF is the volume of water evaporated from the global green water resources (rainwater stored in the soil as soil moisture). Finally, grey WF is the volume of polluted water that associates with the production of all goods and services for the individual or community (A Y Hoekstra, 2009).

Direct WF accounts for the direct consumption and pollution of fresh water caused by activities such as domestic water use for a person, operational water use in factories or businesses, and the use of internal national water resources for a country (Haida, Chapagain, Rauch, Riede, & Schneider, 2018). The concept of virtual water acts as a basis of indirect WF (Allan, 2003) and thus accounts for both amount of water that is used during the entire production process and water physically contained in a product.

According to (United Nations, 2016), agriculture contributes to 70% of all water consumption, compared to 20% for industry and 10% for domestic use. In industrialized nations, however, industries consume more than half of the water available for human use. Almost 80% of Deceases in developing countries are linked to water, causing three million early deaths (Water Consumption Statistics, 2017).

There are a few important direct factors that cause high WF. The first factor is the total volume of consumption, which is generally related to gross national income of a country. The next factor is climate. This is proven where in areas with a high evaporative demand, the water requirement per unit of crop production is relatively large. Another factor that contributes to high WF is water-inefficient agricultural practice, which means that water productivity in terms of output per drop of water is relatively low. For example, Thailand’s rice yields averaged 2.5 ton/ha in the period 1997–2001, while the global average in the same period was 3.9 ton/ha (A. Hoekstra & Chapagain, 2007).

A study conducted by (Morera, Corominas, Poch, & Comas, 2016) had shown that there is a reduction of the water footprint by 51.5% and 72.4% achieved using secondary treatment and phosphorous removal respectively. This postulate a large decrease in the grey water footprint compared with the no-treatment scenario; albeit the detection of a small blue water footprint.

According to (A. Hoekstra & Chapagain, 2007), WF can also be reduced by breaking the link between economic growth and increased water use, for instance by adopting production techniques that require less water per unit of product. Next method of reducing WF is by shifting to consumptions patterns that require less water. Water costs are generally not well reflected in the price of products due to the subsidies in the water sector. Another way of reducing WF is by shifting production from areas with low water-productivity to areas with high water productivity, thus increasing global water use efficiency (Chapagain et al., 2005).

2.3.1 Blue Water Footprint

In many river basins, blue WF exceeds blue freshwater availability, causing significant environmental impact. With the world population growing at rapid pace and related changes in lifestyle as well as consumption patterns, competition for water resources between agriculture, industry and energy, sustaining ecosystem health, are a few among several critical issues that are linked to water scarcity (Pahlow & Mekonnen, 2012). In most areas, groundwater is being pumped at rates higher than replenishment, depleting aquifers and the base flows of rivers (Postel, 2012).

A basin is considered water scarce if the total blue WF of all human activities combined exceeds water availability (runoff minus environmental flow requirements) in any given month (Hogeboom, Knook, & Hoekstra, 2018). Blue water scarcity values are classified into four levels of water scarcity – 1. Low Blue Water Scarcity (<100%): the blue water footprint is lower than 20% of natural runoff and does not exceed blue water availability, river runoff is unmodified or slightly modified and environmental flow requirements are not violated, 2. Moderate Blue Water Scarcity (100-150%): the blue water footprint is between 20 and 30% of natural runoff, runoff is moderately modified and environmental flow requirements are not met, 3. Significant Blue Water Scarcity (150-200%): the blue water footprint is between 30 and 40% of natural runoff, runoff is significantly modified and environmental flow requirements are not met and lastly, 4. Severe Water Scarcity (>200%); The monthly blue water footprint exceeds 40% of natural runoff, so runoff is seriously modified and environmental flow requirements are not met. (A. Y. Hoekstra & Mekonnen, 2011).

To study the environmental sustainability of water use in a river basin, the WF needs to be considered in the context of the maximum sustainable WF, which depends on the available water resources in the basin. The maximum sustainable blue WF in a river basin is defined as the volume of renewable freshwater that is ultimately available over time within a year for consumptive uses, given available runoff, environmental flow requirements and storage possibilities. A comparison can be made between the maximum sustainable ground-WF, considering groundwater recharge, maximum acceptable groundwater level decline and required base flow to the river, and the maximum sustainable surface WF (Arjen Y Hoekstra et al., 2016).

2.3.2 Artificial Neural Network

Human has developed an application to imitate the brain function in term of problem's solving by referring to previous experience - Artificial Neural Networks (ANNs) (Anderson & McNeil, 1992). Basically, ANNs' principles were initially formulated by McCulloch and Pitts in 1943 and based on five assumptions which are; (1) the ANNs activity is all or nothing (a binary element), (2) in order for a neuron to be excited, a particular fixed number of synapses that larger than 1 must be excited within a given interval of neuron addition, (3) synaptic delay is the only significant delay in the system, (4) the excitation of the neuron will be prevented if there exist any activity of inhibitory synapse, and (5) the interconnection network structure does not change over time (Graupe, 2007).

ANN is a computational model in view of the structure and elements of natural neural systems. Data that courses through the system influences the structure of the ANN because of the fact that a neural system changes - or learns, one might say – according to that input and output. ANN has been widely used in various field of studies and many researchers have been utilising this application to measure the prediction studies such as heat transfer prediction of supercritical water (Chang et al., 2018), prediction of surface tension of binary refrigerant mixtures (Nabipour, 2018) and Brooks & Tucker, 2015 use ANN to predict the electrospinning which was a method to produce nanofibers, while recently Bre, Gimenez, & Fachinotti, 2018 have discovered the pressure coefficient of mean wind on the surfaces of flat-, gable- and hip-roofed rectangular buildings. In term of minimising the energy consumptions, (Martellotta, Ayr, Stefanizzi, Sacchetti, & Riganti, 2017) used the ANN to display the household energy utilizations.

Previously, several reports have shown that ANN application is useful in hydrology field especially in forecasting and predicting parameters (Silverman & Dracup, 2000). Application of ANN by researchers in analysing water-based cases are quite enormous and directly related to one of our biggest challenge in managing the water issues- water quality. ANN application are playing a major role in predicting water quality parameters (Najah, El-Shafie, Karim, & El-Shafie, 2013) and in the prediction on the groundwater recovery cost for drinking use based on quality of water resources.

One of the interesting finding is a development of prediction modelling by using ANN to predict the monthly values of two parameters for water quality of Delaware River, Pennsylvania (Heydari et al., 2013). Other than that, ANNs can also predict solar radiation accurately if compare with conventional methods (Yadav & Chandel, 2014). Moreover, (Veintimilla-Reyes, Cisneros, & Vanegas, 2016) conducting a research to create a model that allows predicting the flow of "Tomebamba" river at any specific day of a year, based on ANN method. (Alizadeh & Kavianpour, 2015) use ANN to predict a variety of ocean water quality parameters while (Gümrah, Öz, Güler, & Evin, 2000) predicting water quality of the polluted aquifer.

2.3.3 Nonlinear Autoregressive

Nonlinear autoregressive (NAR) is one of the tools that being used to solve a nonlinear time series problem with a dynamic neural network where it involve the prediction study. By using NAR, we predict the result in future by inserting the past values or existence data into it. NAR has been massively used by many researchers due to its less-complex process, such as in predicting the NOx emission of diesel engine by improving the linear and nonlinear auto-regressive model (Ma, Xu, Huang, & Huang, 2016). Other than that, real time damage detection can also be analysed using time varying auto-regressive model and recursive principal components (Krishnan, Bhowmik, Hazra, & Pakrashi, 2018).

In the study of forecasting Indian Index of Industrial Production (IIIP), the external data from Consumer Price Index (CPI), Gross Domestic Product (GDP),Wholesale Price Index (WPI) and Index of the Eight Core Industries (Electricity, Steel, Refinery Products, Crude Oil, Coal, Cement, Natural Gas and Fertilizers) has been inserted to develop the future IIIP trends (Potdar, 2017). While, (Ahmed & Khalid, 2017) used the NAR to obtain an accurate wind forecasting up to six steps in future. The development industry in the automotive field also give an impact on the use of NAR tool where it has been developed in energy management strategy for battery /ultra-capacitor hybrid electrical vehicles (Ibrahim, JeMay, Wimmer, & Hissel, 2016).

2.3.4 Backpropagation Method

Backpropagation (BP) or also known as propagation of error is one of the method with ability to teach artificial neural network to perform the tasks that being instructed to them. It was initially portrayed by Arthur E. Bryson and Yu-Chi Ho in 1969, and on 1986, this method was recognized by David E. Rumelhart, Geoffrey E. Hinton and Ronald J. Williams through their work and thus become popular in ANN research (Vamsidhar, Varma, Rao, & Satapati, 2010). In ANN, there are three tools that being used to predict the result of the study which we need to choose one out of three to be used in backpropagation method. The three tools are NARX (Nonlinear Autoregressive models with exogenous input), NAR (treatment) and Net Fitting tool. NAR is the most suitable tools that being chose to be further use in analysing the water footprint assessment as the existence of the previous data.

CHAPTER 3

STUDY AREA AND METHODOLOGY

3.1 Introduction

Pahang Darul Makmur is the biggest state in Peninsular Malaysia and third in Malaysia after Sarawak and Sabah. It covers about 35 965 km^2 and divided into 11 districts; Kuantan, Pekan, Rompin, Maran, Bera, Jerantut, Temerloh, Raub, Bentong, Lipis and Cameron Highlands- with a total population of 1.6 million and 43 people for each km^2. The main focus of the study is on the Kuantan district which also the state capital of Pahang.

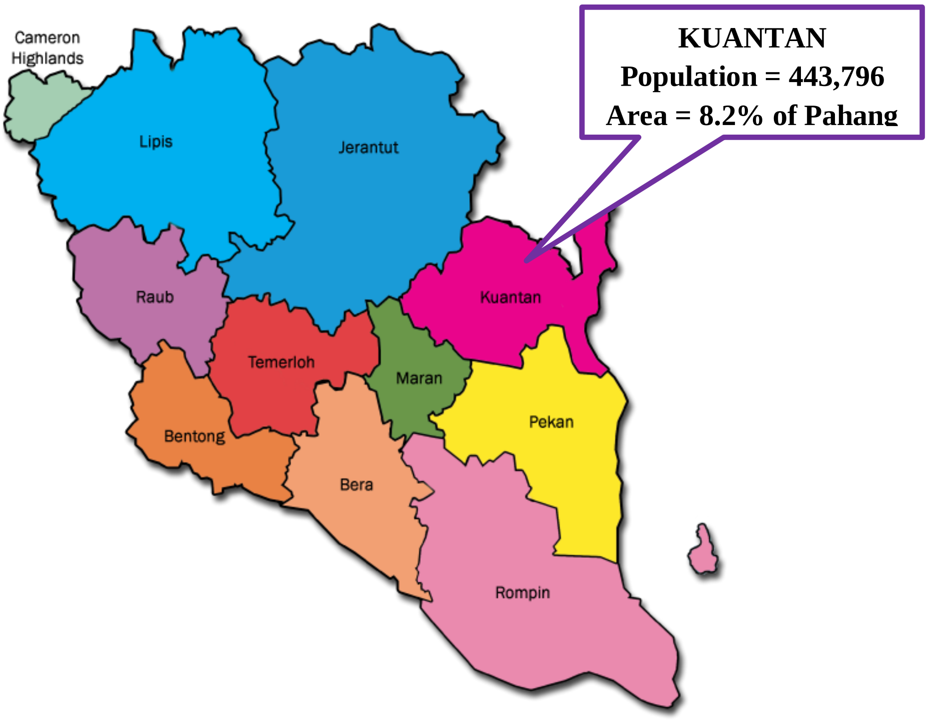

Figure 3.1 Map of Kuantan’s District

(Source: https://www.pahang.gov.my/index.php/pages/view/348)

The sub-districts involved in this research are Kuala Kuantan, Beserah, Sungai Karang, Ulu Kuantan and Penur. The dominant area of the population is Kuala Kuantan sub-district which is urban areas and there exists a rapid development with the focus of 76.11% of the population. For sub-district of Sungai Karang and Beserah, they were the second focus of the population (16.75%) where the sectors involved are tourism and industrial sector. The rest, 7.14% of the population lives in sub-districts of Ulu Kuantan, Penur and Ulu Lepar where the major activities by the people are forestry and agriculture.

Table3.1 Population Distribution in Kuantan

District	Populations	Percentages (%)
Kuala Kuantan	337,754	76.11
Beserah	19,485	4.36
Sungai Karang	54,838	12.36
Penur	7,720	1.74
Ulu Kuantan	7,102	1.60
Ulu Lepar	16,897	3.81
Total	**443,796**	**100**

Population projection for residents of Kuantan is growing exponentially from time to time and it was influenced by certain factors that contribute to this growth: (1) majority of residents still concentrate in the area of Kuala Kuantan, Beserah and Sungai Karang and (2) Penur and Ulu Kuantan experienced significant population growth with recommendations for recognition UNESCO in Sungai Lembing and industrial and infrastructure development in the area bordering Kuantan.

Table 3.2 Population Projection of Kuantan

District	2000*	2010*	2015	2020	2025	2030	2035
Kuala Kuantan	269,721	337,754	394,624	449,167	508,168	567,600	637,966
Beserah	11,744	19,485	27,101	32,189	37,723	42,643	49,274
Sungai Karang	31,625	54,838	57,270	67,331	73,251	81,043	89,513
Penur	5,767	7,720	9,206	10,690	12,841	15,777	19,408
Ulu Kuantan	8,434	7,102	9,310	10,572	12,042	13,544	15,309
Ulu Lepar	17,028	16,897	19,690	20,672	21,290	23,591	25,097
Total	344,319	443,796	517,200	590,621	665,315	744,198	836,567

3.2 Data Collection

In this particular study, all data used were classified as secondary data where certain parameters involved such as rainfall intensity, river flowrate, temperature and volume of water intake are directly obtained for the local authorities whose responsible in collecting data directly from the events or sites. Department of Drainage and Irrigation (DID), Malaysia Meteorological Department and Pengurusan Air Pahang Berhad (PAIP) or been called as Jabatan Bekalan Air (JBA) before this were the local party involves in providing the available data. Land use development data study of Kuantan district was being collected from Majlis Perbandaran Kuantan (MPK) who is responsible in developing Kuantan in structured and compatibility through the “Draf Rancangan Tempatan Daerah Kuantan 2035 (Penggantian)”.

Table 3.3 Water Intake from Kuantan River

Date	WTP PANCHING	WTP SEMAMBU	WTP BUKIT UBI	WTP SG LEMBING	WTP BUKIT SAGU
1/1/2016	122,178	220,400	22,972	4,771	5,787
2/1/2016	128,598	220,400	24,927	4,677	6,565
3/1/2016	134,572	220,400	23,946	4,746	5,979
4/1/2016	135,652	220,400	23,384	4,599	6,058
5/1/2016	103,751	220,400	23,164	4,025	6,605
6/1/2016	115,572	220,400	23,230	4,526	5,494
7/1/2016	124,803	224,527	23,170	4,437	6,656
8/1/2016	124,806	221,769	24,205	4,616	5,994
9/1/2016	121,129	228,420	23,318	4,519	5,896
10/1/2016	127,860	226,444	24,303	4,576	5,694
11/1/2016	125,802	222,852	24,391	3,685	5,550
12/1/2016	141,780	217,254	23,267	4,659	5,770
13/1/2016	139,973	217,726	24,839	4,758	6,800
14/1/2016	146,961	215,560	24,542	4,443	4,051
15/1/2016	146,348	220,988	25,166	4,436	6,502
16/1/2016	144,217	219,591	23,432	4,610	6,125
17/1/2016	130,981	241,379	23,959	4,668	6,360
18/1/2016	122,056	223,834	25,376	4,825	5,648
19/1/2016	121,901	218,319	24,944	4,621	6,510
20/1/2016	122,878	216,768	23,743	4,756	5,997
21/1/2016	126,409	215,344	25,759	4,826	6,380
22/1/2016	129,808	223,885	25,925	4,467	6,854
23/1/2016	125,288	219,128	23,216	4,921	5,245
24/1/2016	133,759	219,962	25,758	4,200	6,765
25/1/2016	122,292	217,705	21,337	4,744	1,366
26/1/2016	125,412	219,145	25,391	4,590	3,534
27/1/2016	116,503	216,331	23,475	4,615	6,381
28/1/2016	127,509	221,345	25,655	4,324	7,092
29/1/2016	126,540	212,502	24,328	3,171	6,977
30/1/2016	115,461	208,800	24,942	4,477	6,967
31/1/2016	128,130	220,400	24,202	4,509	5,920

3.3 Blue Water Footprint

Water Footprint accounting in this study is distinctly put the centre of attention to the Blue Water Footprint. It is assumed that, quantification of water footprint is considered for all unit processes for each WTP in Kuantan. The amount of BWF at the end of the month or year is directly proportional to the manipulated variables which are rainfall events and water intake. BWF is the volume of both surface and ground water or in the other hand, a consumptive water use. It is a formulative process which can be expressed in the following equation:

$$WF_{blue} = BWE + BWI + LRF \qquad \text{Equation 3.1}$$

where;

BWE= Blue water evaporation

BWI = Blue water Incorporation

LRF = Lost Return flow

The SI unit of the processed blue water footprint is volume of per unit of time. LRF is not being considered in the calculation due to it absentness while Green and Grey water footprint is not being accounted in this study.

