ANALYSIS OF CURRENT CONDITIONS AND FUTURE NEEDS OF THE PUBLIC WATER SUPPLY SYSTEM IN DILI, EAST TIMOR

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MASTER OF SCIENCE

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ABSTRACT

This research focuses on the public water supply system in East Timor's capital, Dili. Through this research the performance of the current public water supply system is evaluated, shortages in system capacity and operation are identified, and the future need is analyzed. Only 41.77% of Dili's urban population currently has access to the public water supply system. A better documentation and record keeping of the water treatment plants' operations is needed. As the population grows and city develops, more water will be needed in the future. The current public water supply system will not be adequate to supply water in the future because the water demand outweighs the design capacity of the current system. Therefore, a proper water supply system and management is highly needed, especially if the government of East Timor wants to achieve their target to supply continuous water in East Timor's urban areas by 2030.

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LIST OF ABBREVIATIONS

FAO..Food and Agriculture Organization

FRETILIN..Frente Revolucionária do Timor Leste Independente

GDP..Gross Domestic Product

GNI ....Gross National Income

HDI ....Human Development Index

JICA ....Japan International Cooperation Agency

JMP ....Joint Monitoring Programme

LNG ....Liquefied Natural Gas

MCM..Millions Cubic Meter

NGO...non-governmental organization

SDP ....Strategic Development Plan

UNDP...United Nations Development Programme

UNFPA ....United Nations Fund for Population Activities

UNICEF ....United Nations Children’s Emergency Fund

UNTAET..United Nations Transitional Administration in East Timor

WHO...World Health Organization

WTP ....water treatment plant

INTRODUCTION

Water is an essential substance in our lives and it cannot be substituted. Humans, animals, and plants need water to survive. We as humans need water for our daily activities, such as bathing, cooking, cleaning, and washing. Besides daily activities, we use water for agricultural, industrial, and transportation purposes, as well as for an energy source.

Water can cause disasters if there is too much or too little. When there is too much, water can cause a flood and when there is too little, it causes famine. The world is facing a falling groundwater table, which leads to water scarcity (Brown, 2001). This happens due to over pumping of aquifers, where the majority of water being pumped is for the agricultural purposes (Brown, 2001). Water scarcity can have huge impacts on humans. One of the impacts is the scarcity of food due to the lack of water to support the agricultural process. This will get worse as the world's population increases, which is projected to be 9 billion by 2050 (Solomon, 2010). A larger population means more food will be needed, and to grow more food more water is needed. Moreover, water scarcity also results in political tensions, for example water conflicts have happened between cities and farmers in China, India and Yemen, and between tribes in Kenya (Brown, 2008).

Besides water quantity, water quality also plays an important role for people who consume it. The quality of water should meet certain standards for it to be consumed. If it happens otherwise, it can cause spread of waterborne diseases and result in taking people's lives; for example, "cholera in 1849 and 1853 killed 20,000 people in London because nearly every one of hundreds of victims had drunk water, which got its water supply untreated from the sewage-infested Thames" (Carr, 1966). Another modern example is Arsenic contaminated water consumed by people in Bangladesh, which was confirmed in 1993 and caused skin lesions to the people who consumed it (Smith *et al*., 2000).

In East Timor, not all people have access to an improved water supply. An improved water supply is “one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter” (JMP, 2015a). In urban areas, 91.5% of the total population has access to an improved water supply (General Directorate of Statistics, 2015). Even though the percentage is high, the majority of this percentage has access to the water supply through their private shallow wells. The public water supply system is unreliable in providing continuous water service to the population. East Timor is one of the youngest countries in the world, which attained its independence in 2002; as the country develops and population increases every year, more water is needed. Above all, a proper water supply system is highly needed.

In East Timor’s rural areas, where 70% of its population lives, the access to improved water supply is far behind as compared to urban areas. Only 68.6% of the total rural population has access to an improved water supply (General Directorate of Statistics, 2015). Women and children in households that do not have access to improved water suffer the most, because they are in charge of collecting water. They have to walk long distances and in the dry season they also have to wait for long hours at the spring for the water to fill their containers (Michael, 2006). Besides water shortages, the quality of the water sources is unknown and the only treatment done prior to consuming the water is boiling (Michael, 2006).

Problem Statement, Purposes, and Objectives

The importance of water is unquestionable, both to improve people's living standard and to support economic development. When people do not have access to improved water, it becomes difficult to fulfill their daily needs and results in lower living standards. Economic development is also hindered when there is insufficient access to improved water. The problem addressed in this research is the need of a proper public water supply system in East Timor's capital, Dili. The purposes of this research are to provide a clear status of the current conditions of the public water supply system and to identify future needs. The objectives of this research are to analyze the current conditions, to identify the shortages through comparisons with other similar cities and international standards, to estimate the future needs based on the population growth rate trend, and lastly to provide recommendations to address the findings.

Expected Results and Benefits

Through this research, the status of the current conditions of Dili's public water supply system and future needs will be identified. This research will also provide recommendations to improve the performance and operation of the current water supply system, to increase the design capacity of the current water supply system, and to implement water fees. The ultimate benefit gained from this research will be to improve the living standard of Dili's population and support the development process. This research will also benefit the parties who are involved in water resource related issues in East Timor, particularly in Dili, such as government, international agencies, and national and/or international non-governmental organizations (NGOs).

METHODOLOGY

A quantitative study was carried out in this research. Data used in this research can be divided into two categories primary and secondary sources. The data obtained from the primary source is the population data. It was obtained from the national census data in the year 2015 by the General Directorate of Statistics with the support from the United Nations Fund for Population Activities (UNFPA). The population data includes:

- Dili's total urban population;
- Annual growth rate;
- Average household size.

The secondary sources include the National Water and Sanitation Directorate and the Japan International Cooperation Agency (JICA). Data collected from the secondary sources includes:

- Total population covered by the public water supply system;
- Per capita water demand per day;
- Design capacity and actual water production of Dili's public water supply system;
- Daily operational hours of Dili's public water supply system.

The analysis conducted in this research is explained as follows:

- **Current conditions**

  The analysis of the current conditions was done by evaluating the performance of the current water supply system as compared to the design capacity. The current water supply system includes water treatment plants (WTPs) and wells. For WTPs, the 2013 and 2014 actual water production data, as well as data from the previously conducted study by JICA in the year 2010 was used. As for the wells, only 2014 data was used. The challenges of the current water supply system were identified through the performance evaluation.

- **Shortages**

The shortages identification was done by evaluating per capita water provided by the current water supply system in comparison to the water demand. The shortage identification is not only limited to this comparison, but also includes the identification of the system capacity, operational problems, funding issues, personnel qualification and training, as well as the coverage of the current water supply system.

- **Future needs**

The analysis of the future needs was done in order to analyze and identify the estimation of the future water supply needed to meet the future population in Dili's urban areas. The estimation of the future water demand assumes 100% coverage of the water supply system. The forecasting method by Wallingford (2003) was used in calculating the future water demand. This forecasting method was based on population growth rate, where the projected population was multiplied by the per capita water demand (Wallingford, 2003). The estimation was done from the year 2016 through 2030 in order to assess the adequacy of the current water supply system to provide the continuous water supply to all the population of Timor-Leste. The target is to have continuous water supply service in East Timor's urban areas by 2030. Figure 1 illustrates the process flow of this research.

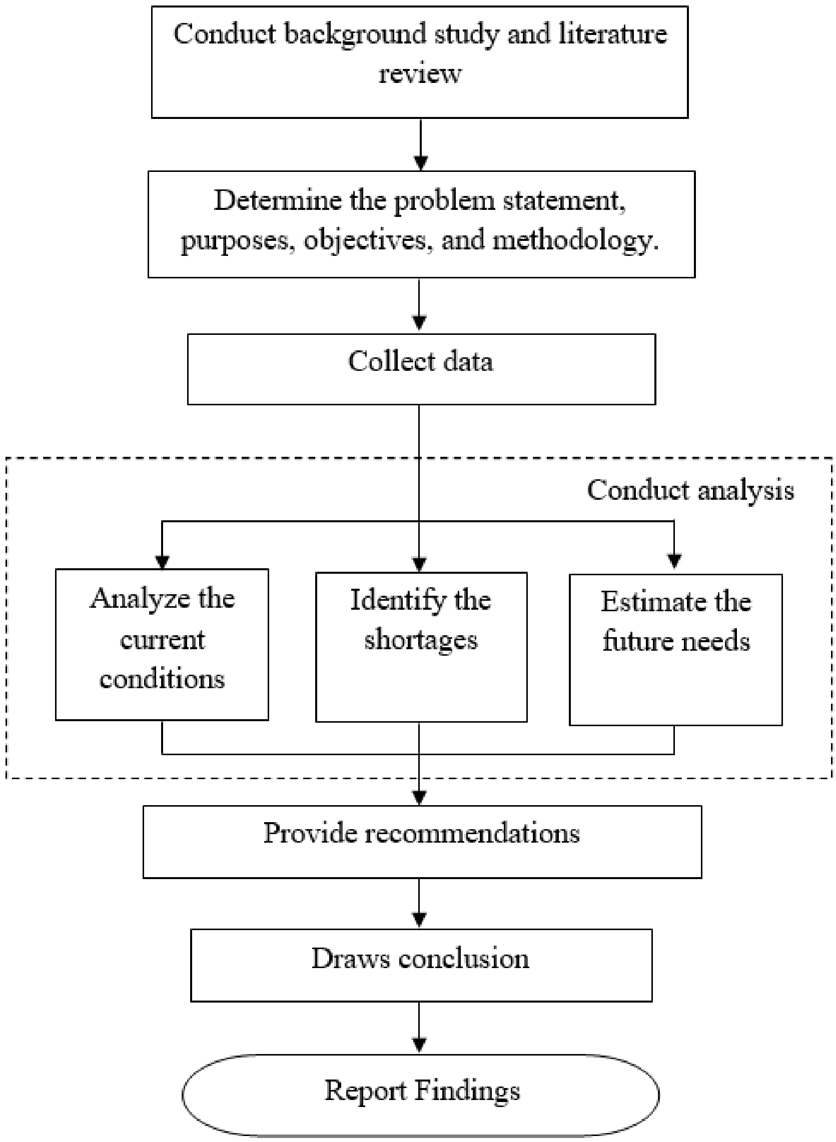


Figure 1. Flow chart for the analysis of the Dili, East Timor water supply system. The process started with a conducted background study and literature review. The problem statement, purposes, and objectives, as well as methods were determined. The next process was collecting data, and then, data analysis was conducted including the current conditions, shortages, and future needs. The next process, recommendations were provided to address the findings, and lastly, derived research conclusions.