3.4 Effect of Land Use Development to Water Footprint Accounting

Land use change can cause a big effects on the provision of ecosystem services and biodiversity (Lawler et al. 2014, Millennium Ecosystem Assessment, 2005). The transformation of land from less to more rigorous uses, such as conversion of grassland into concrete forests can simply change the nature activities of the ecosystem and therefore a well-coordinated planning of land use should be carried efficiently. The very strong connection between the land use and blue water footprint accounting indicates how importance to be prepared on the increasing consumption of water along with more land to be developed. A good development process shall bring a great impact on the growth of population, demands of basic necessities such as food and water and more on the economic value of the region.

Pursuing the development of land use history, many changes has taken place especially on the use of land for industrial, commercial and housing purposes which lead to the increment in population of Kuantan. As tabulated in Table 3.1, a rapid growth on population comes from a significant change of land use which directly influence the demand of treated water. Treated water from Panching WTP is being distributed to two sub-districts, Penor and Kuala Kuantan while Bukit Ubi and Bukit Sagu WTP provide the water to Bandar Kuantan and Felda Bukit Sagu respectively. Semambu WTP distribute water to the industrial area of Sg. Karang and Beserah and Sg Lembing WTP provide the water to the area where forestry and agriculture are dominant.

Table 3.4 Land Use of Kuala Kuantan Sub-district

Type of land use	2016		2035	
	Hectare (Ha)	Percent (%)	Hectare (Ha)	Percent (%)
Residential	3,804.53	4.79	13,097.17	16.36
Commercial	570.71	0.72	1,402.05	1.75
Industry	692.72	0.87	2,795.80	3.49
Institution & Public Facilities	2,890.11	3.64	3,439.91	4.3
Infrastructure & utility	636.02	0.8	1,067.02	1.33
Recreation & Open Field	720.13	0.91	2,216.45	2.77
Agriculture	33256.6	41.86	26,806.87	33.48
Forestry				
• **Fixed Reserved**	16,097.15	14.88	11,765.00	14.69
• **Land Forest**	11,823.35	20.26	12,021.14	15.01
Transportation	3,957.49	4.98	4,095.96	5.12
Under Utilised	3,458.87	4.35	-	-
"Badan Air"	1426.86	1.8	1,308.73	1.63
Beach	112.38	0.14	60.61	0.08
Total	79,446.92	100	80,076.26	100

Table 3.5 Land use of Beserah sub-district

Type of land use	2016		2035	
	Hectare (Ha)	Percent (%)	Hectare (Ha)	Percent (%)
Residential	295.56	9.53	1,532.31	49.39
Commercial	25.57	0.82	133.88	4.31
Industry	5.87	0.19	9.91	0.32
Institution & Public Facilities	45.21	1.46	83.44	2.69
Infrastructure & utility	32.08	1.03	29.27	0.94
Recreation & Open Field	19.05	0.61	51.44	1.66
Agriculture	1,221.17	39.36	559.34	18.03
Forestry				
• **Fix Reserved**	437.56	14.1	437.56	14.1
• **Land Forest**	288.11	9.29	-	-
Transportation	217.62	7.01	239.83	7.73
Under Utilised	457.51	14.75	-	-
"Badan Air"	15.82	0.51	2.82	0.09
Beach	41.59	1.34	22.92	0.74
Total	3,102.72	100	3,102.72	100

Table 3.6 Land Use of Sg. Karang Sub-district

Type of land use	**2016**		**2035**	
	Hectare (Ha)	**Percent (%)**	**Hectare (Ha)**	**Percent (%)**
Residential	7,755.58	2.85	3,986.66	14.16
Commercial	217.78	0.8	969.45	3.44
Industry	1,487.22	5.46	7,140.18	25.36
Institution & Public Facilities	541.54	1.99	785.51	2.79
Infrastructure & utility	467.13	1.71	525.08	1.87
Recreation & Open Field	48.3	0.18	112.41	0.4
Agriculture	3,166.93	11.62	4,612.39	16.38
Forestry				
• **Fixed Reserved**	7,421.38	27.24	6,500.64	23.09
• **Land Forest**	7,617.13	27.95	880.55	3.13
Transportation	1,381.54	5.07	1,651.30	5.67
Under Utilised	3,558.71	13.06	-	-
"Badan Air"	261.39	0.96	713.10	2.53
Beach	304.17	1.12	276.30	0.98
Total	27,248.80	100	28,153.57	100

Table 3.7 Land Use of Penur Sub-district

Type of land use	**2016**		**2035**	
	Hectare (Ha)	**Percent (%)**	**Hectare (Ha)**	**Percent (%)**
Residential	385.37	1.73	4,377.33	19.64
Commercial	16.55	0.07	965.87	4.33
Industry	1.58	0.01	65.86	0.3
Institution & Public Facilities	244.43	1.1	262.52	1.18
Infrastructure & utility	7.7	0.03	13.73	0.06
Recreation & Open Field	19.9	0.09	38.39	0.17
Agriculture	14,921.45	66.95	12,698.20	56.98
Forestry				
• **Fixed Reserved**	-	-	-	-
• **Land Forest**	5,941.19	26.66	2,749.73	12.34
Transportation	296.82	1.33	765.15	3.43
Under Utilised	48.03	0.22	-	-
"Badan Air"	280.27	1.26	266.07	1.19
Beach	122.87	0.55	83.31	0.37
Total	22,286.16	100	22,286.16	100

Table 3.8 Land Use of Ulu Kuantan Sub-district

Type of land use	**2016**		**2035**	
	Hectare (Ha)	**Percent (%)**	**Hectare (Ha)**	**Percent (%)**
Residential	175.99	0.2	332.46	0.38
Commercial	12.15	0.01	20.96	0.02
Industry	605.35	0.68	685.35	0.11
Institution & Public Facilities	41.07	0.05	70.01	0.08
Infrastructure & utility	30.45	0.03	241.47	0.27
Recreation & Open Field	45.73	0.05	1,613.38	1.82
Agriculture	16,019.17	18.08	15,172.87	17.12
Forestry				
• **Fix Reserved**	58,032.95	65.49	52,966.35	65.49
• **Land Forest**	11,359.16	12.82	10,071.41	11.37
Transportation	238.11	0.27	321.69	0.36
Under Utilised	2.42	0.01	-	-
"Badan Air"	2,053.98	2.32	2,053.98	2.32
Total	88,616.53	100	88,616.53	100

It is notable that the land use distribution of development (industrial) for the study area above are increasing with minimum of 0.11 percent in Ulu Kuantan and maximum of 25.36 percent recorded in Sungai Karang. This great changes would eventually affect the water footprint of Semambu WTP. Therefore, the effect of land use development to the BWF accounting can be obtained by comparing the water footprint and water capacity.

3.5 Industrial Zone Analysis

A high concentration of industry in a small space is one of the main feature to classify the place as an industrial zones also known as industrial park. These industrial zones are usually based on implementation of Foreign Direct Investment (FDI) and on investment incentives while form of cluster they take only in some isolated cases. Building of industrial zones has become a successful tool to attract investment, because one of the key factor that influence the location of the investment is availability of land and of buildings of required parameters, high quality connection to the technical and information infrastructure and proximity to strategic buyers or suppliers (Jetmar 2008).

In this analysis of study, the land use for industrial activities in Kuantan is being divided according to their respective sub-district. It is therefore, to determine the amount of water distributed by the WTPs to the industrial area, the summation of the total water footprint at all five WTP must be find beforehand. The equation to determine the water distributed to industrial can be found below;

$$WD = \frac{Percent}{100} x\ TWF\ (\frac{m^3}{year}) \qquad \text{Equation 3.2}$$

where;

WD = Water distributed to Industrial Area

Percent = Percentage of land use

TWF = Total Water Footprint in one year

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the discussion on the data that were obtained previously will be shown. The result of this study was arranged according to the research objectives, which are the determination of Blue Water Footprint accounting for industrial activities in Kuantan River Basin, followed by the effect of land use development to the Blue Water Footprint accounting and the prediction of sustainability of water supply treatment process at Kuantan River Basin.

There are five (5) Water Treatment Plants (WTP) involved in this study, where all of them vary to each other in terms of size and their role in distributing the water. The five (5) WTP are Sg. Lembing Water Treatment Plant, Bukit Sagu Water Treatment Plant, Panching Water Treatment Plant, Semambu Water Treatment Plant and Bukit Ubi Water Treatment Plant. The water demand for Kuantan district is accommodated by all of them and the figures of clean water demand will keep increasing from time to time. Hence, it is very important to forecast whether all these five WTPs can effectively work proportionally to the increment in water demand. Ulu Lepar sub-district is not being included into accounting as the region has its own water treatment plant.

4.2 Blue Water Footprint Accounting

4.2.1 Water Footprint of Sg. Lembing WTP

In order to support the forestry and agricultural development needs in area Ulu Kuantan, Sg. Lembing WTP is the only water treatment plant that supplies water for Sungai Lembing and Panching Utara area. Located at 3.561, 103.47, it is expected to cover almost 88,616.53 Ha of land use with the capacity of 250 m^3/hour and can reach to 2.19 x 10^6 m^3/year where benefits almost 7,500 of population.

Figure 4.1 Sg. Lembing Water treatment Plant

Table 4.1 Total WF in year 2015

Month	Water footprint 2015 (m^3/month)
Jan	482,384.75
Feb	777125.987
Mar	413146.967
Apr	492277.628
May	520725.425
June	420460.275
July	498194.4
Aug	528167.638
Sept	421092.714
Oct	606711.71
Nov	510216.497
Dec	541391.81

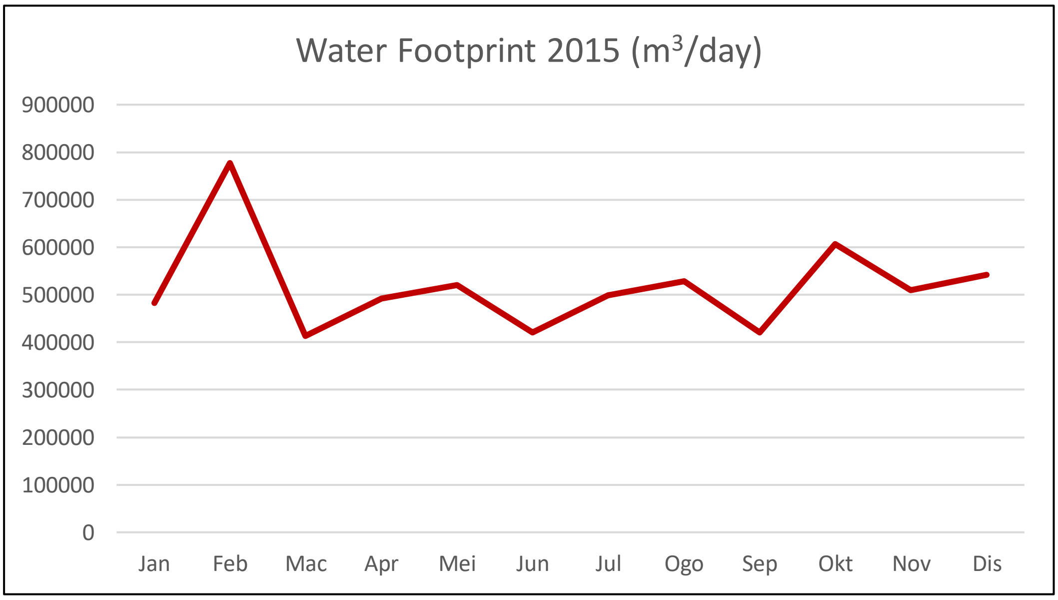

Figure 4.2 Total WF in 2015

Based on the graph of water footprint of Sungai Lembing WTP for 2015, the graph shows a great fluctuation throughout the year. In January, the value of water footprint was 482384.745 m^3/day, which then increased greatly to 777125.987 m^3/day in February, where the highest reading of water footprint for year 2015 was obtained. In March, the reading dropped to the lowest value for the year, which was 413146.967 m^3/day. This low value might be due to less amount of rainfall for that particular month. The data of water footprint increased again in April and May, and dropped again to 420, 460.275 m^3/day in June. This trend continued until the end of the year, where the water footprint decreased and increased alternately for every month starting from July towards December.

The Malaysian monsoon has a great impact on the fluctuation of water footprint value. There are two monsoon seasons that occur in Malaysia, namely the Southwest Monsoon, which occurs from late April to October, and the Northeast Monsoon which takes place from October to February (Seasons in Malaysia, 2018). The study area is located in the north of peninsular Malaysia. The Northeast Monsoon causes more rainfall compared to the Southwest Monsoon, and the monsoon is originated from China and the north Pacific. Rainfall intensity will be affecting the amount of green water footprint and it's indirectly increases the total water footprint for that particular period.

Table 4.2 Total WF in Year 2016

Month	**Water footprint 2016 (m^3/month)**
Jan	417883.25
Feb	563551.805
Mar	377707.101
Apr	432942.238
May	639996.255
June	502762.764
July	508296.122
Aug	497488.907
Sept	640548.553
Oct	876205.542
Nov	615849.335
Dec	412173.315
Total	6485405.187

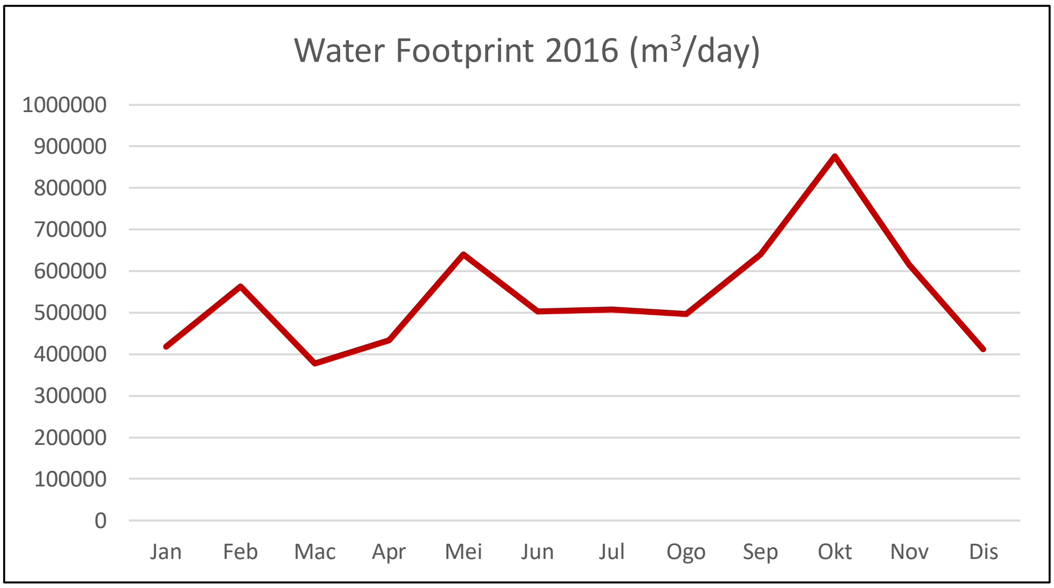

Figure 4.3 Water Footprint in Year 2016

By referring to the water footprint graph plotted for Sungai Lembing WTP in 2016, it can be seen that the pattern of water footprint is almost similar to the Water Footprint Accounting in 2015. Great fluctuation for the amount of water footprint occurred in 2016. The lowest value was 377707.101 m^3/day, which was obtained in March. This is similar to the water footprint in March 2015 where less rainfall occurred in the same month. The value of water footprint increased in April and May, but then had a slight drop starting from June until August. However, it increased greatly in October, with a value of 876205.542 m^3/day, which might be caused by the monsoon that increased the amount of rainfall for the respective month. The reading decreased again in November and December which indicates less rainfall occurred during these two months compared to one that eventuated in October.

Table 4.3 Total WF in Year 2017

Month	Water footprint 2017 (m^3/month)
Jan	351229.502
Feb	363269.82
Mar	350956.018
Apr	348370.127
May	416604.755
June	372017.151
July	380407.358
Aug	367163.708
Sept	404799.709
Oct	427953.512
Nov	387519.248
Dec	-
Total	4170290.908

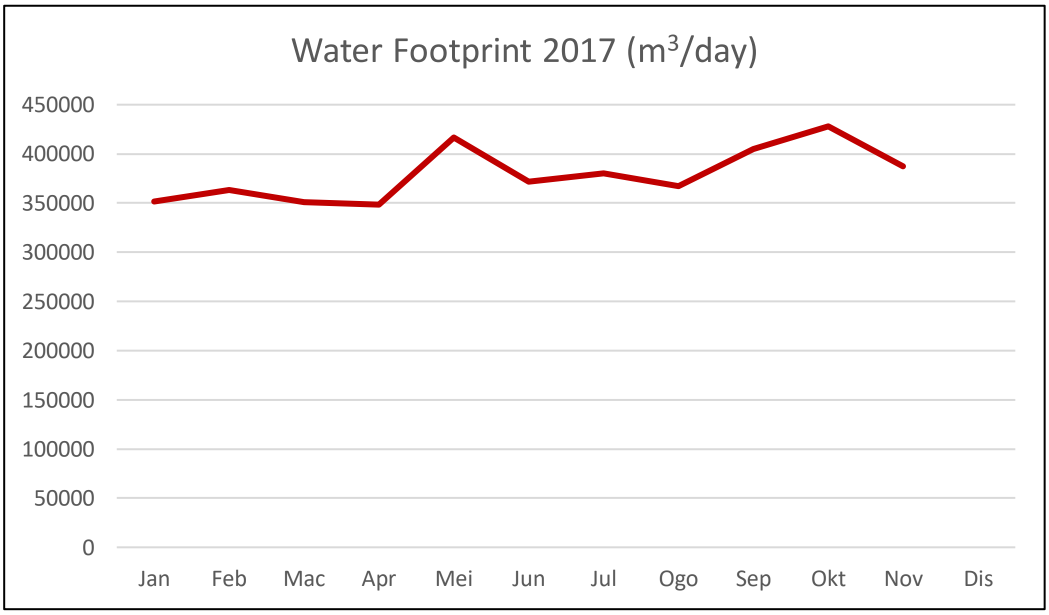

Figure 4.4 Water Footprint in Year 2017

In 2017, the water footprint accounting values were gradual, which can be seen clearly from the graph plotted. In January, the value of water footprint was 351229.502 m^3/day. It increased with a slight amount in February with a value of 363269.82 m^3/day and the value decreased consistently until April. In May, the highest value of water footprint for the year was obtained, which was 416604.755 m^3/day. This indicates the occurrence of heavy rainfall for the month for the month of May. The value of water footprint then decreased steadily until August, and increased again in September and October. In November, the reading dropped from 427953.512 m^3/day to 387519.248 m^3/day. There was no data obtained for the month of December.

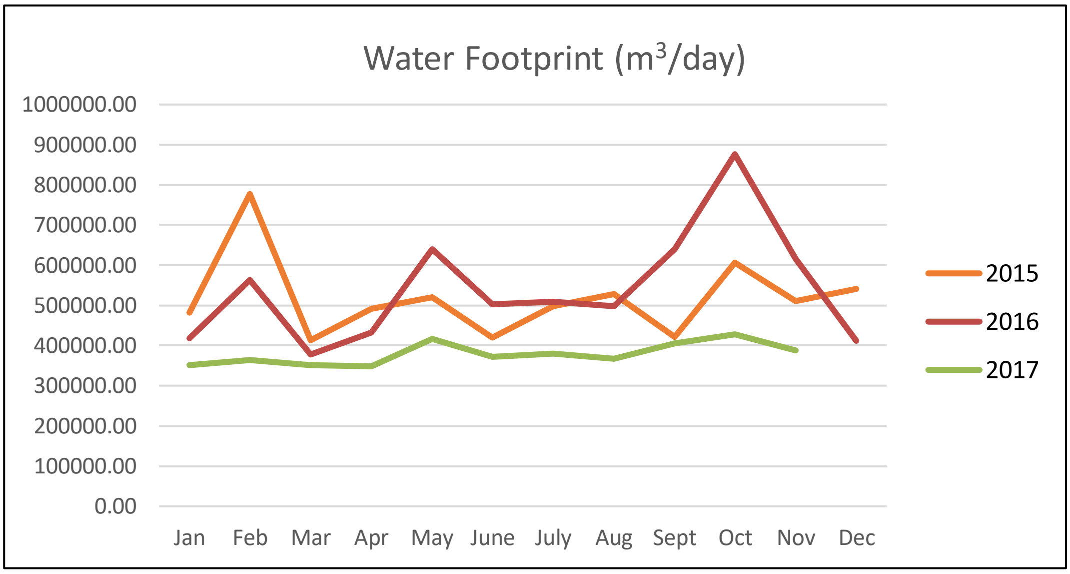

Figure 4.5 Overall WF in Sg. Lembing

4.2.2 Water Footprint of Bukit Sagu WTP

Bukit Sagu WTP is located at 3.5456, 103.1032 and has a capacity of 900 m^3/hour and maximum it can reach is to 7.88 x 10^6 m^3/year. This capacity could be said sufficient enough to cater the bauxite mining industry in that area. Along with the Panching and Semambu WTP, Bukit Sagu WTP is only focussing on supplying the water to a small area of Felda Bukit Sagu.

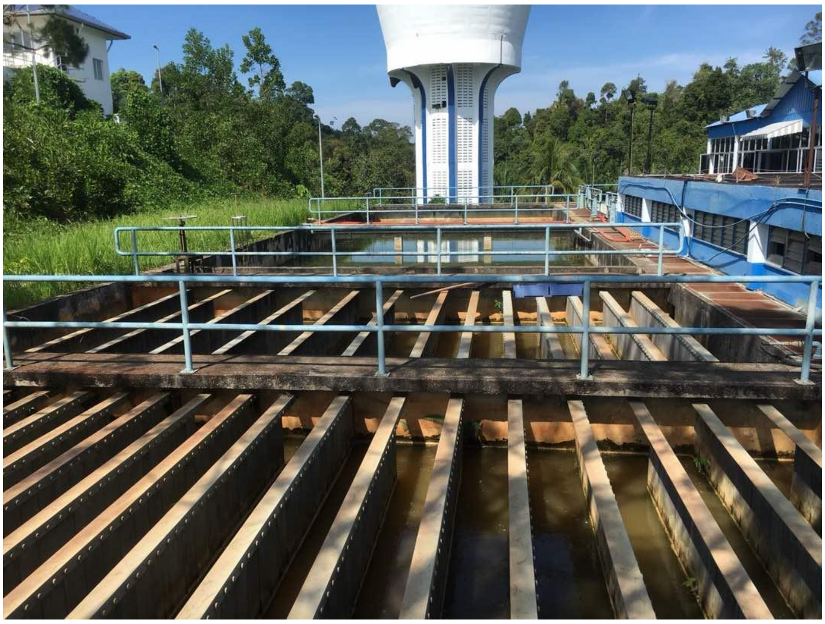

Figure 4.6 Bukit Sagu WTP

Table 4.4 Total WF in year 2015

Month	**Water footprint 2015 (m^3/month)**
Jan	419957.571
Feb	615896.637
Mar	327688.373
Apr	280314.418
May	463533.692
June	440359.012
July	532597.054
Aug	504011.48
Sept	439512.513
Oct	793986.525
Nov	719087.999
Dec	987006.943
Total	6523952.217

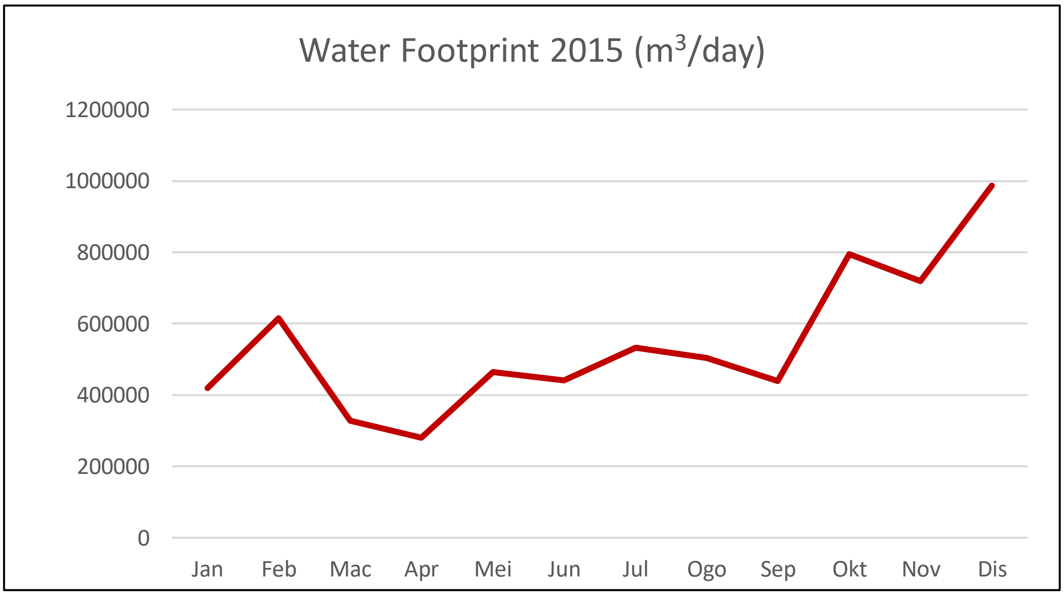

Figure 4.7 Water Footprint in Year 2015

From the data presented in the table above, the values for water footprint at Bukit Sagu WTP in 2015 fluctuated greatly throughout the year. In January, the value of water footprint was 419957.571 m^3/day. It then increased to 615896.637 m^3/day in February which might be caused by heavy rainfall and dropped substantially in March and April. However, the values of water footprint increased gradually from May towards September, and started to increase greatly in October with an increment of

354474.012 m^3/day. Bukit Sagu WTP achieved the highest value of water footprint for year 2015 in December, with a value of 987006.943 m^3/day. This proves that the Northeast Monsoon had taken place and gave a major effect on the value of water footprint.

Table 4.5 Total WF in year 2016

Month	Water footprint 2016 (m^3/day)
Jan	444882.254
Feb	346471.96
Mar	400046.561
Apr	422172.009
May	496482.226
June	451129.829
July	540850.934
Aug	535037.844
Sept	439119.527
Oct	794664.05
Nov	699579.135
Dec	701276.386
Total	6271712.715

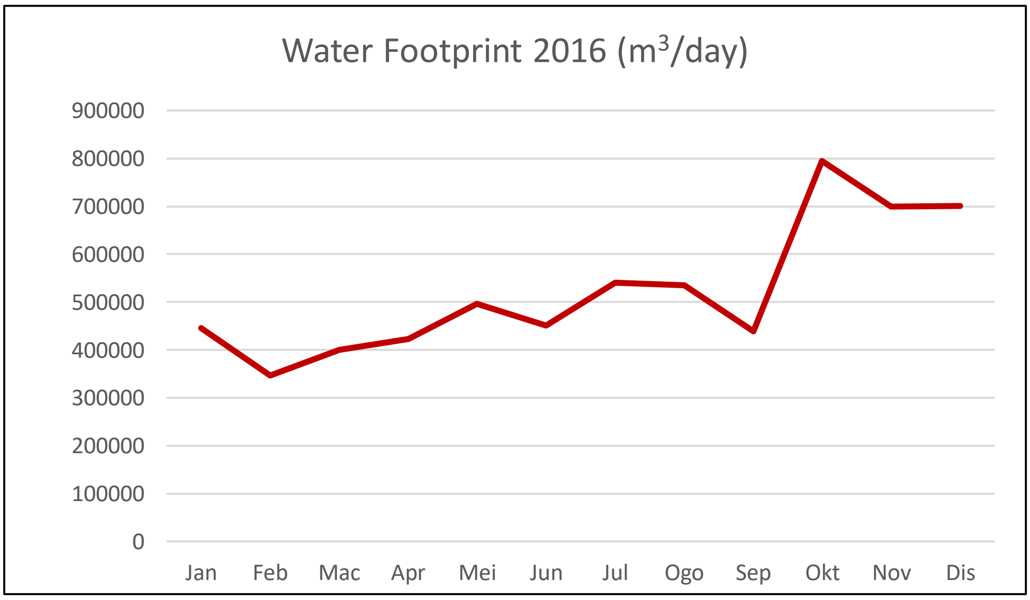

Figure 4.8 Water Footprint in Year 2016

In 2016, the values of water footprint in Bukit Sagu WTP was almost consistent from January until August. There was a gradual increase from February, where the value of water footprint is 346471.96 m^3/day until August (535037.844 m^3/day). The highest data for water footprint was achieved in October due to heavy rainfall from the monsoon that occurred during that month, with a value of 794664.05 m^3/day. The monsoon plays a big role in determining the changes of pattern of water footprint. It can be seen that the value of water footprint was then consistent in both November and December, with a slight difference between these two months.

Table 4.6 Total WF in year 2017

Month	**Water footprint 2017 (m^3/month)**
Jan	389930.835
Feb	357922.96
Mar	328014.551
Apr	361615.241
May	425115.75
June	390783.589
July	419066.714
Aug	422603.668
Sept	422606.985
Oct	465160.372
Nov	383165.888
Dec	-
Total	4365986.553

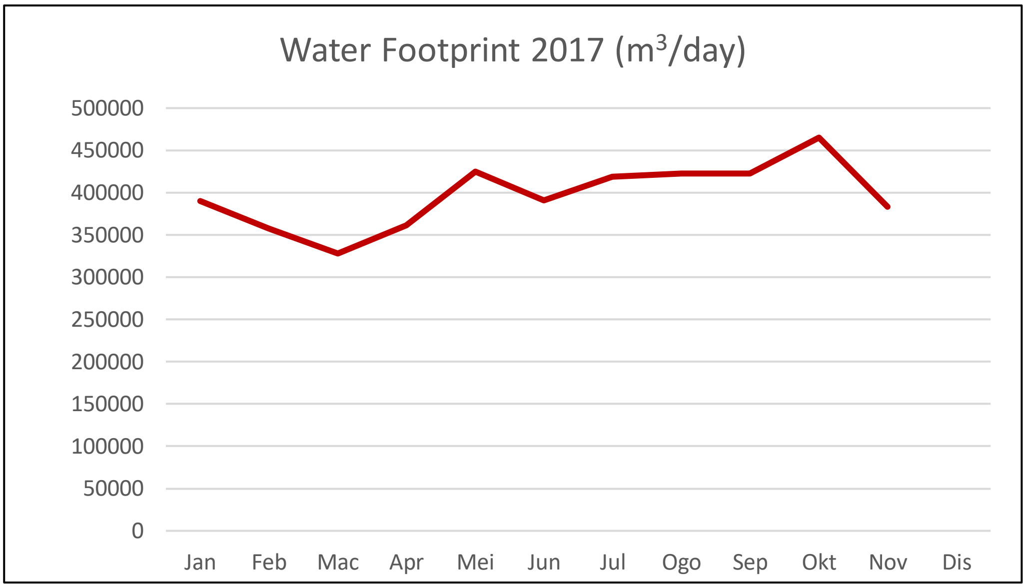

Figure 4.9 Water Footprint in Year 2017

The trend of water footprint accounting at Bukit Sagu WTP in 2017 can be seen by referring to the data as tabulated above. From the table and graph that has been shown, the lowest value of water footprint was obtained in 357922.96 m^3/day, which might happen due to the transition of Southwest Monsoon and Northeast Monsoon. The highest data for water footprint was from the month of October, with a value of 465160.372 m^3/day. This occurrence is similar to both accountings from year 2015 and 2016, where the values of water footprint in October for the respective years are high. This is possibly due to the Northeast Monsoon that has taken place. The data then decreased in November to 383165.888 m^3/day, and there was no data that was attained in December.