LITERATURE REVIEW

The two main sources of water supply are groundwater and surface water. Groundwater is the water present beneath the earth's surface in soil pore spaces and in the fracture of rock formations. Surface water sources include streams, rivers, wetlands, lakes and reservoirs. David and Masten (2004) characterized groundwater and surface water as shown in Table 1.

Table 1. Groundwater and surface water characteristics

Groundwater	**Surface Water**
Constant composition	Varying composition
High mineral content	Low mineral content
Low turbidity	High turbidity
Low or no color	Color
May be bacteriologically safe	Microorganisms present
No dissolved oxygen	Dissolved oxygen
High hardness	Low hardness
H_2S, Fe, Mn	Tastes and odors
Possible chemical toxicity	Possible chemical toxicity

Note: The information is from David and Masten (2004).

A water supply system consists of a water treatment and a distribution system. The commonly used method in water treatment facilities is called the conventional process. There are various terms used to describe a conventional treatment process. Droste (1997) refers to a facility that is a rapid sand filtration water treatment plant (WTP). On the other hand, David and Masten (2004) refer to the conventional facility as a coagulant plant. There are four primary steps of raw water treatment in a conventional facility, which are coagulation, sedimentation, filtration, and disinfection. Dili's public water supply system consists of four conventional treatment facilities, which are commonly referred to as Water Treatment Plants (WTPs) and undergo the exact same steps as mentioned above.

Besides water treatment, the other important part of a water supply system is the water distribution system. The purpose of the water distribution system is to transport the treated water to residential, office, commercial, and industrial places. Water can be distributed through a single-level system or a multi-level system (WHO, 2014). According to Ysusi (2000), the components of water distribution planning and design criteria are water demand, supply, storage, fire demands, distribution system analysis, and service pressures. The analysis of the distribution system is done in order to understand how the system works during the peak hour demand and maximum daily demand, while evaluating the service pressure is to avoid water being wasted due to leakage.

Common water supply problems in developing countries are unreliable water service and the capacity of the supplied water not meeting water demand. Two of the many reasons that cause these problems are the shortages of raw water supply and water losses in the distribution phase due to leakage. According to Klingel *et al*. (2012), in developing countries, the common practice is for distribution systems to be designed and built for continuous supply of water, but actually only supply water intermittently due to the shortages of raw water supply. Renwick (2009) argued that the negative impact of the practice of intermittent water supply is water contamination due to people storing their water in filthy storage containers, as was noted for Ghana. On the other hand, according to Xin *et al*. (2014), the problem of leakage is beyond an economic problem. It includes the problem of environmental sustainability, and is likely a health and safety problem. In comparison to developed countries, developing countries are struggling with an even higher percentage of water loss (Xin *et al*., 2014).

Water Supply Capacity

As pointed out by Postel *et al*. (1996), the total global freshwater available for people to use is about 12,500 km^3, which is less than 1% of the total water on earth; which means that the annual per capita water availability equals to 6,600 m^3. Despite this global water availability, the Joint Monitoring Programme (JMP) reported in 2010 that 13% of the total world population does not have access to an adequate water supply (JMP, 2010). Most of these people inhabit developing countries (Keenan, 2010).

Yadav *et al*. (2014) argued that the expansion of populations, industrialization and urbanization, as well as improving living standards cause an endless increase of water demand. In addition, as pointed out by Idowu *et al*. (2012), "global water demand for all purposes exceeds 3,700 km^3/year" (Idowu *et al*., 2012, page 2110). The United Nations Development Programme (UNDP) determined that the high water demand at this present time is prone to increase water scarcity as more people directly contend for water for their livelihood (UNDP, 2009a). The Food and Agriculture Organization (FAO) stated that by 2025, "1,800 million people will be living in a country or regions with absolute water scarcity and two-thirds of the world population could be under conditions of water stress" (FAO, 2007).

Falkernmark and Molden (2008) argue that the growing population provides a major impact on water, especially when it is not followed by efforts to increase supply and management of demand capacity. In addition, Bogardi *et al*. (2011) believe that the combination of increasing water demand and water shortage will result in harsh water supply issues, if not accompanied by innovative methods, primarily through investments in water technologies and water demand management. In order to manage the increasing water demand, the future water requirement should be determined. Wallingford (2003) introduced various forecasting methods in order to estimate future total water demand, and one of the methods is an estimation based on population growth and per capita water consumption. The advantage of this method is it is inexpensive and needs a limited amount of data, while the disadvantage is using the past trend of total water demand to projects the future demand (Wallingford, 2003). Therefore, this method is used in my research in order to estimate future total water demand in Dili's urban areas.

According to Yance (2004), East Timor's total annual groundwater resources are 265 Million Cubic Meters (MCM), while the annual surface water resource is 4,692 MCM. Costin and Powell (2004) pointed out that this is a large amount of water to meet the demand of East Timor's population, but "this water is very unreliable over time, uneven from place to place, and in the case of deep groundwater, expensive to access" (Costin and Powell, 2004, page 1-2).

There were several studies conducted on Dili's public water supply system (Jansen *et al*., 1999; JICA, 2002; JICA, 2011). The studies pointed out the poor infrastructure (Jansen *et al*., 1999; JICA, 2002), as well as poor management of the public water supply system (JICA, 2011). These studies identified some issues including poor performance of the public water supply system, a poor water distribution system, small public water coverage, lack of man power, and the needs of capacity building for the staff.

According to the JICA's study in 2002, per capita water consumption per day was only 80 liters. This amount of water consumption is not sufficient as compared to the daily water requirement by the World Health Organization (WHO). The optimal daily water consumption determined by WHO is 100 to 200 liters on average which translated to a lower health risk (WHO, 2011).

The 2011 study conducted by JICA is the latest study on Dili's public water supply system, and was limited to three WTPs including Bemos, Lahane, and Central. Therefore, a new study of the public water supply system for both WTPs and wells is needed, in order to evaluate the performance of the entire system.

East Timor's Profile

Geography and Climate

East Timor is located in the southern hemisphere low latitude tropics between 8^o S – 10^o S and 124^o E – 128^o E. It is one of the youngest and one of the poorest countries in the world (UNDP, 2012). As shown in Figure 2, East Timor borders with Australia on the south by the Timor Sea, and Indonesia on the west. The country has total land area of 19,122 km^2 (7,383 $miles^2$), which includes the eastern part of Timor Island, the enclave of Oecussi-Ambeno in the western part of Timor Island, and Atauro and Jaco Island (Weatherbee, 1966). East Timor is divided into 13 districts, which include the capital city Dili, Bobonaro, Liquica, Baucau, Manatuto, Lautem, Cova-Lima, Ainaro, Manufahi, Viqueque, Ermera, Aileu, and Oecussi-Ambeno. Figure 3 shows the location of each district.

Figure 2. Location of East Timor and its neighboring countries. East Timor borders with Australia on the south by the Timor Sea and with Indonesia on the west. (National Geographic, n.d).

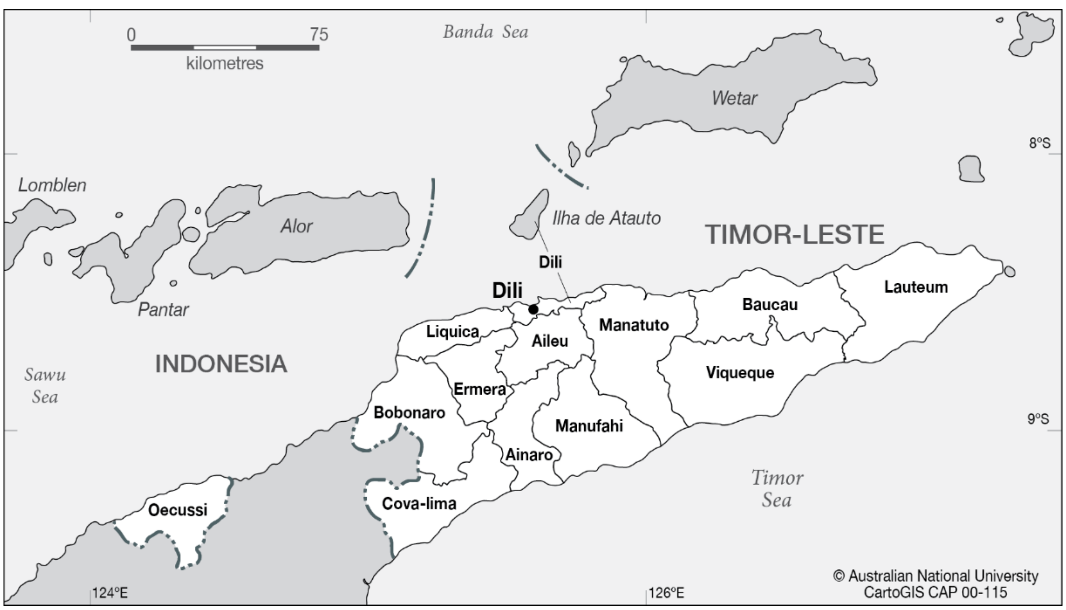


Figure 3. Districts of East Timor. Oecussi district is located in the western part of Timor Island, exactly in the middle of Indonesia. The only way to get to Oecussi district is by sea. (Australian National University, n.d.).

The climate in East Timor is influenced by the West Pacific Monsoon, which is caused by wide variance of temperature between land and ocean (Pacific Climate Change Science Program Partners, 2011). East Timor's climate is divided into wet and dry seasons. The wet season ranges from November to May, while the dry season ranges from June to October. During the wet season, the monthly rainfall averages 180 mm, and in the dry season, it averages 43 mm (World Bank Group, 2012). The average monthly temperature in East Timor is 25 °C (World Bank Group, 2012). In general, the climate is humid with humidity ranging between 70% and 80% (Ministry of Agriculture and Fisheries, 2004).

<u>History</u>

East Timor was colonialized by the Portuguese in the 16th century up until 1975. During the time of colonialization, East Timor was called Portuguese Timor. Sandalwood was the prominent trade which brought Portuguese to East Timor (Weatherbee, 1966). In 1975, Portugal withdrew from East Timor due to the decision to dismiss the colonial empire (BBC Monitoring, 2013). In the same year, Indonesia forcefully entered the eastern part of Timor Island and later officially announced East Timor as the 27th province of Indonesia, named Timor-Timur (Government of East Timor, 2015). The Indonesian invasion of East Timor was supported by the government of the United States of America because they saw a threat from the Frente Revolucionária do Timor Leste Independente (FRETILIN), a Marxist organization in Timor region (Government of East Timor, 2015).