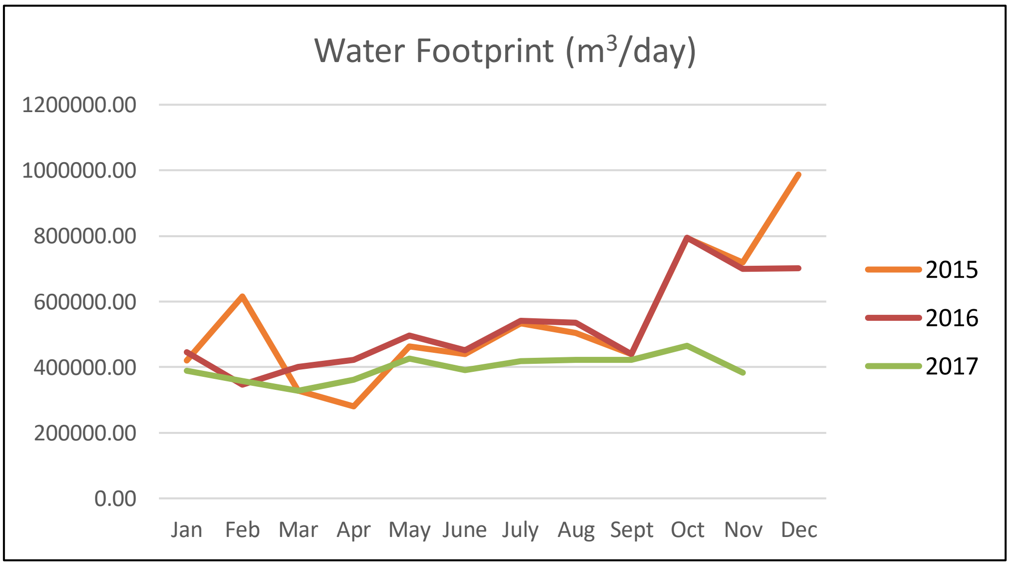

Figure 4.10 Overall Water Footprint in Bukit Sagu

4.2.3 Water Footprint of Panching WTP

Kuantan River has become the source of water intake for Panching WTP. It is the second bigger WTP in Kuantan district and located at 3.5020, 103.1238 where the areas of water supply are both for Penur and Kualan Kuantan. The capacity of 7,000 m^3/hour and expected to be 6.13 x 10^7 m^3 /year will be able to sufficiently provide 389,000 people with treated water including the residential area and as well as 5600 Ha of industrial area.

Figure 4.11 Panching Water Treatment Plant

Table 4.7 Total WF in year 2015

Month	**Water footprint 2015 (m^3/month)**
Jan	-
Feb	2760576.2
Mar	3132207
Apr	3271455
May	4750800.6
June	4670342.3
July	5199264
Aug	5253300.8
Sept	4777217.5
Oct	5140575.4
Nov	4732376.6
Dec	4985638.2
Total	48673753.6

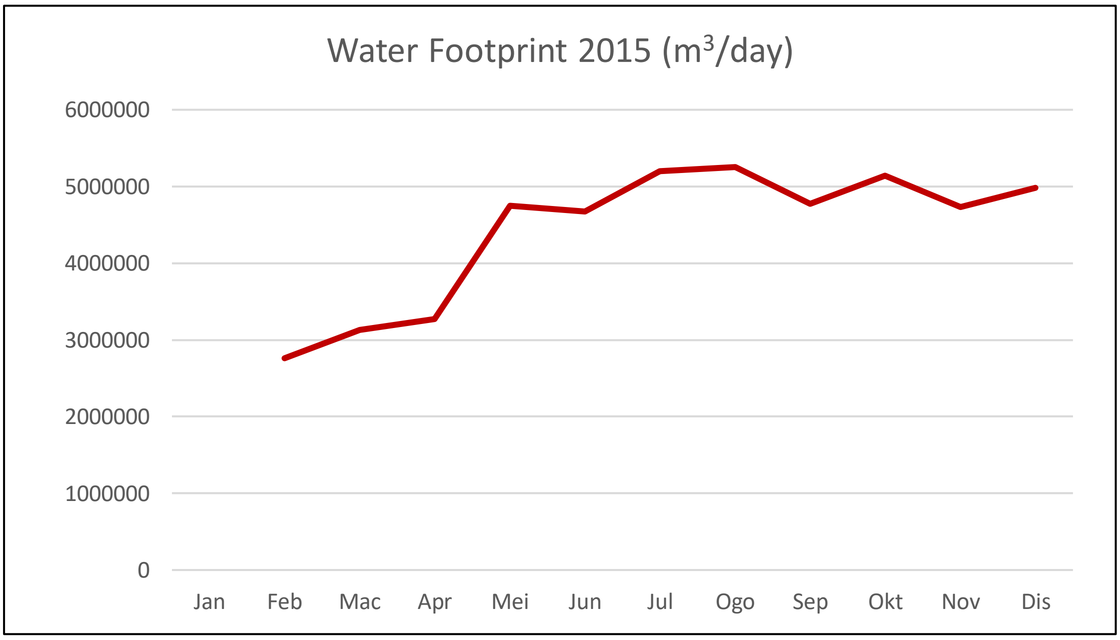

Figure 4.12 Water Footprint in Year 2015

In February 2015, the graph shows the lowest result of water footprint with the value 2760322 m^3/day. The value that was shown might be due to the beginning of operation of Panching WTP, which started their operation in February 2015. In the beginning of the operation, there was no backwash thus none grey water footprint was recorded. There was only green and blue water footprint at that time. The value of water footprint gradually increased from February until April, and increased greatly in May with a value of 4750800.6 m^3/day. By referring to the graph, it can be seen that the water footprint increased gradually until August and become constant until the end of the year.

Table 4.8 Total WF in year 2016

Month	**Water footprint 2016 (m^3/month)**
Jan	4524827.526
Feb	4508682.468
Mar	4669823.352
Apr	4522155.315
May	5224373.347
June	5092312.577
July	5580779.566
Aug	5288767.845
Sept	5342433.106
Oct	4198732.457
Nov	4828474.454
Dec	4650349.215
Total	58431711.23

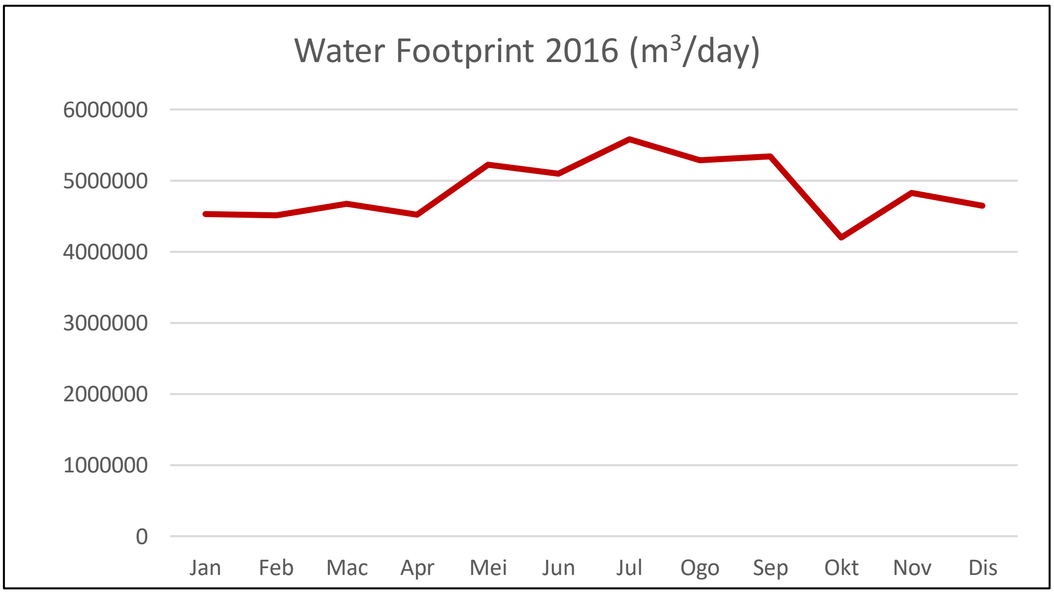

Figure 4.13 Water Footprint in Year 2016

Based on the plotted graph as shown above, the values of water footprint at Panching WTP in 2016 were consistent from January until September. Starting from January until April, there were minor differences of value for water footprint. The values of water footprint are 4524827.526 m^3/d, 4508682.468 m^3/d, 4669823.352 m^3/d and 4522155.315 m^3/d respectively. In May, the water footprint increased to 5224373.347 m^3/day and decreased slightly to 5092312.577 m^3/day in June. This trend of minor increase and decrease continued until September, and dropped significantly in October with a value of 4198732.457 m^3/day. This occurrence might happen due to less rainfall throughout this month.

Table 4.9 Total WF in year 2017

Month	**Water footprint 2017 (m3/month)**
Jan	4313816.891
Feb	3968489.056
Mar	1047142.186
Apr	4003413.515
May	3873377.296
June	3745340.092
July	4015751.566
Aug	4226555.845
Sept	3932103.091
Oct	4696695.777
Nov	4459303.439
Dec	-
Total	42281988.75

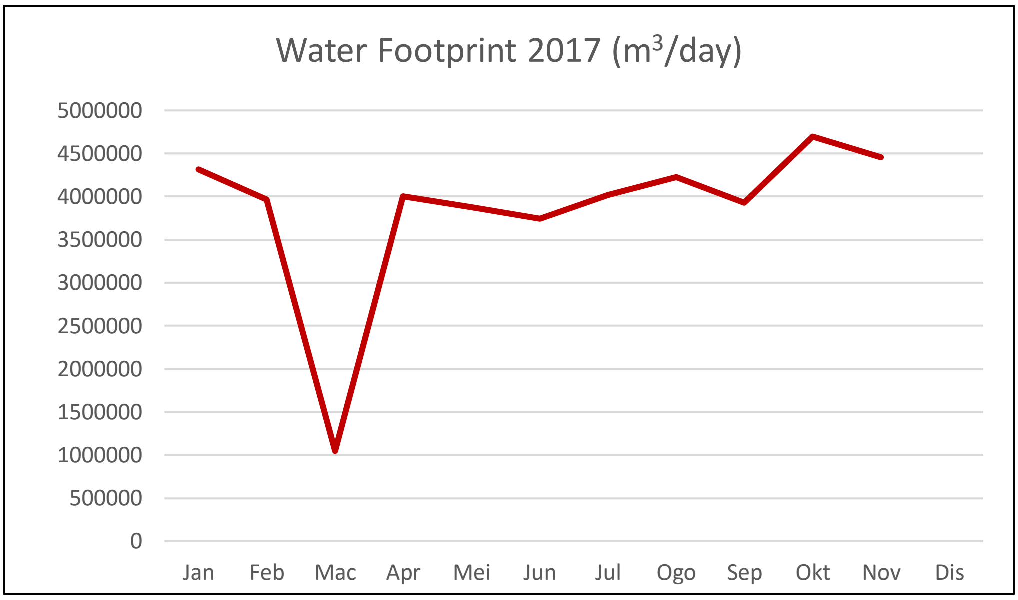

Figure 4.14 Water Footprint in Year 2017

The water footprint accounting for Panching WSTP in 2017 is as shown in the table above. A major drop of value of water footprint can be seen in the graph, where the value decreased greatly from 3968489.056 m^3/day in February to 1047142.186 m^3/day in March. This is caused by major changes in rainfall intensity. The data increased again in April, with a significant value of 4003413.515 m^3/day and increased gradually until November. The highest data for water footprint accounting was achieved in October, which was 4696695.777 m^3/day. Similar to other WTPs, October has the highest data for water footprint due to high occurrence of rainfall.

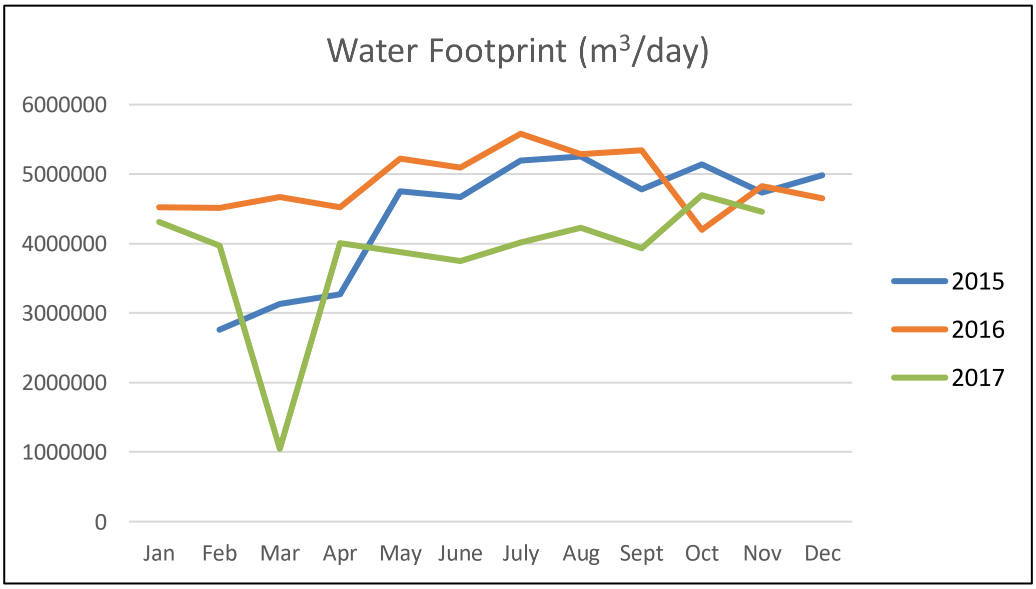

Figure 4.15 Overall Water Footprint for Panching WTP

4.2.4 Water Footprint of Semambu WTP

Sub-districts of Sungai Karang and Beserah has received treated water from the Semambu WTP. Although located at 3.521, 103.2016 and 18 km away from the intake location, it is recognised as the biggest WTP's capacity with 12,000 m^3/hour and will increase to 1.05 x 10^8 m^3/year. The average population of 92,800 occupied in areas of 30,300 ha benefited from this water treatment plant. Residential area of Kotasas and industrial park of Semambu and Gebeng has become the major receiver of treated water.

Figure 4.16 Semambu Water Treatment Plant

Table 4.10 Total WF in Year 2015

Month	Water footprint 2015 (m^3/month)
Jan	159311.77
Feb	140841.62
Mar	155680.55
Apr	148829.31
May	160667.25
June	150760.41
July	151787.26
Aug	144477.09
Sept	125138.07
Oct	129079.16
Nov	125402.25
Dec	129393.51
Total	1721368.25

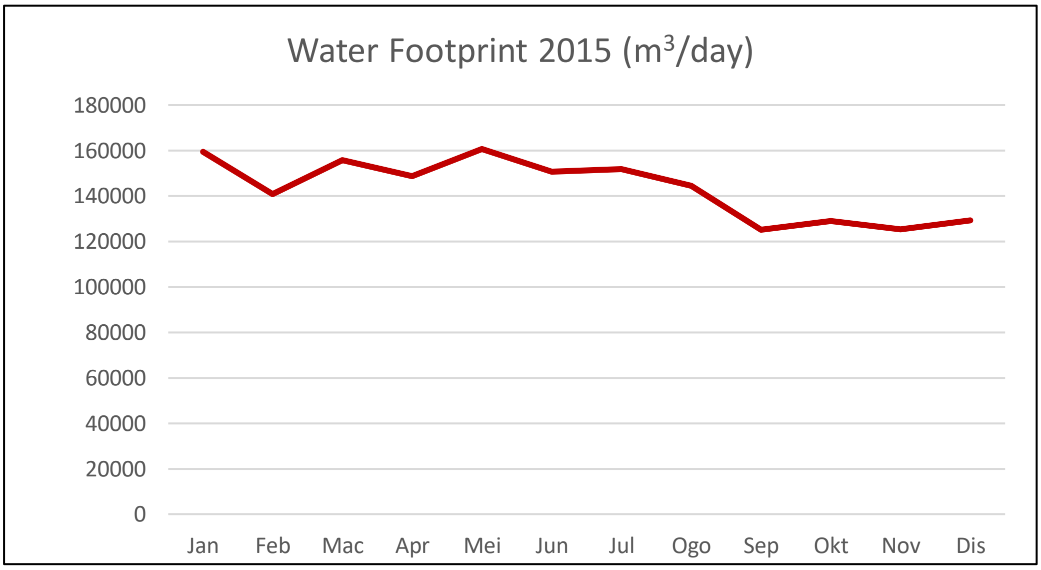

Figure 4.17 Water Footprint in Year 2015

The water footprint accounting of Semambu WTP in 2015 has low values compared to other WTPs in this study. From the graph that was plotted, it can be seen that the trend of water footprint in this WTP is gradually decreasing. A small fluctuation occurred from January until June, and a steady decrease can be seen starting from July towards the end of the year. The highest data obtained was from May, which was 160667.25 m^3/day. The lowest data was obtained from September, which was 125138.07

m^3/day. This might be caused by the decrease in volume of water intake from Kuantan river basin.