East Timor became independent from Indonesia after a public referendum, where on August 30, 1999, 78.5% of the population voted to secede from Indonesia (United Nations Department of Public Information, 2002). From 1999 to 2002, East Timor was run under a transitional government by the United Nations, called the United Nations Transitional Administration in East Timor (UNTAET). UNTAET was established on October, 25th 1999 (UN Department of Public Information, 2002). The independence of East Timor was recognized internationally on May 20, 2002. In 2006, a conflict erupted as the result of tension between the national police and armed forces (UNDP, 2012). This conflict caused death and destruction, and many Timorese people fled from their homes and stayed in refugee camps in Dili because of the unsafe situations. The government made efforts to resolve the conflict and create stability in the country and to continuously recover from this conflict. In 2012, presidential and parliamentary elections were held peacefully and fairly. Today, the government continues to ensure the country's stability and the development process to improve people's living standard.

Population and Education

The total 2015 population of East Timor was 1,167,242 (General Directorate of Statistics, 2015). Even though the annual population growth rate decreased from 2.41% in 2010 to 1.81% in 2015, it still ranks as the second highest in the south-east Asian region (General Directorate of Statistics, 2015). This is because East Timor is one of the countries with the highest fertility rates in the world, with an average of every woman having seven children (UNFPA, 2010). More than 70% of the population lives in rural areas. Based on the 2015 census, the total urban population was 328,281, and the population of Dili alone was 252,884; this accounts for more than 70% of the total urban population (General Directorate of Statistics, 2015). The average household size in East Timor is 5.7 (General Directorate of Statistics, 2015). The population is predominantly young, with 41.4% 15 years old and younger, and 53.9% between 15 and 64 years of age; the remaining population is 65 years old and above (General Directorate of Statistics, 2010). The life expectancy rate of East Timor in 2013 was 68, which is slightly higher compared to the average life expectancy rate in similar income countries (World Bank Group, 2015).

In education, the rate of school enrollment based on the 2010 census is 70.6% for primary school, 23% for pre-secondary school, and 16% for secondary school (General Directorate of Statistics, 2010). The primary school includes grade 1-6; the pre-secondary school includes grade 7-9; and the secondary school includes grade 10-12. According to United Nations Children's Emergency Fund (UNICEF), the total adult literacy rate in East Timor was 58.3% (UNICEF, 2013). This represents the people age 15 and over who can read and write.

Another criterion that can be used to assess the development of a country is the Human Development Index (HDI). HDI is a "summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and a decent standard of living" (UNDP, 2015). East Timor's HDI in 2007 was 0.489, ranked 162 of 182 countries (UNDP, 2009b). In 2013, East Timor ranked 128 under the category of medium human development (UNDP, 2015).

Economic Condition

East Timor's Gross Domestic Product (GDP) per capita in 2014 was $1,280.42 (World Bank Group, 2015). Figure 4 shows the trend of GDP per capita over the past 14 years in East Timor based on data extracted from the World Bank report. As shown in Figure 4, "the GDP fell during 2002 and 2003 due in part to a drought that adversely affected crop yields" (World Bank Group, 2009). In 2004, non-petroleum GDP started a slow recovery, which led to an increase in 2005 (World Bank Group, 2009). In 2006, it dropped again due to the open conflict between the national police and the armed forces. GDP increased since 2006, mostly due to the oil and gas exploration in the Timor Sea, but has declined in 2014 due to drop of oil prices. According to its GNI per capita, World Bank classifies East Timor as a lower middle income country.

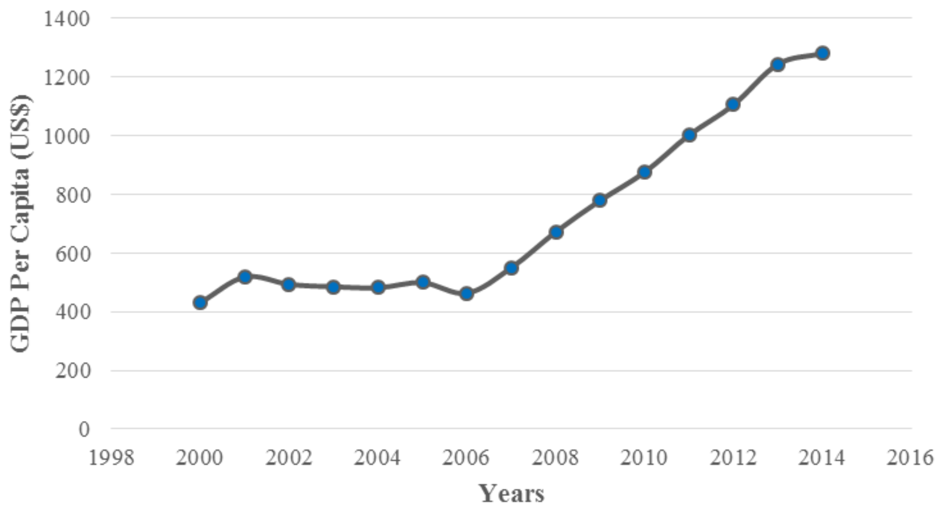


Figure 4. East Timor's per capita GDP. (World Bank Group, 2015)

Natural Resources and Agriculture

East Timor is rich with natural resources, such as gold, copper and iron, and oil and gas (UNDP, 2005). The country is now focusing on the exploration of oil and gas in the Timor Sea. The project consists of building a refinery and petrochemical industries, a Liquefied Natural Gas (LNG) plant, and a supply base to support the growing oil and gas activities in the Timor Sea.

Agriculture is the livelihood of 80% of East Timor's population (Da Costa, 2003). The agricultural products include maize, rice, cassava, and beans (Da Costa, 2003). The country also produces white potato, sweet potato, and peanut as well as general commercial crops, such as coffee, candlenut, vanilla, and coconut (Da Silva and Valentin, 2004). Agriculture is also the biggest consumer of water. Water use for agriculture purposes, such as irrigation, accounts for 91% of the total national water use (Yance, 2004). Even though it employs the majority of the population, the soil in East Timor is not suitable for agriculture due to being relatively unproductive, low fertility, and fragile as results of its geology (Costin and Powell, 2004). The common slash-and-burn agriculture practice also contributes to land degradation in East Timor (World Bank Group, 2009). Furthermore, there is a high level of soil erosion, which increases the accumulation of sediment downstream (World Bank Group, 2009). According to Costin and Powell (2004), “in many locations, soil erosion and pollution has made the [water] resource frequently unsuitable for safe domestic consumption unless costly water treatment processes are employed. Short-term urban water shortages are common, particularly following heavy rains when high sediment loads in streams make the water unsuitable for treatment.”

Water

The Joint Monitoring Programme (JMP) in 2011 reported that only 69% of East Timor’s total population has access to an improved water supply (JMP, 2011). An improved water supply is “one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter” (JMP, 2015a). Drinking water in East Timor mainly comes from the groundwater and is classified by the JMP as piped into premises, other improved sources, and other unimproved sources (JMP, 2015b). The improved sources include public taps, tube well/boreholes, protected wells or springs, and rainwater collection. The unimproved sources include unprotected wells or springs, surface water, bottled water, and water tanker-trucks.

As the population and income grow, the needs for water and sanitation services will also increase. East Timor’s population growth rate is 1.81% (General Directorate of Statistics, 2015) with a projected GDP growth rate of 7% (World Bank Group, 2015). If the population and income continue to grow at this rate, more water will be needed in the future to fulfill people’s daily needs and support the development process. The government of East Timor realizes this potential problem and has made an effort to address this problem, which can be seen in East Timor's Strategic Development Plan (SDP) 2011-2030. In this strategic plan, the government aims to extend the coverage of improved water supply in East Timor. The target is for all of the population, urban and rural, to have access to an improved water supply by 2030 (Government of East Timor, 2010). This target will be achieved in the short-term, medium-term, and long-term (Government of East Timor, 2010).

OVERVIEW OF DILI'S PUBLIC WATER SUPPLY SYSTEM

The discussion of Dili's public water supply system is limited to the urban areas. According to the General Directorate of Statistics and UNFPA (2011), areas classified as an urban area share the following characteristics:

- A population of 2,000 people or more;
- Less than 50% employed in the agriculture/fisheries sectors and the remaining people employed in the modern sector;
- Electricity and piped water;
- Access to schools, medical care, and recreational facilities.

Dili's Urban Areas

Dili is the capital city of East Timor, located in the northern coast of the country. The total land area of Dili is 368.1 km^2 (National Statistics Directorate and UNFPA, 2011). The topography of Dili is flat and surrounded by mountains. As shown in Figure 5, Dili is divided into six sub-districts including Atauro, an island approximately 30 km north off the coast of Dili's city center, Cristo Rei, Dom Aleixo, Metinaro, Nain Feto, and Vera Cruz. Out of these sub-districts, only four sub-districts are classified as urban areas, which are Cristo Rei, Dom Alexio, Nain Feto, and Vera Cruz (National Statistics Directorate and UNFPA, 2011). These four sub-districts are comprised of 24 *Suku* (villages). *Suku* is the smallest administrative division in East Timor, comprised of one or more *aldeias* (hamlets) (Government of East Timor, n.d.). Table 2 provides the information on total population and land area, and population density of each *suku* in these four urban sub-districts.

Figure 5. Sub-districts of Dili, East Timor. Dili has 6 sub-districts and one of it is Atauro located 30 km north off the coast of Dili town. This map is from the National Local Administration Directorate (2014).

The total population of these four sub-districts is 220,697 and the total land area is 136.4 km^2 (National Statistics Directorate and UNFPA, 2011). Urban areas are only about 30% total of the Dili area. The average household size is 6.5 (National Statistics Directorate and UNFPA, 2011). Based on the data of total population and land area of these four sub-districts, the population density can be calculated by dividing the total population with the total land area. Therefore, the population density is approximately 1,618.3 people/km^2, in comparison to the whole Dili district's population density, which is 635.7 people/km^2, thus the population density of these urban areas is more than double.

The climate in Dili is divided into wet and dry seasons. The wet season ranges between November and May and the dry season ranges between June and October. Figure 6 shows the average monthly rainfall for both seasons in Dili.

Table 2. Total population, land areas, and population density of urban areas of Dili, East Timor.

Sub-Districts	*Suku*	Total Population	Total Land Area (km^2)	Population Density (persons/km^2)
VERA CRUZ		**34,015**	**32.77**	**1,037.99**
	Lahane Ocidental	5,467	3.16	1,730.06
	Vila Verde	9,554	2.73	3,499.63
	Mascarenhas	6,683	1.26	5,303.96
	Caicoli	4,323	0.62	6,972.58
	Colmera	3,315	0.58	5,715.51
	Motael	2,877	0.55	5,230.90
	Dare	1,796	23.88	75.20
NAIN FETO		**26,592**	**5.15**	**5,163.49**
	Santa Cruz	5,195	0.48	10,822.91
	Acadiru Hun	2,593	0.22	11,786.36
	Bemori	5,527	0.59	9,367.79
	Lahane Oriental	10,886	3.29	3,308.81
	Bidau Lecidere	1,225	0.33	3,712.12
	Gricenfor	1,166	0.23	5,069.56
DOM ALEIXO		**105,154**	**33.12**	**3,174.93**
	Fatu Hada	7,178	0.81	8,861.72
	Kampung Alor	4,697	0.49	9,585.71
	Comoro	65,404	25.18	2,597.45
	Bairropite	27,875	6.64	4,198.04
CRISTO REI		**54,936**	**65.33**	**840.90**
	Culu Hun	8,904	0.95	9,372.63
	Becora	20,893	8.74	2,390.50
	Camea	7,589	2.31	3,285.28
	Hera	7,376	41.24	178.85
	Balibar	1,265	3.97	318.63
	Meti Aut	716	4.89	146.42
	Bidau Santana	8,193	3.23	2,536.53

Note: Data of total population and land area is from the report of the 2010 census by the National Statistics Directorate and UNFPA (2011).

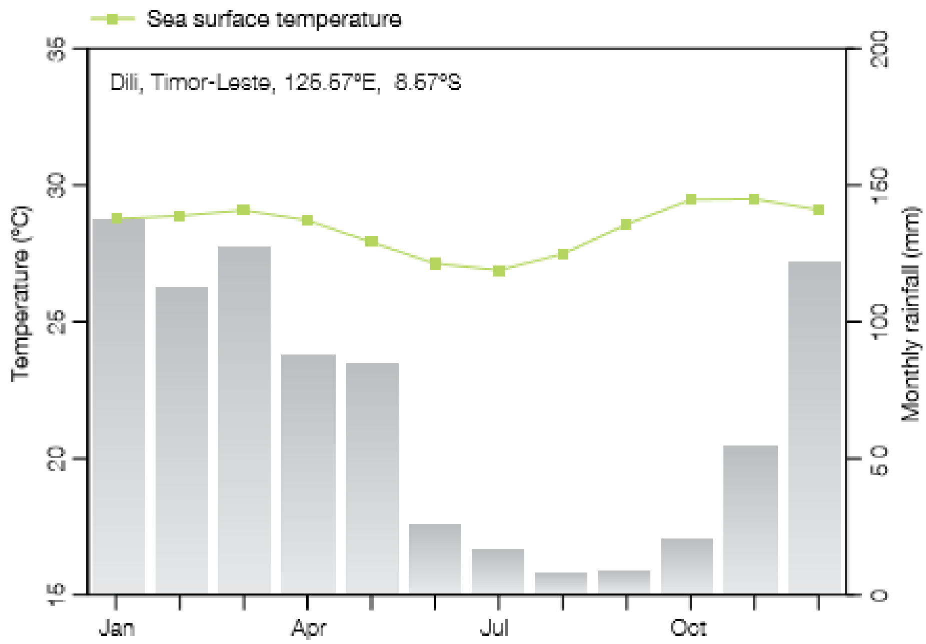


Figure 6. The average monthly rainfall in Dili, East Timor. During wet season, the average monthly rainfall is 100 mm, while during dry season, the average monthly rainfall ranges between 30 – 40 mm. This graph is from the Pacific Climate Change Science Program (2011).

Water Supply System

Water sources for urban areas of Dili include both surface water and groundwater. The type of surface water use is river water, such as the Bemos, Maloa, Bemori, and Benamauk rivers. The raw water from the river is pumped to WTPs for treatment before being distributed. The other sources are the groundwater from alluvial aquifers (Jansen *et al*., 1999). An alluvial aquifer is an aquifer typically comprised of gravel, sand, silt, or clay deposited in river channels and/or floodplains (Geoscience Australia, n.d.). Groundwater is pumped from several wells across the urban areas, and is more reliable than the surface water because surface water depends on precipitation, which in the dry season is low and causes low river flow. Ultimately this affects the actual water supply through the WTP.

Water Treatment Plants

There are four conventional WTPs that treat the raw water before it is distributed to residential, office, and commercial places in Dili's urban areas. The four WTPs are Bemos, Central, Lahane, and Benamauk. Figure 7 shows the location of each WTP. These WTPs undergo the same treatment process as follows:

1. Raw water intake from the river is transferred through transmission pipelines to the WTP.
2. The first treatment process is coagulation. In this process, coagulants are added to the raw water in order to "destabilize colloidal particles and allow them to agglomerate or flocculate with other suspended particles to form larger more readily settled particles" (Droste, 1997, page 220).
3. The next process is sedimentation. In the sedimentation process, the readily settled particles are allowed to settle down to the bottom of the tank by gravitational forces.
4. The next process is filtration. In the filtration process, water is filtered through a rapid sand filtration unit.
5. The last process is disinfection. In this process, disinfectant (chlorine) is added to the water to inactivate pathogens that still remain in the water after the filtration process.
6. After undergoing all of the abovementioned processes, the treated water is stored at reservoirs and/or distributed to the urban areas. Figure 8 illustrates the treatment process.

Figure 7. Locations of water treatment plants in Dili, East Timor. Bemos WTP is located in the south-western part of Dili; Central WTP is located in the central part of Dili; Lahane and Benamauk WTPs are located around the south-eastern part of Dili. This picture was extracted through Google Earth's software (2016).

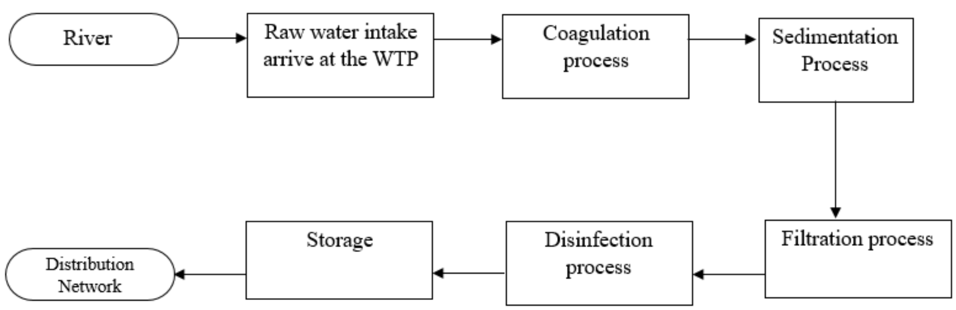


Figure 8. The water treatment system's flow diagram for a typical water treatment plant in Dili, East Timor. Major treatment unit processes are: coagulation, sedimentation, filtration, and disinfection.

Every WTP has a different design capacity. All of the WTPs are designed to operate 24 hours a day, but in practice they are not operating 24 hours a day. This is due to the shortage of a constant power supply caused by frequent electricity shut-downs (National Water and Sanitation Directorate, 2015). Daily operational hours affect the total actual water supply by the WTPs. Therefore, the ratio of actual daily water production to the design capacity is less than 100%.

Bemos WTP

The Bemos WTP was constructed in 1984. Raw water for this WTP comes from the Bemos River. The design capacity of the Bemos WTP is 3,500 m^3/day (105,000 m^3/month). Based on the 2014 data, the average daily water production of this WTP was 2,955.6 m^3 (National Water and Sanitation Directorate, 2014). Table 3 shows the actual monthly water production of this plant in the year 2013 and 2014, while Figure 9 shows the renovated Bemos WTP's facility.

As shown in Table 3, in the year 2013, the monthly water production of this WTP was less than 50% of the design capacity. Moreover, in February, the water production was only 3% of the design capacity. In the year 2014, there were five months in which the monthly water production exceeded the design capacity. In contrast the other seven months, this WTP supplied significantly less water than the design capacity. Overall, the total water production of the Bemos WTP 2014 was more than double compared to 2013.

Table 3. Monthly water production of Bemos water treatment plant in 2013 and 2014 in Dili, East Timor

Months	Actual Water production (m^3/month)	
	2013	2014
January	45,496	155,520
February	3,245	150,336
March	44,616	59,616
April	50,496	103,680
May	49,696	106,272
June	50,536	108,864
July	51,376	108,864
August	27,835	101,088
September	29,435	41,472
October	30,235	38,880
November	30,735	77,760
December	31,735	11,664
Total	**445,436**	**1,064,016**

Note: The Data is from the annual report of WTPs is from the National Water and Sanitation Directorate (2013 and 2014).

Figure 9. The Bemos water treatment plant in Dili, East Timor. This plant was renovated in 2007 by Dai Nippon Construction. This picture is from Dai Nippon Construction (2007).

Central WTP

The Central WTP is the newest and the largest WTP in Dili. It was constructed in 2004. Raw water for this WTP comes from the Maloa River. The design capacity of the Central WTP was 7,680 m^3/day (230,400 m^3/month). Based on the 2014 data, the average daily actual water production of this WTP was 4,933.89 m^3 (National Water and Sanitation Directorate, 2014). Table 4 shows the monthly actual water production of this plant in the year 2013 and 2014.

As shown in Table 4, both in the year 2013 and 2014, the actual monthly water production of this WTP did not reach the design capacity. In 2013, the total actual water supply only averaged 59.51% of the design capacity; in the year 2014, it was slightly higher, reaching 64.24% of the design capacity. Even though it increased, in August and September the actual water production was significantly less than the design capacity. Overall, the actual total water production of Central WTP in the year 2014 was only increased by 7.94% from the year 2013.

Table 4. Monthly water production of Central water treatment plant in 2013 and 2014 in Dili, East Timor

Months	Actual Water production (m^3/month)	
	2013	2014
January	149,865	176,256
February	153,240	181,782
March	132,761	161,303
April	155,490	184,032
May	158,865	184,032
June	162,765	173,664
July	166,290	178,848
August	169,215	165,888
September	102,075	8,812
October	94,135	54,432
November	98,657	129,600
December	102,182	177,552
Total	**1,645,540**	**1,776,201**

Note: The Data is from the annual report of WTPs from the National Water and Sanitation Directorate (2013 and 2014).

Lahane WTP

The Lahane WTP is the oldest WTP in Dili. It was constructed in 1954. Raw water for this WTP comes from the Bemori River. The design capacity of this WTP is 2,600 m^3/day (78,000 m^3/month). Based on the 2014 data, the average daily water production of this WTP was 2,527.2 m^3 (National Water and Sanitation Directorate, 2014). Table 5 shows the monthly actual water production of the Lahane WTP in the year 2013 and 2014, while Figure 10 shows the renovated Lahane WTP's facility.