Table 4.11 Total WF in year 2016

Month	Water footprint 2016 (m^3/month)
Jan	158554.791
Feb	221774.49
Mar	254766.24
Apr	243548.9
May	254836.18
June	243732.72
July	254871.38
Aug	257001.45
Sept	245621.37
Oct	256906.59
Nov	245686.83
Dec	256954.71
Total	2894255.651

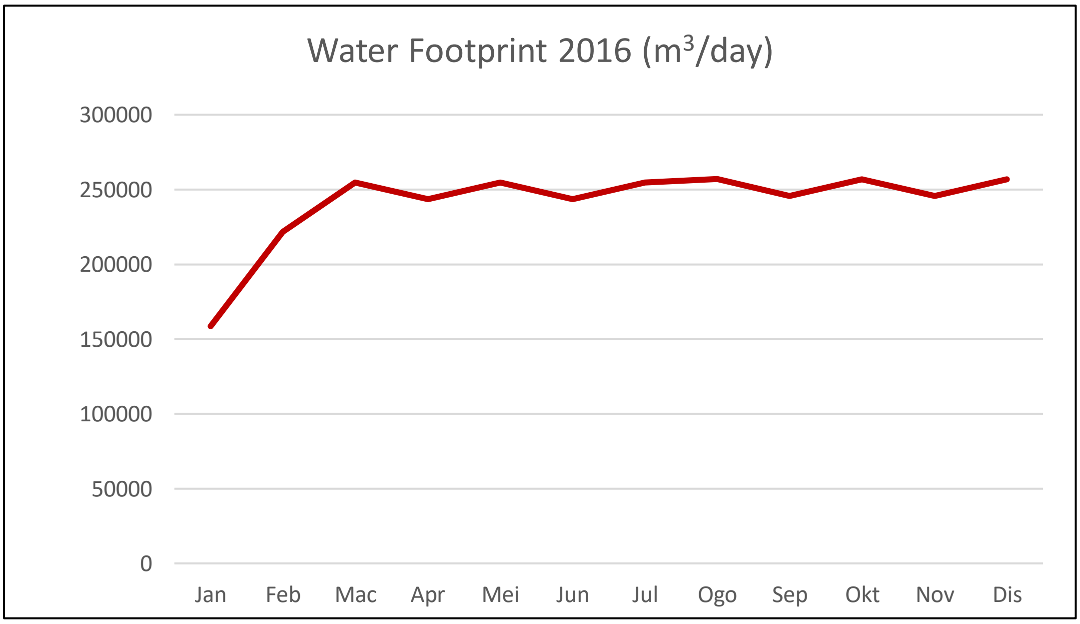

Figure 4.18 Water Footprint in Year 2016

By referring to the graph of Water Footprint Accounting 2016, it can be observed that the lowest data of water footprint at Semambu WTP is in January with a value of

158554.791 m^3/day. This might be due to the start-up of the plant in the beginning of the year which caused a low volume of water intake at the WTP. The value increased substantially in February and March, which was 221774.49 m^3/day and 254766.24 m^3/day respectively. The trend of the water footprint was consistent until the end of the year, where a minor decrease and increase occurred every month. The highest data of water footprint accounting at Semambu WTP was obtained in August, which was 257001.45 m^3/day.

Table 4.12 Total WF in year 2017

Month	Water footprint 2017 (m^3/month)
Jan	158554.791
Feb	221774.49
Mar	254766.24
Apr	243584.92
May	254836.18
June	243732.72
July	254871.34
Aug	257001.45
Sept	245621.37
Oct	256906.59
Nov	245686.83
Dec	
Total	2637336.921

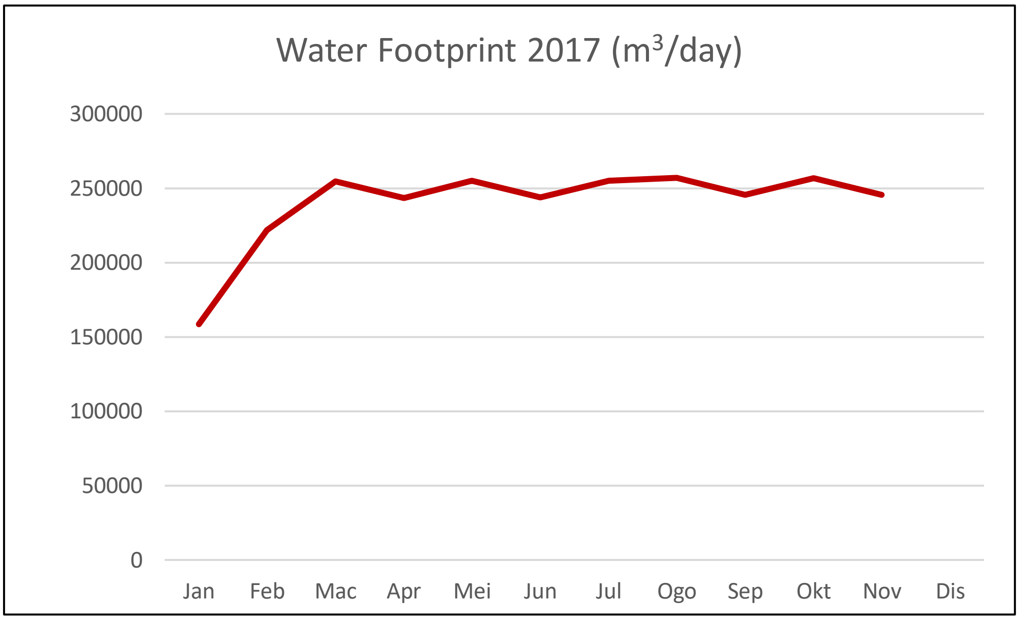

Figure 4.19 Water Footprint in Year 2017

Similar trend of Water Footprint Accounting at Semambu WTP from 2016 can be seen in 2017. The lowest value of water footprint was obtained in January, where the data was only 158554.791 m^3/month. The values increased in February and March, where the data obtained were 221774.49 m^3/month and 254766.24 m^3/month for each particular month. The trend was consistent and gradual from April right towards the end of the year, where the highest value of water footprint was obtained in August with a value of 257001.45 m^3/month. However, there was no value recorded for the month of December.

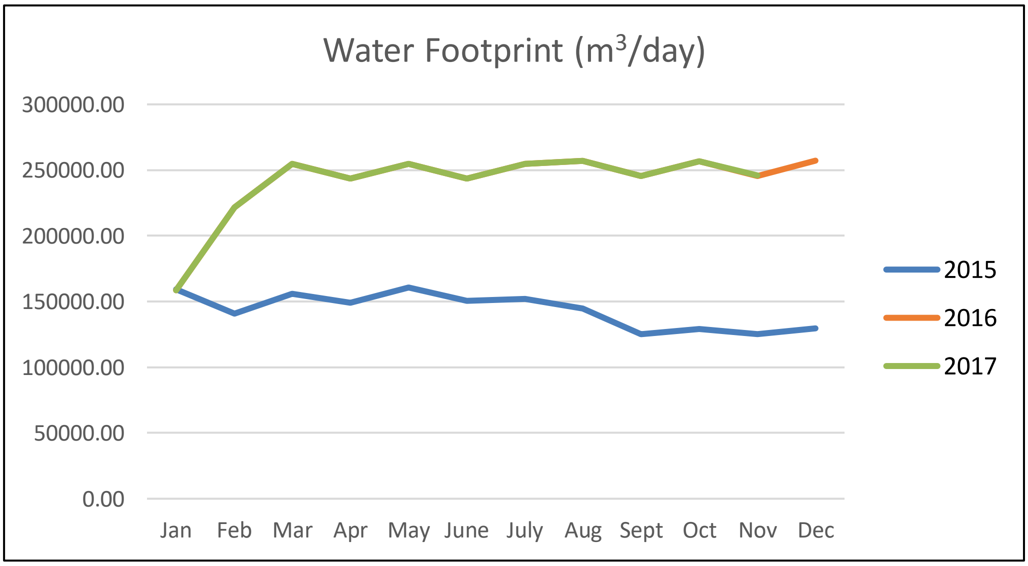

Figure 4.20 Overall Water Footprint for Semambu WTP

4.2.5 Water Footprint of Bukit Ubi WTP

The treated water supply foe commercial area in Kuala Kuantan is being covered by the one and only, Bukit Ubi WTP. Located at 3.4920, 103.1973 which at the centre of the town area, the maximum area of water distributed to that particular commercial area is 1500 m^3/hour and exponentially growth to 1.31 x 10^7 m^3/year, making it third highest within all WTP.

Figure 4.21 Bukit Ubi WTP

Table 4.1 Total WF in year 2015

Month	Water footprint 2015 (m^3/month)
Jan	1082303.571
Feb	1976360.637
Mar	1109095.373
Apr	1088788.418
May	1212985.692
June	1116037.015
July	1209324.054
Aug	1199428.48
Sept	970476.599
Oct	1379957.525
Nov	1270851.227
Dec	1250644.014
Total	14866252.61

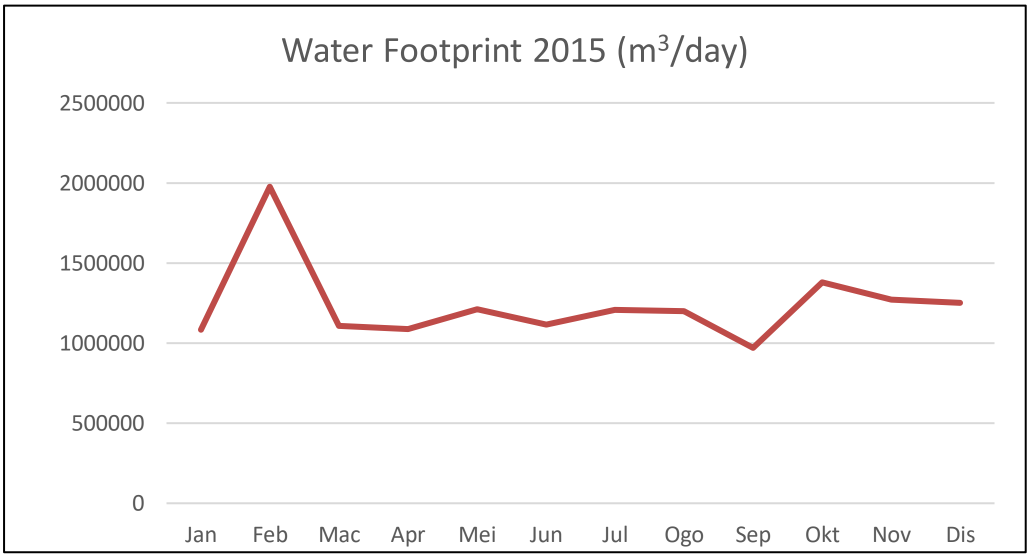

Figure 4.22 Water Footprint in Year 2015

The Water Footprint Accounting for Bukit Ubi WTP in 2015 can be seen as shown in the table and graph above. Based on the data that was shown, the reading for the first month of the year was 1082303.571 m^3/day. The reading escalated greatly to 1976360.637 m^3/day in February, where the highest value for year 2015 was obtained. The water footprint value decreased back to 1109095.373 m^3/day in March, and had a consistent value towards August. However, there was a significant drop in September where the lowest value of water footprint for year 2015 was obtained at a value of 970476.599 m^3/day. This might be due to lack of water intake at the WTP, as well as less number of rainfall intensity. The value increased again in October and gradually decreased until the end of the year.

Table 4.14 Total WF in year 2016

Month	Water footprint 2016 (m^3/month)
Jan	1097918.969
Feb	1917772.966
Mar	1068179.477
Apr	901133.992
May	986028.769
June	981419.642
July	1012405.126
Aug	1103130.054
Sept	1073533.9
Oct	1243272.24
Nov	1168798.943
Dec	1258081.21
Total	13811675.29

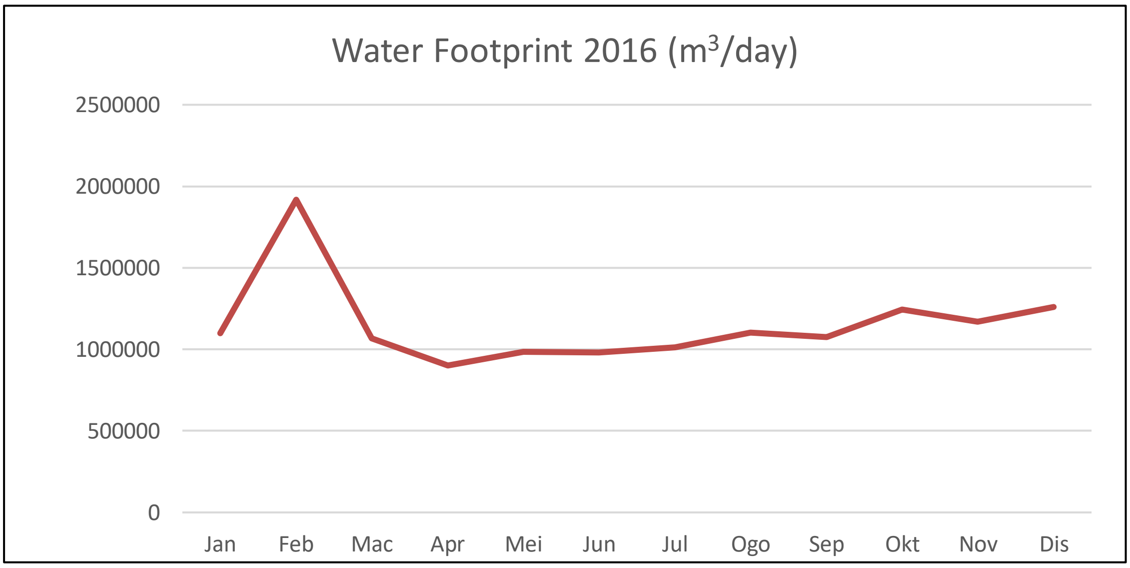

Figure 4.23 Water Footprint in Year 2016

The trend of Water Footprint Accounting at Bukit Ubi WTP in 2016 is similar to the discussed Water Footprint Accounting in 2015. This can clearly be seen by comparing the two graphs plotted for year 2015 and 2016. In January 2016, the water footprint value was 1097918.969 m^3/day, and rose greatly to 1917772.966 m^3/day in February. The highest value of water footprint in February indicates frequent rainfall that occurred during that particular month. The value decreased again in March and April, where the lowest value of water footprint for year 2016 was obtained in April with a value of 901133.992 m^3/day. In May, the water footprint value started to increase gradually towards the end of the year.

Table 4.15 Total WF in year 2017

Month	Water footprint 2017 (m^3/month)
Jan	1054836.881
Feb	1740378.405
Mar	903820.445
Apr	891275.978
May	998099.5
June	1064962.829
July	1042574.295
Aug	1104009.604
Sept	1144436.814
Oct	1199722.793
Nov	1024573.114
Dec	-
Total	12168690.66

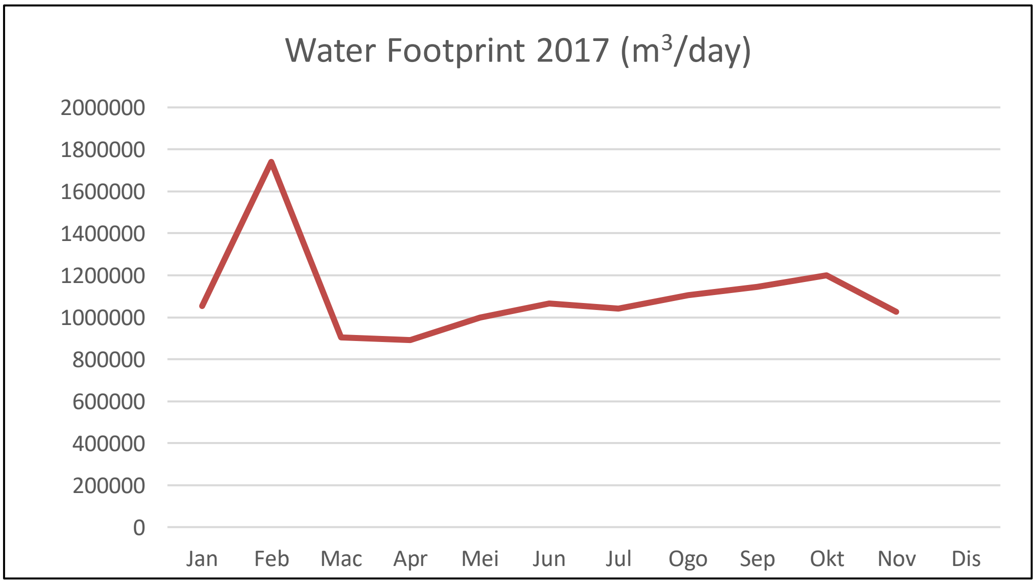

Figure 4.24 Water Footprint in Year 2017

In January 2017, the value of Water Footprint Accounting at Bukit Ubi WTP was 1054836.881 m^3/day. The value increased significantly in February, which was identified as the highest value of water footprint for the year, where the value was 1740378.405 m^3/day. The value of water footprint dropped greatly in March (903820.445 m^3/day) and April (891275.978 m^3/day), where these values are the lowest for year 2016. The trend then increased gradually until the end of the year.