As shown in Table 5, in the year 2013, the actual water production of this WTP is significantly less than the design capacity. It was only averaging 24.64% of the total design capacity. In the year 2014, there were four months which the actual water production exceeded the design capacity which included April, May, October, and November; and on the other months, it was close to the design capacity. Overall the total actual water production of the Lahane WTP in 2014 was increased more than three times from the year 2013.

Table 5. Monthly water production of Lahane water treatment plant in 2013 and 2014 in Dili, East Timor

Months	Actual Water production (m^3/month)	
	2013	2014
January	17,050	77,760
February	18,613	72,576
March	16,268	75,168
April	19,919	82,944
May	21,516	80,352
June	19,944	25,920
July	20,100	75,168
August	22,690	72,576
September	21,152	77,760
October	18,437	103,680
November	16,875	108,864
December	18,126	57,024
Total	**230,690**	**909,792**

Note: The Data is from the annual report of WTPs from the National Water and Sanitation Directorate (2013 and 2014).

Figure 10. The Lahane water treatment plant in Dili, East Timor. This facility was renovated in 2007 by Dai Nippon Construction. This picture is from Dai Nippon Construction (2007).

Benamauk WTP

The Benamauk WTP was constructed in 1993. Raw water for this WTP comes from the Benamauk River. The design capacity of the Benamauk WTP is 900 m^3/day (27,000 m^3/month). Based on the 2014 data, the average daily actual water production of this WTP was 842.6 m^3 (National Water and Sanitation Directorate, 2014). Table 6 shows the monthly actual water production of the Lahane WTP in the year 2014. The monthly data in the year 2013 is not available due to a broken meter. As explained by one of the National Water and Sanitation Directorate's employees, it took four years to fix this issue, because of a very minimum budget allocation by the government to the water and sanitation sector. Figure 11 shows the renovated Benamauk WTP's facility.

As shown in Table 6, there are five months which the actual water production slightly exceeds the design capacity which included January, March, April, November, and December.

During the other months, the actual water production was reaching the design capacity. Overall the average monthly water production in the year 2014 was 93.62% of the design capacity.

Table 6. Monthly water production of Benamauk water treatment plant in 2014 in Dili, East Timor

Months	Actual Water production (m^3/month)
January	27,319
February	24,364
March	27,993
April	28,512
May	26,956
June	26,784
July	24,105
August	12,856
September	22,809
October	25,920
November	28,512
December	27,216
Total	**303,346**

Note: The Data is from the annual report of WTPs from the National Water and Sanitation Directorate (2014).

Figure 11. The Benamauk water treatment plant in Dili, East Timor. This facility was renovated in 2007 by Dai Nippon Construction. This picture is from Dai Nippon Construction (2007).

Groundwater Wells

The total number of public water supply wells in Dili's urban areas is 25 (National Water and Sanitation, 2016). Four of them are new wells and still not operating, one well is broken, and two wells are not used. Therefore, only 18 wells supply water to the population (National Water and Sanitation Directorate, 2016). These wells are operating 24 hours/day (National Water and Sanitation Directorate, 2014). Table 7 summarizes the information of the current operating wells in the urban areas including the average monthly water production and the percentage of the design capacity in the year.

Table 7. Average of monthly actual water production and its percentage of design capacity in 2014 of the groundwater wells in Dili, East Timor

Wells	Average Actual Water Production (m^3/month)	% of the Design Capacity
Comoro A	56,203	61.95
Comoro B1	65,680	49.68
Comoro B2	13,684	35.19
Comoro C	31,552	67.62
Comoro D	50,708	88.92
Comoro E	37,356	55.43
Manleuana	44,077	77.29
Marconi	45,187	79.24
Bairropite	45,878	80.45
Mascarenhas	67,046	**172.44**
Bidau 2	44,227	65.62
Bidau 3	21,606	**104.19**
Bidau 4	5,204	40.15
Culuhun A	58,367	62.54
Culuhun B	72,770	93.58
Becora 1 (Civpol)	22,057	**106.36**
Becora 2 (Mota Laran)	50,458	55.61
Becora 3 (Mercado)	49,118	**105.27**

Note: Data is from the report of National Water and Sanitation Directorate, Water Supply Department, Dili District (2014).

As shown in Table 7, there are five wells which the actual water production exceeds the design capacity including Mascarenhas, Bidau 3, Becora 1 (Civpol), and Becora 3 (Mercado) wells. The Mascarenhas well substantially exceeds the design capacity, while the other three wells are slightly exceeding the design capacity. On the other hand, the actual water production of the Comoro B2 and Bidau 4 wells is significantly less than the design capacity.

Only 2014 water production data is used for analysis because the 2013 data is questionable due to the high variations, and for some wells the monthly water production is significantly higher than the design capacity. Moreover, there are some missing data in the year 2013 for some wells (See Appendix A). The 2013 data for Becora 3 (Mercado) well was not available because the well wasn't built yet. The data for the other four wells including Comoro B2, Marconi, Bairo Pitte, and Mascarenhas is missing because it is not available from the 2013 report provided by the National Water and Sanitation Directorate.

Water Distribution System

The distribution system is comprised of ten distribution zones. Figure 12 shows the distribution zones on a map. As shown in Figure 12, the distribution zones are not based on the administrative boundary. This means *aldeias* in the same *suku* could have different distribution zones.

Besides WTPs and wells, there are also several reservoirs that are spread in Dili's urban areas. A reservoir is used for storage of water from the WTPs and wells. Even though it stores water from WTPs and wells, it does not always mean that water is distributed to the population from the reservoir. In some cases, water is directly distributed from WTPs and/or wells to the population if the WTPs and/or wells have higher elevations than the distribution zones. Water is distributed from the reservoir if WTPs and/or wells have lower elevations than the distribution zones. In this case, water is first pumped from the WTPs and/or wells to the reservoir at the higher elevation, and then distributed to the distribution zones. Table 8 shows the list of the existing reservoirs and their capacity.

Table 8. Existing urban reservoirs and their capacity, in Dili East Timor

Reservoirs	Capacity (m^3)
Malinamauk	1,000
Manleuana	1,000
Bemos-1	500
Bemos-2	1,000
Central	3,000
Maloa	60
Aituri Laran-1	27
Aituri Laran-2	60
Carega Tiru	60
Bidau Masau	200
Cristo Rei	27
Culau	600
Mota Ulun	40
Benamauk	100
Cendana-1	27

Note: The Data is from the National Water and Sanitation Directorate (2016).

Water Connections

According to the National Water and Sanitation Directorate, a water connection describes the number of households and commercial and industrial buildings, offices, schools and religious places with access to the public water supply system. This means one household or a building is considered one connection. The calculation of total connections by the National Water and Sanitation Directorate is based on water use categories which include: domestic, general, offices, social, and public tap. Water connections for general use is for commercial and industrial, while social use is for schools and religious places. Table 9 provides the total connections in each water use category.

Table 9. Total water connections based on water use categories in Dili, East Timor

Sub-Districts	Domestic	General	Offices	Social	Public Taps	**Total Connection**
Dom Aleixo	6,747	167	97	20	7	**7,038**
Vera Cruz	1,921	41	54	6	4	**2,026**
Nain Feto	1,473	98	33	18	15	**1,637**
Cristo Rei	2,781	40	52	15	15	**2,903**
Total	**12,922**	**346**	**236**	**59**	**41**	**13,604**

Note: Data is from the National Water and Sanitation Directorate (2016).

As explained before, the average household size is 6.5 people, therefore based on the data from Table 9 the total population with access to a public water system for domestic use is approximately 83,993 people. This number was obtained by multiplying the total connections for domestic use with the average household size. As for public taps, each one serves an average of 200 people (JICA, 2001). By multiplying this number with the total number of public taps in urban areas, the total population utilizing public taps is 8,200.

Based on the abovementioned calculation, the total population with access to a public water supply system for both direct connections to households (domestic) and public taps is approximately 91,193 people. This accounts for only about 41.77% of the total population of 220,697. The rest of the households use their private wells as the source of their water supply.

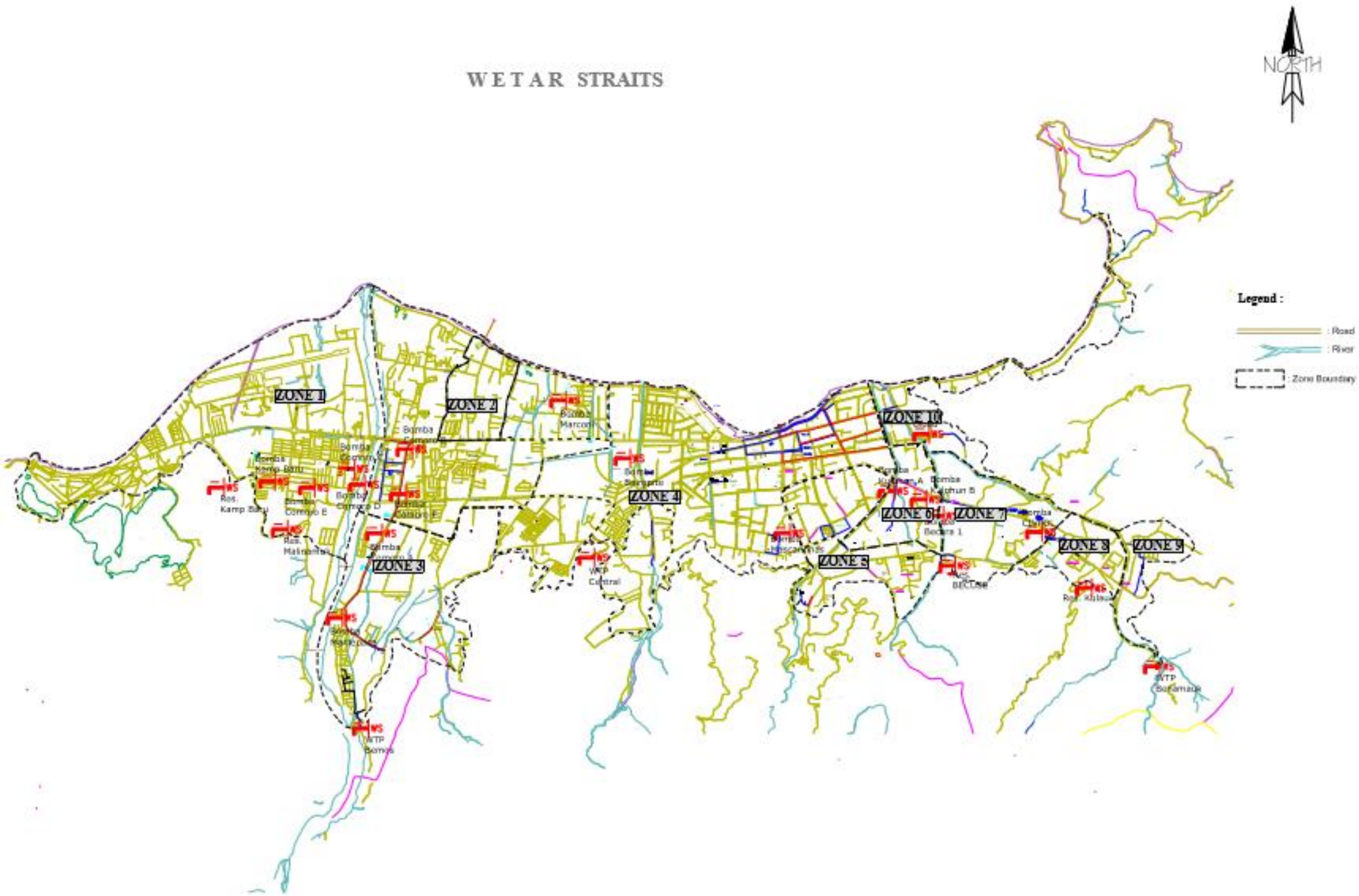


Figure 12. Water distribution zones of Dili, East Timor (National Water and Sanitation Directorate, n.d.)