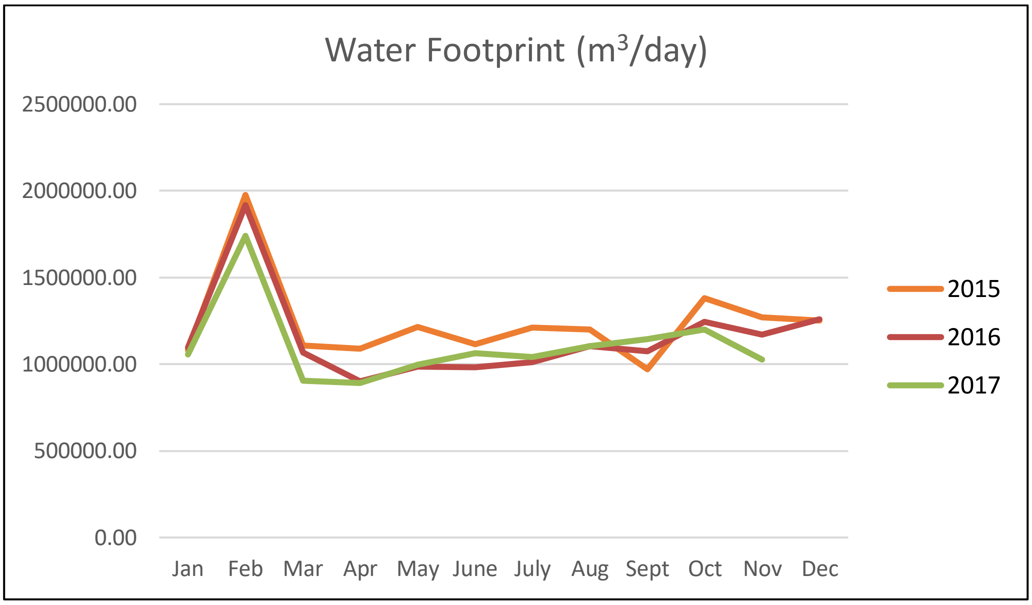

Figure 4.25 Overall Water Footprint for Bukit Ubi WTP

4.3 Effect of Land Use Development

The development of land for any purpose of use shall bring many impact, either in a good way or vice versa. The development of land for any purpose of use will cause many impacts on the surrounding environment, either in a good way or vice versa. In this case, Kuantan district is being divided into 6 sub-district but only five are being studied which are Kuala Kuantan, Penur, Beserah, Sungai Karang, Ulu Kuantan. The divided of sub-district in Kuantan involves five (5) Water Supply Treatment Plant which are Panching WTP, Sg Lembing WTP, Semambu WTP, Bukit Sagu WTP and Bukit Ubi WTP for the water distribution purpose. It must be note that the distribution of water by all five WTP is depending on the demand of water from the particular sub-district. The water demand from each sub-district is highly depending on the economic activities of the people and it will varies from one and another.

As to-date, the area proposed for Kuantan land use development plan is 296,042.09 hectare by the year of 2035 (MPK, 2017). It is however expected to increase to 297,576.20 in the same year. The increment of 1,534.11 hectare are due to the process of soil reclamation throughout the coast for the project development of Kuantan Waterfront Resort City, Kuantan Promenade, Kuantan Maritime Hub as well to upgrade the available Kuantan port. Industrial land proposed for development were only covered 11,156.52 hectare or 3.48% of overall land use.

Table 4.16 Overall Land Use Planning in Kuantan

Type of land use	**2016**		**2035**	
	Hectare (Ha)	**Percent (%)**	**Hectare (Ha)**	**Percent (%)**
Residential	5,748.42	1.94	23,938.71	8.04
Commercial	1,002.34	0.34	3,810.47	1.28
Industry	3,003.71	1.01	11,156.52	3.48
Institution & Public Facilities	3,904.32	1.32	4,889.12	1.64
Infrastructure & utility	1,185.79	0.40	2,170.40	0.74
Recreation & Open Field	859.92	0.29	4,108.50	1.38
Agriculture	102,358.27	34.58	92,625.79	31.26
Forestry				
· Fixed Reserved	109,072.52	36.84	108,117.94	34.62
· Land Forest	49,172.30	16.61	33,278.24	13.12
Transportation	6,733.83	2.27	7,912.24	2.56
Under Utilised	7,580.80	2.56	-	-
"Badan Air"	4,838.86	1.63	5,125.58	1.72
Beach	581.01	0.20	442.69	0.15
Total	296,042.09	100.00	297,576.20	100.00

4.3.1 Industrial Zone Analyses of Kuantan River Basin

Table 4.17 Total WF and Capacity

Year	Water Footprint (m^3/year)	Capacity (m^3/year)
2015	78593024.8	189654000

- Industrial Zone Percentage = 1.85%
- Total Water Footprint based on % = 1,453,970.96 m^3/year
- Total Capacity based on % = 3,508,599.00 m^3/year

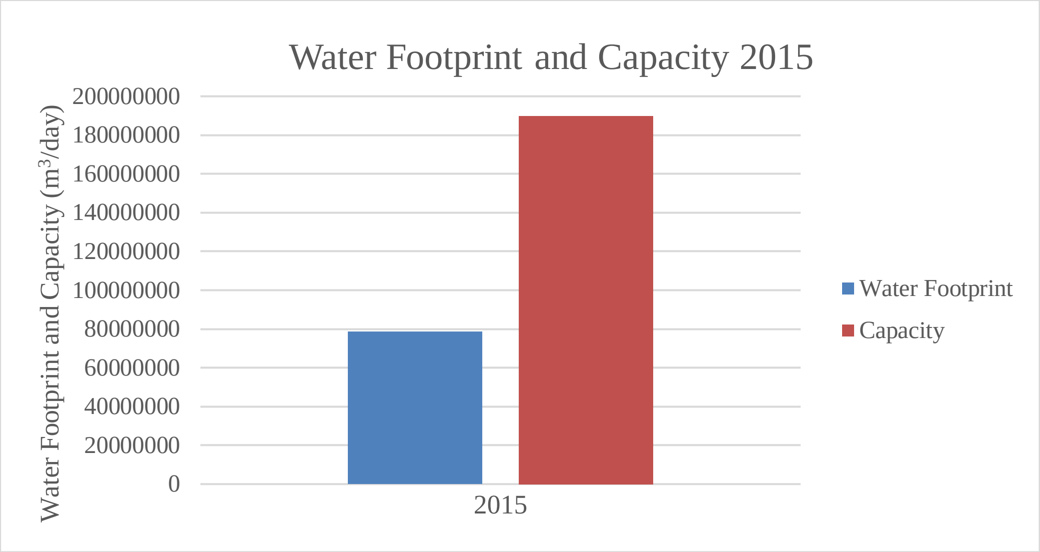

Figure 4.26 Total WF and WTP Capacity for Kuantan District 2015

The graph above shows the Water Footprint and Capacity of Kuantan WTPs in 2015. It can be said that the total water footprint accounting did not exceed the maximum capacity of all WTPs. The total capacity of Kuantan WTPs (Sungai Lembing, Bukit Sagu, Panching, Semambu and Bukit Sagu) is 189654000 m^3/day, whereas the total water footprint for all WTPs was only 78593024.8 m^3/day for the year 2015. This indicates that the WTPs can work effectively if the water footprint produced were still within its capacity limit.

Table 4.18 Total WF and Capacity

Year	Water Footprint (m^3/year)	Capacity (m^3/year)
2016	87743432.9	189654000

- Industrial Zone Percentage = 1.01%
- Total Water Footprint based on % = 886,208.67 m^3/year
- Total Capacity based on % = 1,915,505.40 m^3/year

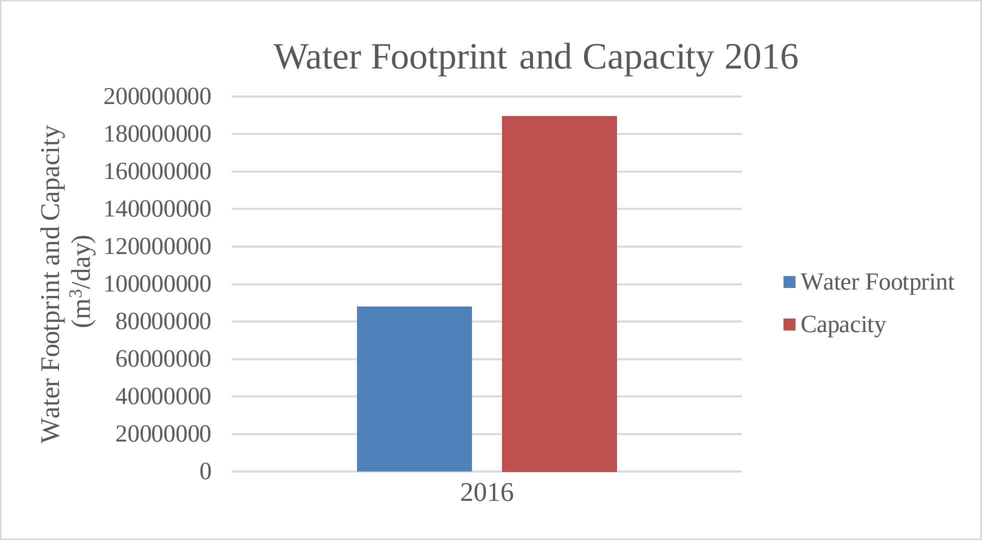

Figure 4.27 Total WF and WTP Capacity for Kuantan District 2016

In 2016, the total water footprint accounting of WTPs at Kuantan (Sungai Lembing, Bukit Sagu, Panching, Semambu and Bukit Sagu) was within the capacity limit of the total capacity of the WTPs in Kuantan. The total water footprint accounting that was obtained was 87743432.9 m^3/day, while the total maximum capacity of the WTPs was 189654000 m^3/day. However, by comparing the total water footprint of 2015 and 2016, the trend has increased by 9150408.1 9 m^3/day. This might be due to more rainfall intensity and volume of water intake that occurred in 2016.

Table 4.19 Total WF and Capacity

Year	Water Footprint (m^3/year)	Capacity (m^3/year)
2017	100484687.9	189654000

- Industrial Zone Percentage = 1.15%
- Total Water Footprint based on % = 1,155,573.91 m^3/year
- Total Capacity based on % = 2,181,021 m^3/year

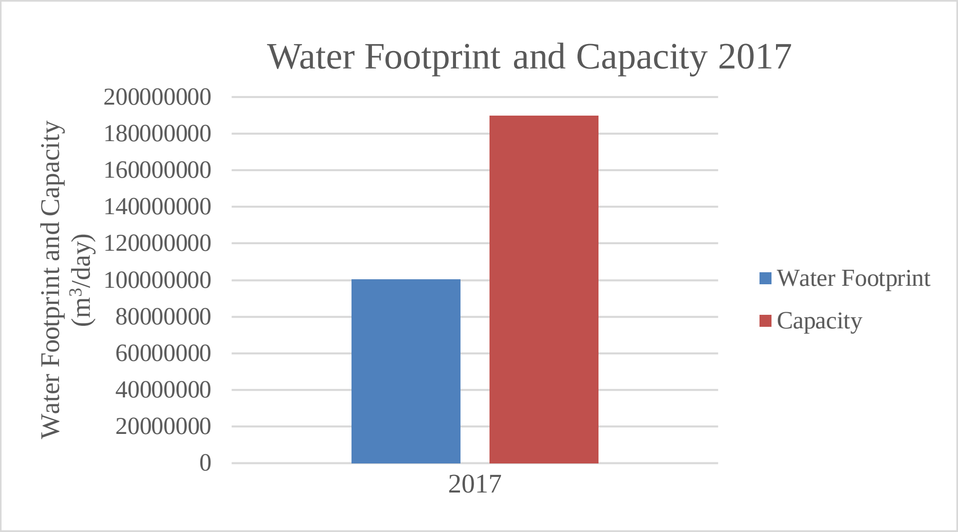

Figure 4.28 Total WF and WTP Capacity for Kuantan District 2017

By referring to the graph of Water Footprint and Capacity of Kuantan WTPs in 2017, the water footprint accounting at Sungai Lembing WTP, Bukit Sagu WTP, Panching WTP, Semambu WTP and Bukit Ubi WTP was not greater than the total capacity limit of all WTPs. This indicates that the maximum capacity of WTPs is able to cater the water footprint at all respective WTPs. The respective values of total water footprint and total capacity of Kuantan WTPs were 100484687.9 m^3/day and 189654000 m^3/day. All in all, the increasing trend from year 2015 to 2017 shows that as the year increases, population growth increases as well and this affects the land use and water footprint accounting at Kuantan.

4.4 Prediction Using Artificial Neural Network

For the purpose of finding the optimal architecture of the ANN model to prevent over-fitting of data, several numbers of hidden layers have been tested in this study. The connection between input and output layer is included in the testing and training. The minimum value of the RMSE for the training and prediction set were used as a basis for the determination of parameter variations. In the process of optimization, the number of hidden neurons were tested from 1 to 10. The increase in number of neurons result in different MSE values for given by the network for training and testing data set. Table 4.21 shows the RSME values for training and testing data as a function of the number of hidden layer. The neuron selected is neuron 2.

Table 4.20 Analysis of error and correlation coefficient for training and testing set as a function of hidden neuron.

Hidden Neuron	Training	Testing
	RMSE	
1	1.03 x 10ˆ-9	1.23 x 10ˆ-8
2	5.76 x 10ˆ-8	1.98 x 10ˆ-5
3	6.57 x 10ˆ-6	5.28 x 10ˆ-6
4	9.28 x 10ˆ-5	6.78 x 10ˆ-4
5	7.79 x 10ˆ-7	4.30 x 10ˆ-3
6	9.43 x 10ˆ-6	1.11 x 10ˆ-3
7	5.36 x 10ˆ-6	3.21 x 10ˆ-4
8	5.55 x 10ˆ-5	9.28 x 10ˆ-4
9	1.1 x 10ˆ-6	4.97 x 10ˆ-3
10	5.18 x 10ˆ-5	8.65 x 10ˆ-6

4.4.1 Sungai Lembing WTP Prediction

Table 4.21 Prediction Value of Water Footprint

Year	Prediction Value (m^3/year)	Total Water Footprint (m^3/year)
2015	11769779.72	6211895.8
2016	12287369.83	6485405.19
2017	7974327.143	4170290.91

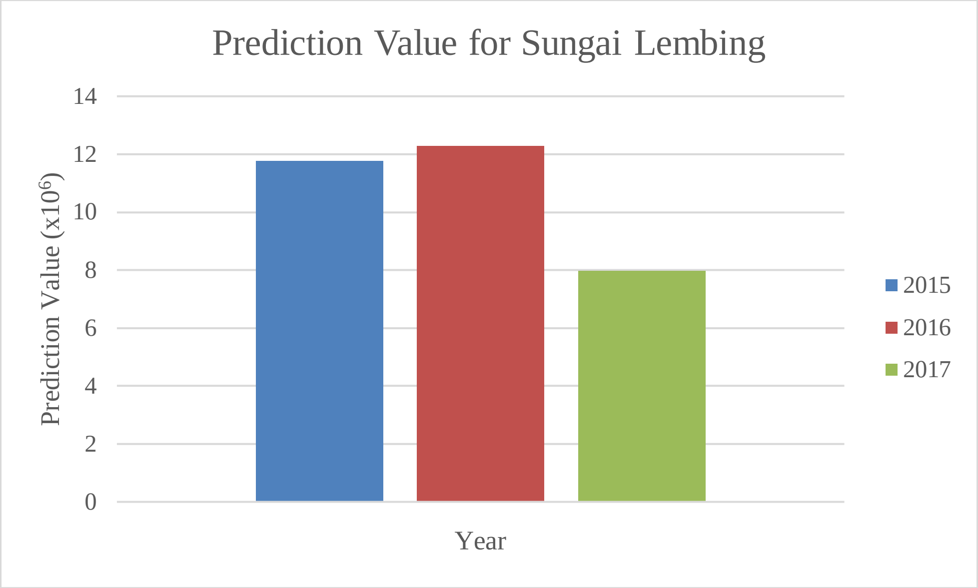

Figure 4.29 Forecast Value of Water Footprint

The graph above shows the prediction value of water footprint at Sungai Lembing WSTP. Based on the graph, it can be seen that the actual value in 2015 (6211895.8 m^3/day) was much lower than the prediction value of water footprint, which was 11769779.72 m^3/day. This happened due to less rainfall intensity at Sungai Lembing. The same occurrence happened in the following year, where the prediction value was 12287369.83 m^3/day, more than the actual value of 6485405.19 m^3/day. The WSTP was predicted to have a water footprint accounting of 7974327.143 m^3/day in 2017. However, the actual value of water footprint decreased substantially compared to the previous years, where the value was only 4170290.908 m^3/day. This happened due to the unavailability of data for December 2017, which contributes to the low value of water footprint in 2017.