ANALYSIS AND DISCUSSION

The analysis and discussion of the water supply system in the urban areas of Dili, East Timor is focused on the current conditions, identifying the shortages of the current conditions, and determining the future needs based on a growing population.

Current Conditions

Analysis of the current conditions was completed by evaluating the performance of the current water supply system, which included the WTPs and wells. Performance evaluation for the WTPs was done by analyzing the actual water production data in the year 2013 and 2014, as well as data from the previously conducted study by JICA in the year 2010. The performance evaluation for the wells was completed by analyzing the actual water production in the year 2014 only.

Water Treatment Plants

The WTPs' annual water production data in 2010, 2013, and 2014 is shown in Table 10, while the percentage of the actual water production to the design capacity is shown in Table 11.

Table 10. The annual water production of water treatment plants in the years 2010, 2013, and 2014 in Dili, East Timor

WTPs	Water Production (m^3)		
	2010	2013	2014
Bemos	239,904 – 317,880	445,436	1,064,016
Central	N/A	1,645,540	1,776,201
Lahane	97,488 – 311,908	230,690	909,792
Benamauk	0 – 90,000	N/A	303,346
Total	**337,392 – 719,788**	**2,321,666**	**4,053,355**

Note: The actual water production data in the year 2010 is derived from daily actual water production as reported by JICA (2011); the 2013 and 2014 data is derived from the monthly actual water production by the National Water and Sanitation Directorate.

Table 11. The percentage of annual water production to its design capacity in the years 2010, 2013, and 2014 in Dili, East Timor

WTPs	% of the design capacity		
	2010	2013	2014
Bemos	19.04 – 25.22	35.35	84.44
Central	N/A	59.51	64.24
Lahane	10.41 – 33.32	24.64	97.2
Benamauk	0 – 27.77	N/A	93.62

Note: The annual design capacities are 1,260,000 m^3, 2,764,800 m^3, 936,000 m^3, and 324,000 m^3 for Bemos, Central, Lahane, and Benamauk WTPs respectively (National Water and Sanitation Directorate).

As shown in Table 10, the water production data for the Central WTP in the year 2010 and the Benamauk WTP in the year 2013 was not available. The Central WTP's data was not available because the Central WTP was not included in JICA's renovation project. As for the Benamauk WTP, the water production data is not available due to a broken meter that caused the data not to be recorded (National Water and Sanitation, 2013). The annual water production was increased significantly in the year 2013 as compared to the year 2010 and it continued to increase in the year 2014. Overall the increase from the year 2010 to 2014 was almost six fold due to the significant improvement of daily operational hours. In addition, in the year 2014, there were some months where the actual water production exceeded the design capacity (See Tables 3-6).

In their evaluation study, JICA identified several issues in 2010 that caused the low quantity of the water production including:

- **Shortage of staff**

  Due to the staff shortage, the WTPs only ran at maximum 12 hours per day. This problem occurred in all three WTPs being evaluated including Bemos, Lahane, and Benamauk WTPs.

- **Low raw water quantity in the dry season**

  At the Lahane WTP low river flow in the dry season caused the decrease of raw water quantity.

- **Water is stolen**

  This problem happened at the Lahane WTP, where "water is frequently stolen from conduits connected with the plant, resulting in insufficient raw water" (JICA, 2011, page 6).

- **Plant stoppage due to high water turbidity**

  In the wet season, particularly in the months of February until April, there were about three plant stoppages due to the water turbidity exceeding the treatment capacity of the plant. This happened at the Lahane WTP.

- **Shortage of fuel for the generator**

  The electricity at the Benamauk WTP was off since the completion of the renovation because the National Water and Sanitation Directorate did not pay the electricity fee. Therefore, this WTP only operated four days a month by using a generator to supply power to the WTP. Poor fuel distribution management caused the shortage.

All of the abovementioned issues contributed to very low daily operational hours. As reported by JICA, the daily operational hours of these WTPs are shown in Table 12. A minimum in daily operational hours resulted in a minimum of water production. As shown in Table 11, the percentage of the design capacity in the year 2010 was less than 35% for all three WTPs.

Table 12. Daily operational hours of Bemos, Lahane, and Benamauk water treatment plants in 2010 in Dili, East Timor

WTPs	Daily Operational Hours
Bemos	February until April: 8 hours May until January: 10 hours
Lahane	July until December: 2.5 hours January until June: 8 hours
Benamauk	10 hours. Only four days a month.

Note: Data is from JICA (2011).

The issues still faced by the National Water and Sanitation Directorate at the water supply system level are as follows:

- Shortage of a consistent power supply and low raw water intake in the dry season which causes inconsistency of monthly water production
- Shortage of knowledgeable and skillful staff
- Financial issues

In comparison to the issues identified by JICA in the year 2010, the issues of water being stolen and shut down operation due to high water turbidity at the Lahane WTP don't occur any more. This is a good sign of improvement and contributed to the increase of water production in the year 2014. As shown in Table 11, the percentage of the design capacity in the year 2014 was more than 60% for all the WTPs and the Lahane WTP alone was 97.2%.

Shortage of power supply and low raw water intake in the dry season

Electricity shut-down, which happens sometimes, causes shortage of power supply to conduct the treatment process. In addition, low river flow in the dry season caused the low raw water intake. These two issues result in high variations of monthly water production of the WTPs. Figures 13 through 16 show the graph of each WTP's monthly water production in the year 2014, which was derived from the monthly water production data in Tables 3 through 6.

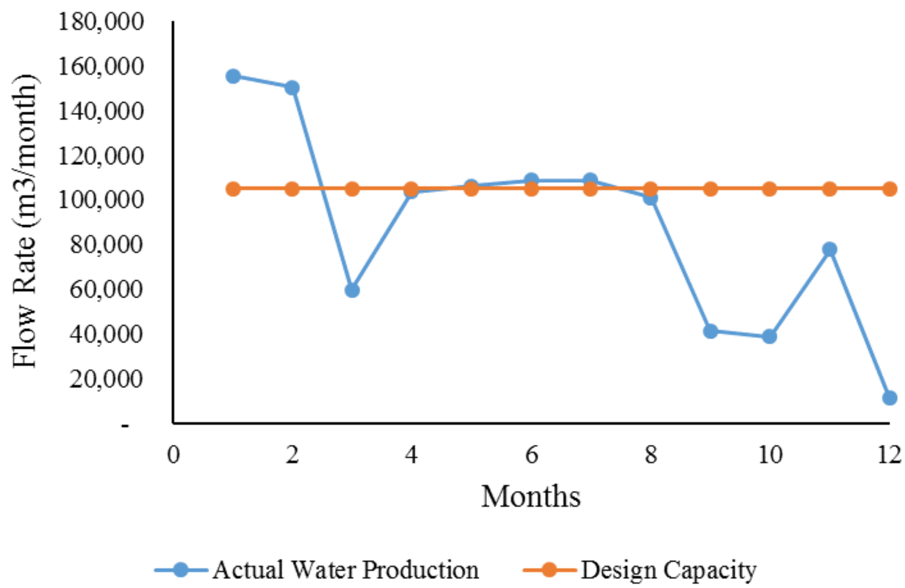


Figure 13. The Bemos water treatment plant's monthly water production in 2014 in Dili, East Timor. As shown in the graph, on March, September, October, and December the actual water production of this WTP were less than the design capacity.

As shown in Figure 13, there were only five months, where the Bemos WTP operated at its monthly design capacity, which was April until August 2014. In the months of January and February, this plant operated beyond its design capacity, which is due to the rainy seasons where the water resources available in an amount that was more than the normal period. On March, September, October, and December, the Bemos WTP operated less than its design capacity.

During these months, the percentage of water production to the design capacity were 56.77, 39.49, 37.02, and 11.1 respectively.

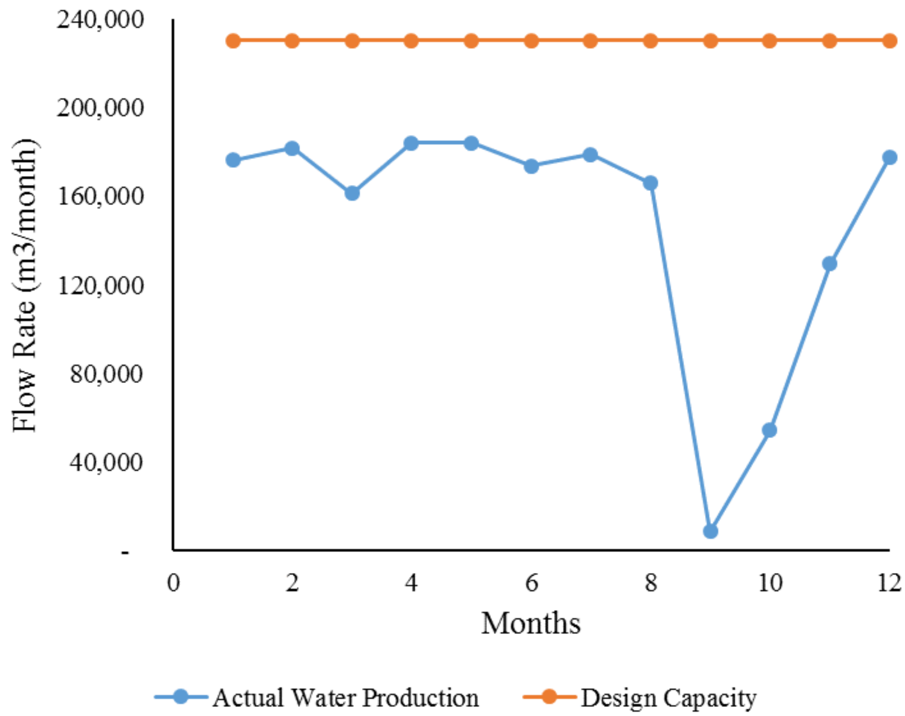


Figure 14. The Central water treatment plant's monthly water production in 2014 in Dili, East Timor. As shown in the graph, the actual water production of this WTP is less than its design capacity through the whole year.