4.4.2 Bukit Sagu WTP Prediction

Table 4.22 Prediction Value of Water Footprint

Year	Prediction Value (m^3/day)	Total Water Footprint (m^3/day)
2015	9225517	6523952.22
2016	8874740.418	6271712.72
2017	6189457.584	4365986.55

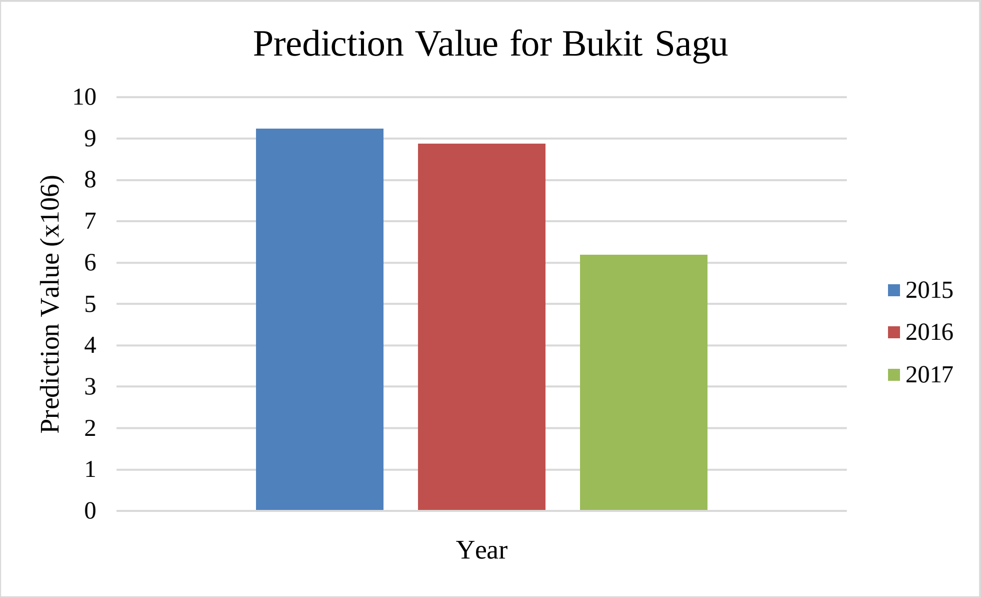

Figure 4.30 Forecast Value of Water Footprint

By referring to the graph as shown above, the trend of prediction value of water footprint for Bukit Sagu WSTP decreased from year 2015 to 2017. In 2015, the actual value of water footprint was 6523952.217 m^3/day, which was lower than the predicted value of 9225517 m^3/day. The trend recurred again in 2016, where the actual value was less than the predicted value, with values of 6271712.715 m^3/day and 8874740.418 m^3/day respectively. In 2017, the trend of water footprint at Bukit Sagu WSTP in 2017 was the same as the previous years, where the actual value was lower than the predicted value. Bukit Sagu WSTP was predicted to have a water footprint accounting of 6189457.584 m^3/day, but produced an actual value of 4365986.553 m^3/day. It can be assumed that there was less rainfall intensity in Bukit Sagu WSTP, which explains why the prediction values are higher than the actual values of water footprint accounting

4.4.3 Panching WTP Prediction

Table 4.23 Prediction Value of Water Footprint

Year	Prediction Value (m^3/day)	Total Water Footprint (m^3/day)
2015	1246293.257	48673753.6
2016	1546447.3	58431711.2
2017	2047405.925	42281988.8

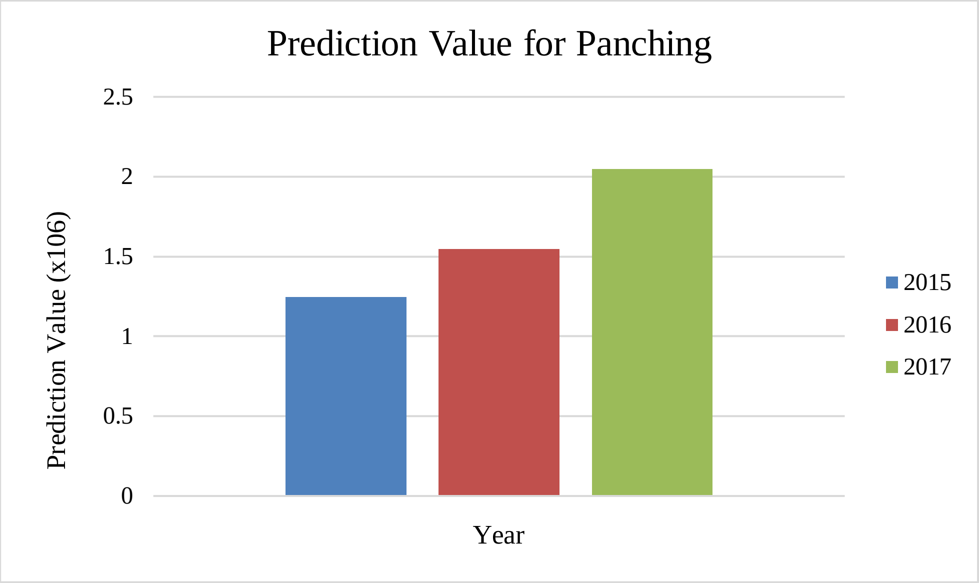

Figure 4.31 Forecast Value of Water Footprint

Panching WSTP has an increasing trend for prediction value of water footprint accounting from year 2015 to year 2017. The WSTP was predicted to have a water footprint accounting of 1246293.257 m^3/day in 2015, but somehow the actual value for water footprint increased to 48673753.6 m^3/day. In 2016, the trend increased for both actual and predicted value, where the values are 58431711.2 m^3/day and 1546447.300 m^3/day respectively. The prediction value of water footprint at Panching WSTP in 2017 was the highest among all three studied years, which was 2047405.925 m^3/day. The actual value produced was significantly higher than the predicted value, which was 42281988.8 m^3/day. An increasing trend indicates an increase of population in a certain area, which leads to increased land use and increased water demand.

4.4.4 Semambu WTP Prediction

Table 4.24 Prediction Value of Water Footprint

Year	Prediction Value (m3/day)	Total Water Footprint (m3/day)
2015	13039579.83	1721368.25
2016	21948896.28	2894255.65
2017	20000774.68	2637336.92

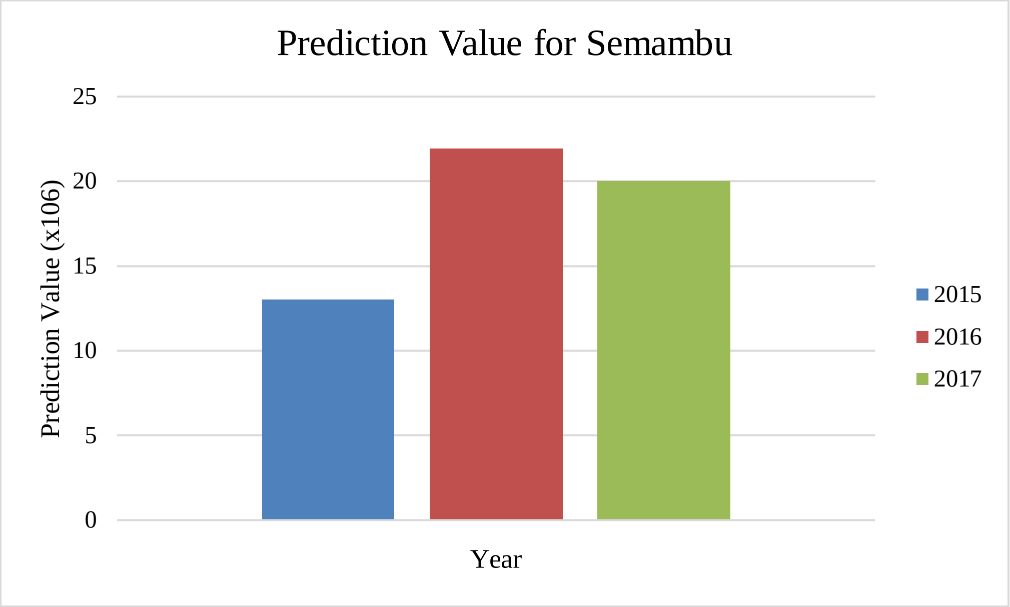

Figure 4.32 Forecast Value of Water Footprint

Based on the graph of Prediction Value for Semambu WSTP, a fluctuation of values can be seen. In 2015, where the prediction value is the lowest among the three years, the value of water footprint accounting that was predicted was only 13039579.83 m^3/day. The actual value that was obtained was 1721368.25 m^3/day, which was lower than the predicted value. The prediction value of water footprint accounting at Semambu WSTP in 2016 was higher than the previous year, which is 21948896.28 m^3/day. However, the actual value was only at a low of 2894255.65 m^3/day. Despite the low actual value that was produced in 2016, it was higher than 2015, which indicates higher rainfall intensity throughout that year. In 2017, the WSTP was predicted to have a water footprint accounting of 20000774.68 m^3/day, but was only able to produce 2637336.92 m^3/day. Low water footprint accounting was due to low volume of water intake and low rainfall intensity at the WSTP.

4.4.5 Bukit Ubi WTP Prediction

Table 4.25 Prediction Value of Water Footprint

Year	Prediction Value (m^3/day)	Total Water Footprint (m^3/day)
2015	13562724.14	14866252.6
2016	12728661.47	13811675.3
2017	11209986.01	12168690.7

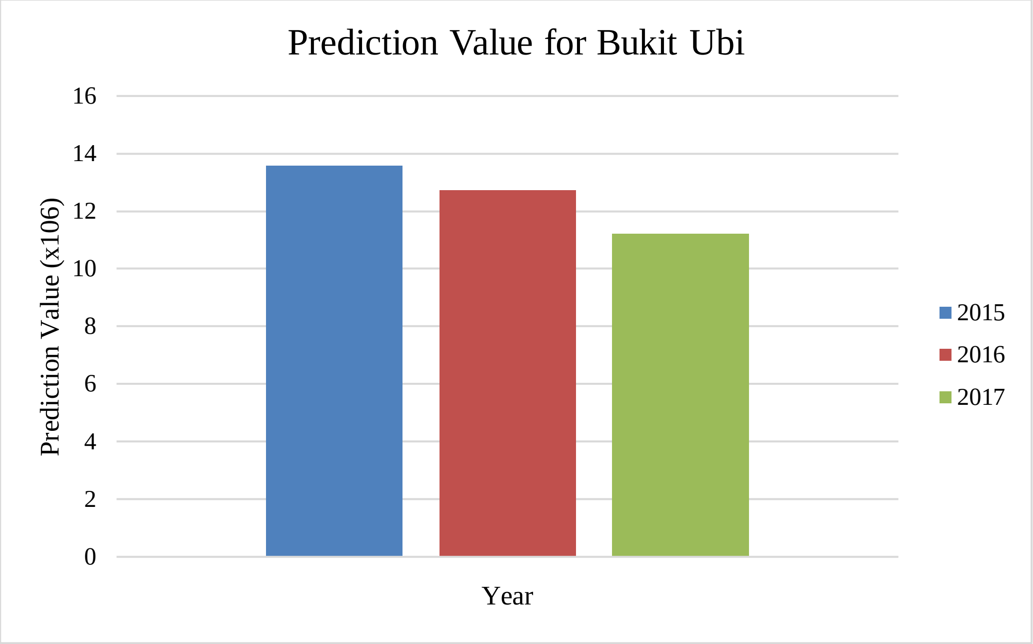

Figure 4.33 Forecast Value of Water Footprint

At Bukit Ubi WSTP, the trend that can be seen for prediction value was decreasing. The prediction value of water footprint accounting in 2015 was 13562724.14 m^3/day. However, the actual value that was obtained was 14866252.6 m^3/day, which was higher than the predicted value. In 2016, the WSTP was predicted to have a water footprint accounting of 12728661.47 m^3/day. The WSTP produced a higher actual value, which was 13811675.3 m^3/day. Finally, in 2017, the values for prediction and actual values were 11209986.01 m^3/day and 12168690.7 m^3/day respectively. Based on the increased actual values that were obtained, it can be concluded that the rainfall intensity was high at this WSTP, which resulted in higher actual values.

CHAPTER 5

CONCLUSION

5.1 Introduction

In summary, the determination of blue water footprint based on industrial activities in Kuantan River Basin can be determined by calculating the blue water footprint at each WTP that involved in this study through the design of water treatment process with consideration of certain parameters. The dependencies of the parameters such as water intake, rainfall intensity towards the uncertainty in many aspects like weather shall be specifically addressed in the accounting of blue water footprint. Thus BWF has been calculated and the highest recorded on 2017, 100484687.9 m^3/year. Therefore, BWF in Kuantan River Basin is increasing by year due to increase in local population.

Next objective is to determine the effect of land use the blue water footprint accounting. The land use development cause the demand of water increase as the increment also happens in the population of particular region based on distributed land use purposes. Thus in Kuantan River Basin, the increment in industrial land use will cause more water to be provided to the respective area. Hence effect the BWF accounting. Although the development of land use could enhance the local economics activities, but it must be well-regulated and well-supervised by the responsible authorities.

Last objective was to predict the sustainability of water supply treatment process by using series of modelling called Artificial Neural Network (ANN) – an Artificial Intelligence (AI) application tools in Matlab – a software – to develop patterns of changes in water footprint in the future with regards to some factors to be considered. Prediction value founded to be increased due to incoming water use activities.

5.2 Recommendations

Generally, these findings provide a notable implications for the better understanding towards maintaining a sustainability resources to the future generations of this country. Benefits of this study shall be extended to the next research findings where some improvements must be taken up in order to produce a better and accurate results. For the BWF accounting, the development of technologies in this era should be fully implemented, especially when it comes to the centralization of data among local authorities. A manual way of collecting data nowadays is partially relevant to the current technologies that exist. It is therefore a better management would be the best way to cater the problem while this study is being conducted.