Figure 14 shows the monthly water production of the Central WTP did not reach its design capacity in the whole year of 2014. This plant only operated for 75 % of the design capacity. Even worse, on September and October, the monthly production was substantially less than the design capacity. This could have happened due to combination of shortage of a consistent power supply, as well as the low water intake during the dry season in Dili. In the months of September and October the percentage of monthly water production to design capacity were 3.82 and 23.62 respectively.

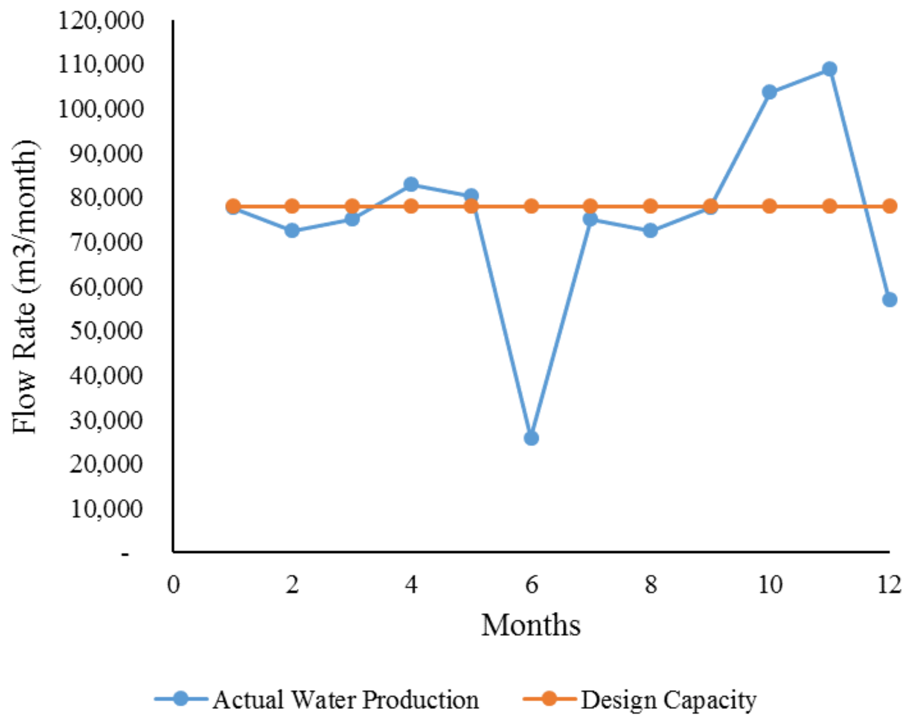


Figure 15. The Lahane water treatment plant's monthly water production in 2014 in Dili, East Timor. As shown in the graph, on June, the actual water production of this WTP was substantially less than the design capacity.

As shown in Figure 15, the Lahane WTP operated around its design capacity. There were only two months where this plant operated below the design capacity, and other two months were it operated beyond the monthly design capacity. In June 2014, the monthly water production of Lahane WTP was substantially less than the design capacity. On this month, the percentage of water production to its design capacity is only 33.23%. According to the staff from the National Directorate of Water and Sanitation, this happened due to shortage of a power supply and machine broke down.

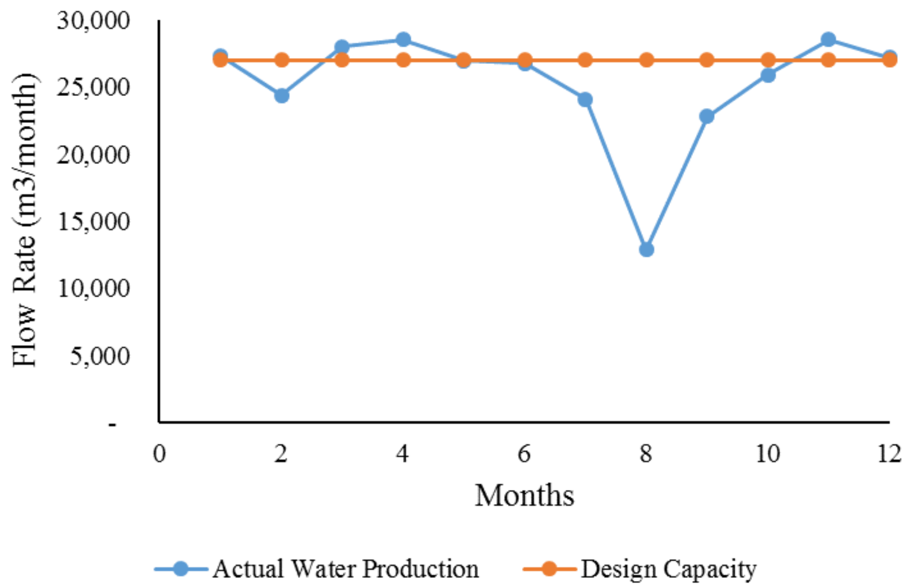


Figure 16. The Benamauk water treatment plant's monthly water production in 2014 in Dili, East Timor. As shown in the graph, in August, the water production of this WTP is substantially less than the design capacity.

The monthly water production of the Benamauk WTP in Figure 16 shows that in 2014 this WTP operated mostly around its design capacity. There was only one month, where the Benamauk WTP operated substantially less than its design capacity. The percentage of the monthly water production to the design capacity in this month was 47.61.

The dry season ranges between June and October (Pacific Climate Change Science Program, 2011). As shown in Figures 13 through 16, the majority of the months which the actual water production was substantially less than the design capacity usually occurred during the dry season. The water production is low during the dry season due to the low raw water intake as a result of low river flow. In the other months, due to the shortage of power supply during the wet season, the monthly water production was also low. The rest of the months were either close to their design capacity or exceeded their design capacity.

Shortage of knowledgeable and skillful staff

JICA in their 2010 report also identified the shortage of staff to perform the operation of the WTPs. This issue is still faced today and is not only limited to operation, but to personnel needed to perform maintenance of the WTP. As pointed out by the National Water and Sanitation Directorate's staff in the discussion, the current staff do not have the knowledge and skills to repair the system whenever issues occur. For instance, every time an issue occurs, they have to contact an external party to do the repair. This takes a longer time because they have to follow a long system of bureaucracy. As a result, it affects the actual water production of the WTP.

Financial problems

Financial resources play an important role for the success of the water supply system's performance. In a discussion with the National Water and Sanitation Directorate's staff, it was pointed out that the budget allocation for the water and sanitation sector, in particular for water supply management is minimum. For instance, it took four years to fix a broken meter at the Benamauk WTP. The staff also pointed out that due to a limited budget they have difficulties in conducting regular maintenance for the water supply system. In the end, these problems will affect the water production of the WTPs.

<u>Groundwater wells</u>

As explained in the previous chapter, there are 18 wells that are currently operating. Figure 17 shows the total monthly water production in the year 2014 as compared to the design capacity.

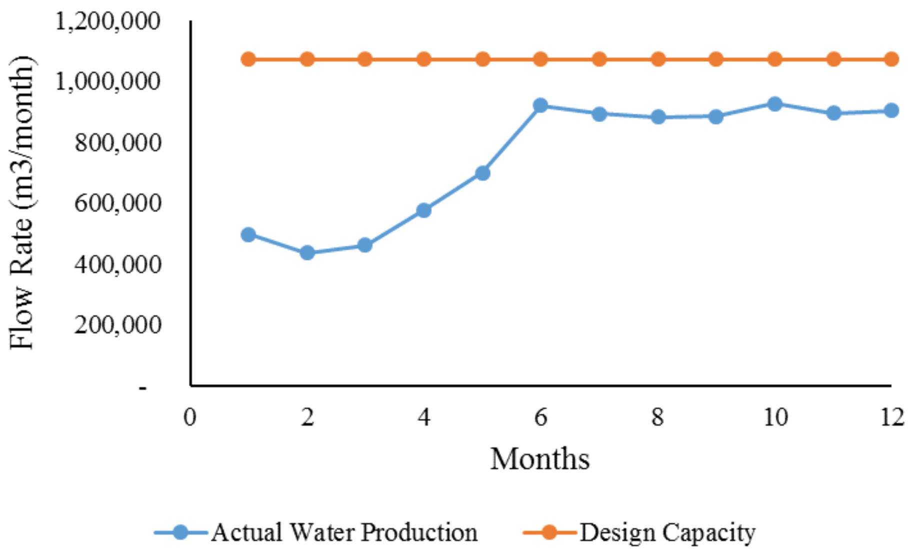


Figure 17. The total monthly water production of groundwater wells in the year 2014 for Dili, East Timor. As shown in the graph, on January until April, the actual water production is significantly less than the design capacity. The percentage of design capacity during these months were 46.42, 40.74, 42.92, and 53.83 respectively.

A table of monthly water production of each well can be found in Appendix B. Based on the tables of the monthly water production of each well, the monthly water production is grouped into three categories: actual water production exceeds the design capacity, actual water production is close the design capacity, and water production is significantly less than the design capacity. When the actual water production exceeded the design capacity it was due to over pumping. Over pumping results in the dropping of the water table which will decrease the capacity in the future. When the actual water production is significantly less than the design capacity it is due to shortage of the power supply. Another possible reason could be a sign of the wells deterioration and dropping of the water table, which result in a decrease of overall capacity.

To summarize, the issues faced by the National Water and Sanitation Directorate include:

- **Power supply shortage**

  The same thing as the WTPs, the electricity shut-down results in shortage of a power supply to operate the pumps. The government needs to put more efforts in the water supply system management in order to provide continuous water supply service to the people.

- **Shortage of knowledgeable and skillful staff**

  A knowledgeable and skillful staff is highly needed, in particular to oversee the record keeping data. It is important to record the correct data in order to provide reliable results used for analysis. The remaining issues are similar as those discussed in the WTPs' section.

- **Financial issues**

  The financial issues that affect the performance of the groundwater wells are the same as previously discussed issues in the WTPs.