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APPENDIX A1

Book of Kuantan District Local Plan

Figure 6.1 Kuantan District Local Plan (Book 1)

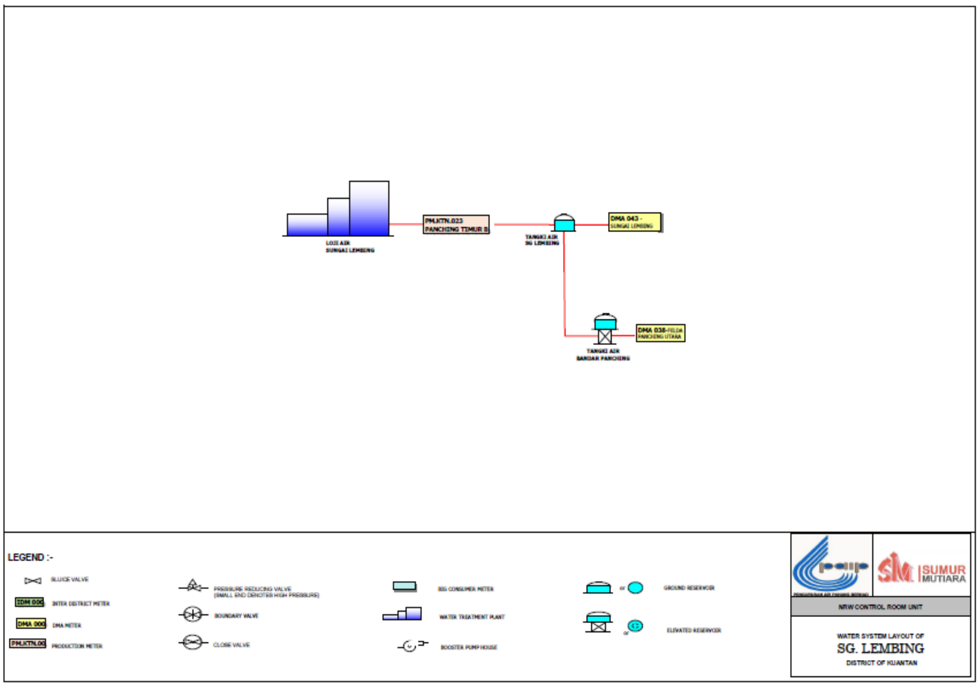
Figure 6.2 Kuantan District Local Plan (Book 2)

APPENDIX A2

Water Supply Treatment Plant

Figure 6.3 Location of Sg. Lembing WTP

(Source: https://www.google.com/maps)



6.4 Sungai Lembing WTP Distribution Flow

Figure 6.5 Location of Panching WTP

(Source: https://www.google.com/maps)

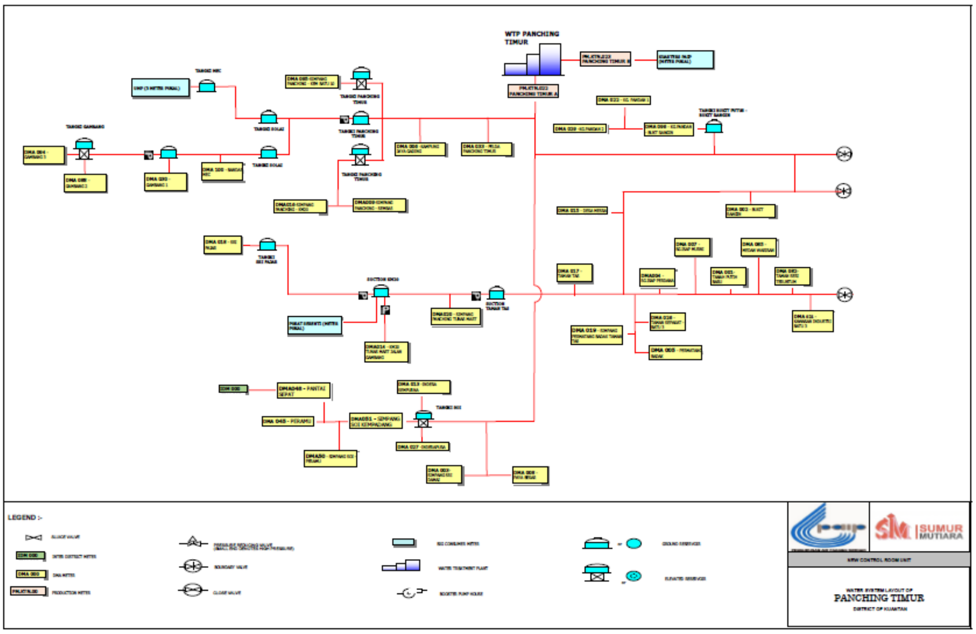


Figure 6.6 Panching WTP Distribution Flow

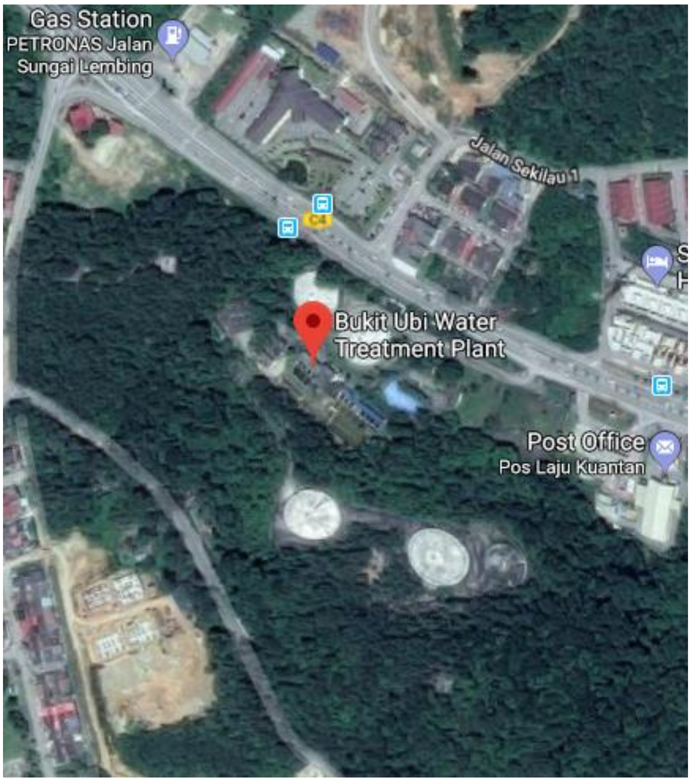


Figure 7 Location of Bukit Sagu WTP

(Source: https://www.google.com/maps)

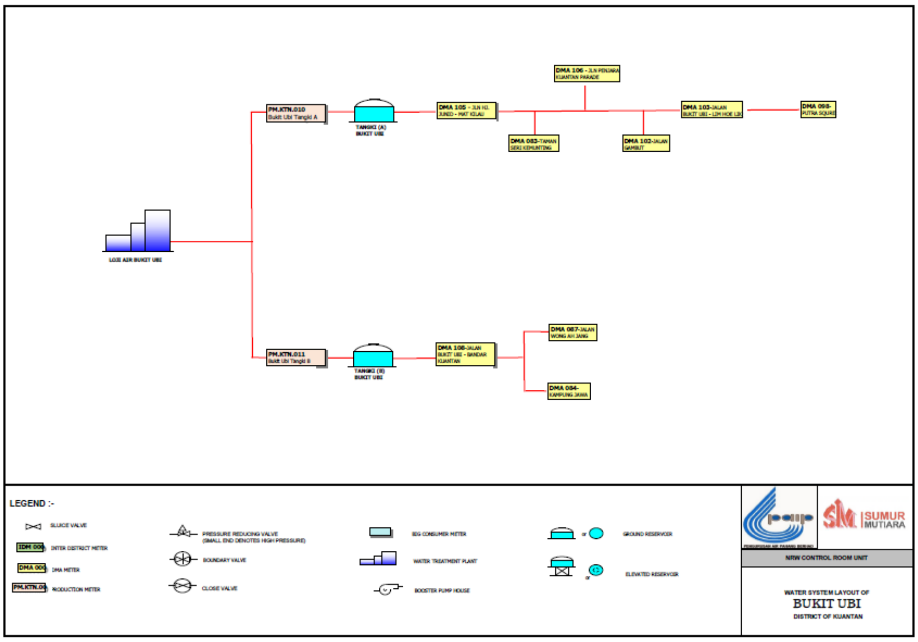


Figure 6.8 Bukit Ubi WTP Distribution Flow

Figure 9 Location of Semambu WTP

(Source: https://www.google.com/maps)

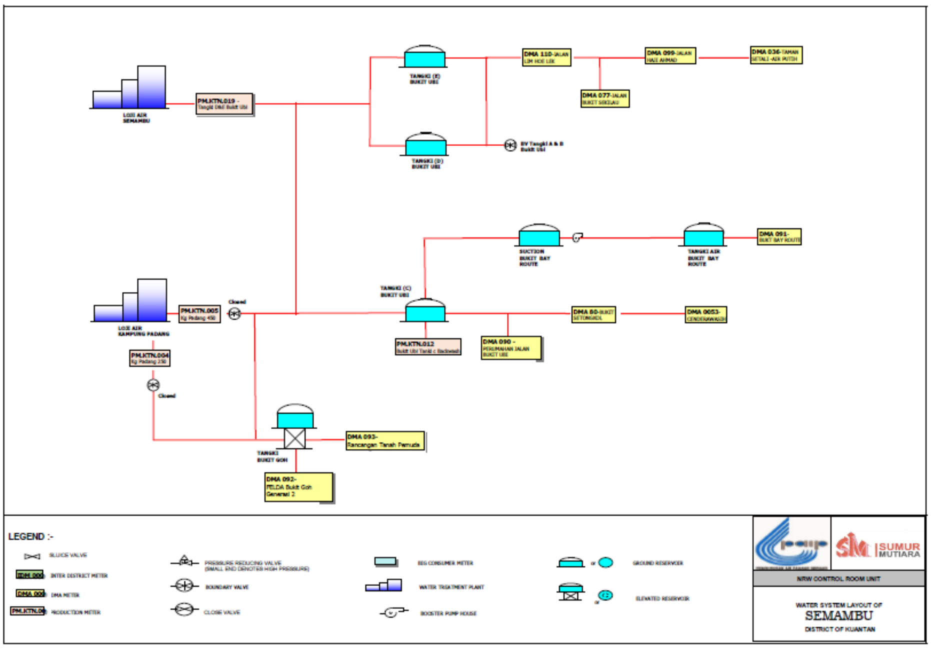


Figure 6.10 Semambu WTP Distribution Flow

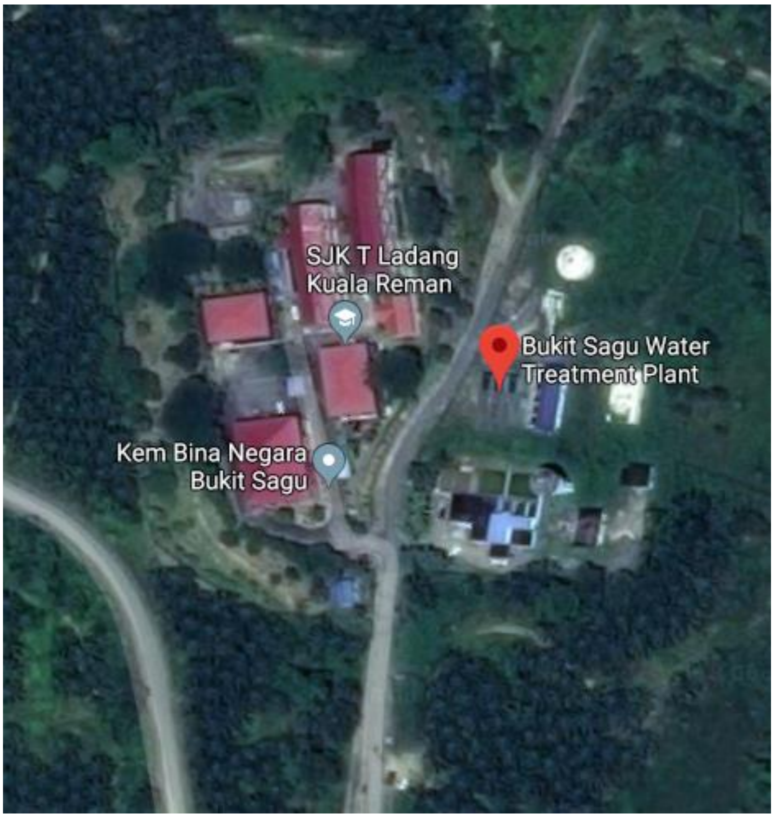


Figure 6.11 Location of Bukit Sagu WTP

(Source: https://www.google.com/maps)

APPENDIX A3

Source of Water Intake

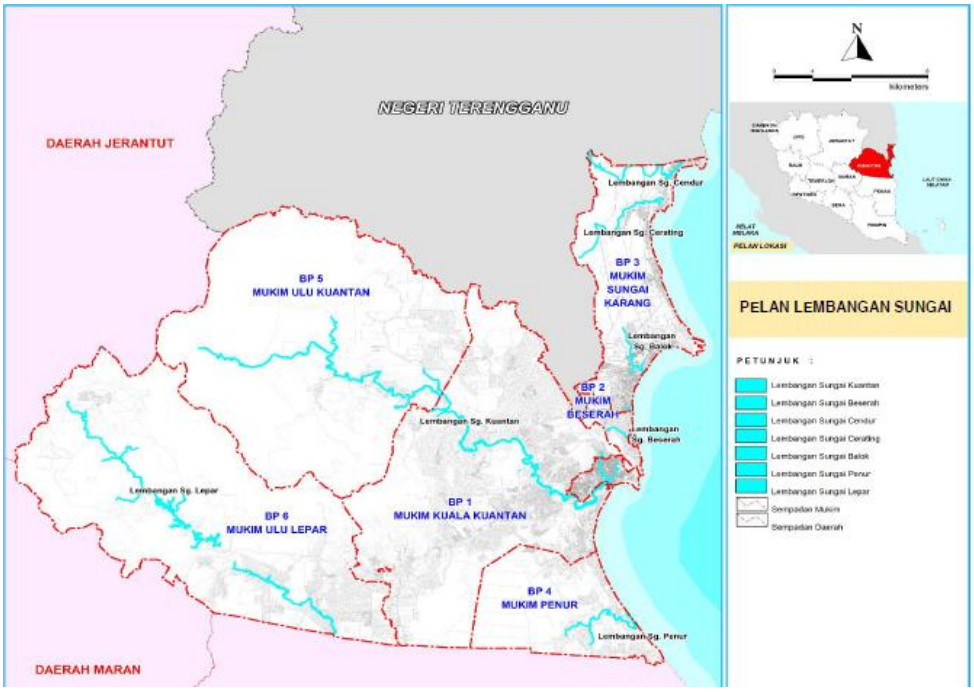


Figure 12 Kuantan River

APPENDIX A4

Artificial Neural Network

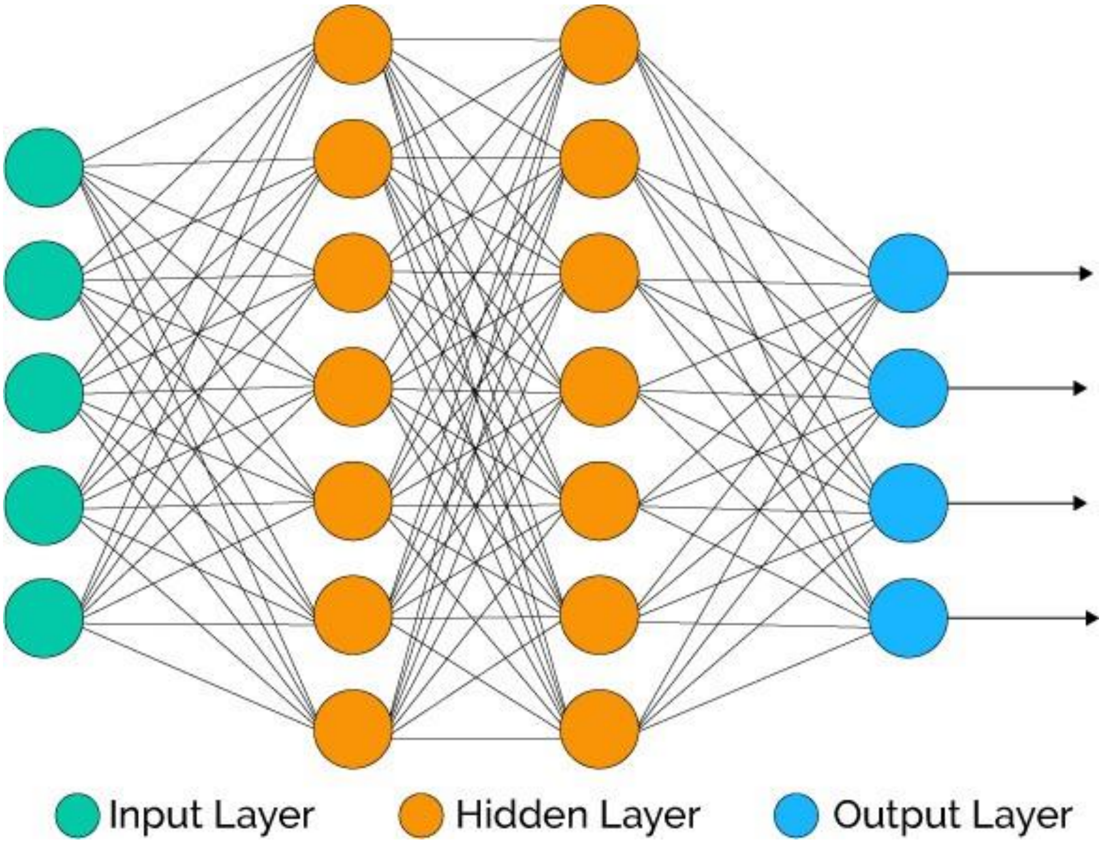


Figure 6.13 Template of Hidden Layers in ANN

(Source: http://technicalsurfing.blogspot.com/2017/12/artificial-neural-networks.html)