The annual actual water production of the WTPs and wells, and the percentage to the design capacity in the year 2014 is shown in Table 13. As shown in Table 13, the total water production in the year 2014 was only 71.76% of the total design capacity. There were months that the WTPs and/or wells produced water exceeded the design capacity, but there were months

Table 13. Annual water production of the current water supply system and the percentage of the design capacity in 2014 in Dili, East Timor

Water Supply System	Actual Water Production (m^3/year)	% to the Design Capacity
WTPs	4,053,355	76.69
Wells	8,981,211	69.74
Total	**13,034,566**	**71.76**

Note: The data is derived from monthly actual water production by the National Water and Sanitation Directorate (2014).

the water supply system produced significantly less water as compared to the design capacity. Therefore, a proper management system is highly needed in order to ensure the water supply system operates at a steady level.

Identification of Shortages

In order to identify the shortages, a definition of shortages is needed. In this research, the word shortages may be divided into two categories, such as system shortage and operation shortage. Operation shortage affects daily water production. System shortage means the system capacity does not meet the demand. In order to identify system shortage, the system capacity is assessed based on per capita water provided by using Equation 1below.

$$\textit{Per capita water provided per day} = \frac{\textit{Total domestic water}}{\textit{Total population covered}} \tag{1}$$

The total domestic water accounts for 70% of the total water production, while the other 30% accounts for the water used for commercial and industrial, as well as water losses during the distribution due to leakage. The calculation of per capita water provided was based on the 2014 total water production of the WTPs and groundwater wells. The 2014 total water production was 13,034,566 m^3/year. The total domestic consumption was 9,124,196 m^3/year. This equals 25,355 m^3/day. The total population covered is 92,193. Therefore, the average per capita water provided per day is 0.274 m^3 or equals 274 liters. The daily per capita water provided for each month in the year 2014 is shown in Figure 18.

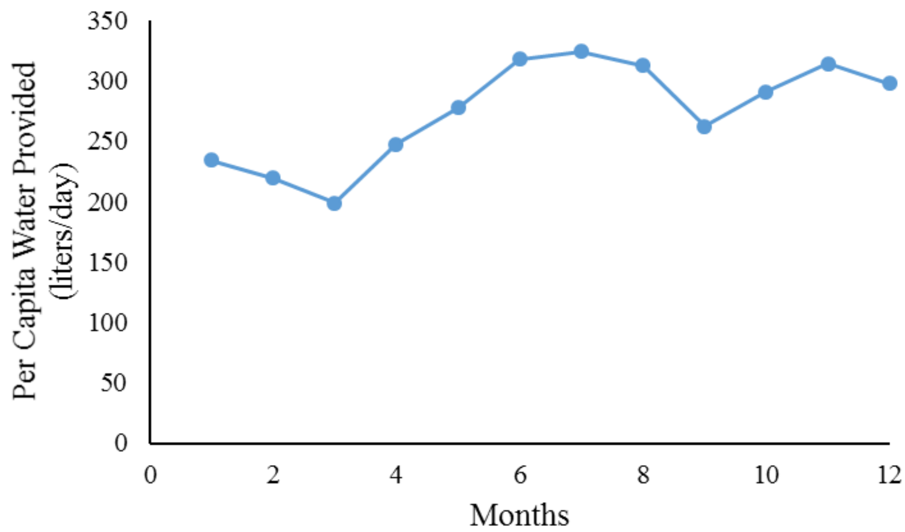


Figure 18. Average daily per capita water provided for each month in 2014 in Dili, East Timor. As shown on the graph, the daily per capita water provided per day for all of the months exceed 200 liters/day, except for the month of March.

Even though the daily per capita water provided is higher than the daily per capita water demand, the coverage of the current water supply system is only 41.77% of Dili's total urban population. This means the distribution of improved water supply is not equal to all the urban areas in Dili, East Timor. The main issue to be addressed is to increase the coverage of the water supply system. In a discussion with one of the National Water and Sanitation Directorate's staff, he explained one of the challenges they face is the difficulties in asking permission for land access from the population for the distribution pipes. Therefore, the government needs to educate the people regarding the importance of providing continuous water service and the advantage of such a practice. The government also needs to negotiate with the people and suggest a compensation for their land.

Future Needs

Water is indispensable; therefore, as the population grows and the country develops, more water will be needed. The government of East Timor has established a Strategic

Development Plan 2011-2030, which aims to provide continuous water supply in urban areas by the year 2030. In order to ensure this target can be achieved, water demand estimation of the future population has been determined to assess whether the current design capacity of the public water supply system will still be adequate to fulfil future water demand.

The forecasting method used to calculate the total future water demand is based on the population growth and per capita water demand (Wallingford, 2003). The future total water demand is determined by using Equation 2 (Idowu *et al*., 2012).

$$W = CP + S + U \tag{2}$$

W: total daily water demand

C: per capita water demand per day

P: total population of the area of interest

S: total sectorial daily water demand

U: unaccounted for water

According to the General Directorate of Statistics (2015), the annual population growth rate of Dili Municipality from the year 2010 to 2015 was 1.55%. The total Dili's urban areas population in 2010 was 220,697, therefore by calculating using the 1.55 growth rate, the total Dili's urban areas population in 2016 is 241,222. Per capita water demand per day is 200 liters, which is the standard of per capita water demand per day in India, the same lower middle income country as East Timor. The sectorial water demand is water use for commercial and industrial uses. This accounts for 30% of the population water demand. The unaccounted water is the water losses during the distribution due to pipes leakage. This accounts for 10% of the population water demand. Table 14 shows the projection of the annual water demand for the year 2016. The calculation of the future water demand was done only for the year 2016 because if in this year the total annual water demand exceeds the annual system design capacity, it means it will also exceed design capacity for the years to come due to the increase of population.

Table 14. Annual water demand in urban areas in the year 2016 in Dili, East Timor

Year	Population	Population water demand (m^3/year) CP	Sectorial water demand (m^3/year) S	Unaccounted water (m^3/year) U	Total water demand (m^3/year) W
2016	241,222	17,367,984	5,210,395.2	1,736,798.4	24,315,177.6

Note: The total water demand assumes 100% coverage of current water supply system.

Based on the annual water demand estimation in Table 14, the adequacy of the current water supply system's design capacity has been assessed. The total design capacity of the current water supply system including both the WTPs and wells is only 18,161,856 m^3/year. Therefore, even if the current water supply system operates at design capacity levels and covered all Dili's urban areas population, it still will not meet the water demand, which in 2016 is 133.88% of the system's design capacity.

The government's SDP target of supplying continuous water in urban areas by 2030 is not feasible by only utilizing the current water supply system. More work needs to be done, not only to increase the coverage to 100%, but also to establish a water supply system that can meet future demand (e.g., building new WTPs and/or groundwater wells). Besides infrastructure, system management needs to be addressed including operation and maintenance, man power, and finances. All of these aspects affect the performance of the needed water supply system.

RECOMMENDATIONS AND CONCLUSION

Recommendations and conclusion are as follows:

Recommendations

Improve the performance and operation of the current water supply system

In order to improve the performance and operation of the current water supply system, the following need to be addressed:

Secure water resources

This is needed for the WTPs because they depend on the quantity of the raw water intake from the rivers. In the dry season, the low river flow caused the low raw water quantity, which resulted in the decrease of water production. Reservoirs can be used to store the excess treated water in the wet season, and the water can then be distributed during the dry season.

Power supply

Power supply is a major issue affecting the consistent flow in the current water supply system. This can be addressed by providing a back-up generator for each WTP and well, therefore when there is electricity outages, the WTPs and wells can continue to operate. Another alternative is to use solar power or a hybrid approach as the source of power supply. This will be expensive in the initial stage, but as time goes on solar power will be more efficient and environmentally friendly as compared to a generator.

Capacity building for the staff

The capacity building for the staff is critical because right now the National Water and Sanitation Directorate lack knowledgeable and skillful staff. The staff are the people who are directly responsible for operation the water supply system. Capacity building should not only be limited to the operations of WTPs and wells, but also extended to other aspects including performance of regular maintenance, conducting asset management, and providing solutions to suddenly occurring issues. Periodic training is also needed, especially for the technical staff.

Increase total design capacity of the current water supply system

The current capacity of the public water supply system will not be adequate in meeting future demand of all of Dili's urban population. One of solution is to build new WTPs and/or wells, and also reservoirs for seasonal storage. In order to build new WTPs and/or wells, further research needs be conducted on water resources carrying capacity. Building new WTPs, wells, and reservoirs is not enough if not accompanied by a good system of management. Therefore, the government needs to train the staff and provide sufficient financial resources in order to support the expansion of the current public water supply system.

Land acquisition is another issue that needs to be considered in building new WTPs. Building new WTPs mean there will be new water supply zones, where the route of the pipes will go through a community's land. The government might need to incorporate the land acquisition process in developing the plan when they decide to build new WTPs.

Implement water fees

Due to a limited government budget allocation for the water and sanitation sector, the implementation of water fees is one of the alternatives to solve financial issues. Many studies conducted on assessing people's willingness to pay for the public water service in developing countries, show that people are willing to pay if the system provides a good and continuous service (Tarfasa & Brouwer, 2011). Money from the collection of water fees can be used for operation and maintenance expenses, including staff costs. For instance, the fees could be used to purchase chemicals for treatment process or to purchase a generator and its fuel as a power supply back-up to be used when the electricity is shut-down.

Establish a correct record keeping data

As shown by the 2013 groundwater well data, there were missing data for some wells, and for some wells that had the data, the variation of the data were high. Moreover, some wells had very high monthly water production as compared to the design capacity. Therefore, correct record keeping is highly needed because correct data will provide more accurate and reliable analysis. The analysis can be used as one of the tools for the decision makers, including particular government officials.

Conclusion

Water is indispensable and therefore, it is necessary for people to have access to improved water in order to fulfill their needs. In East Timor’s capital of Dili, only 41.77% of the population has access to the public water supply. The rest of the population is using their own private wells as the source of their water supply. As the population grows and the city develops, more water will be needed. Therefore, the increase of coverage needs to be accompanied by a proper water supply system and management.

REFERENCES

Australian National University. (n.d). *Timor-Leste*. Retrieved on March 20, 2016 from: http://asiapacific.anu.edu.au/mapsonline/base-maps/timor-leste-0

BBC Monitoring. (2013). *East Timor country profile – overview*. Retrieved on February 3, 2016 from: http://www.bbc.com/news/world-asia-pacific-14952878

Bogardi, J. J., Dudgeon, D., Lawford, R., Flinkerbusch, E., Meyn, A., Pahl-Wostl, C., *et al*. (2011). Water security for a planet under pressue: Interconnected challenges of a changing world call for sustainable solutions. *Current Opinion in Environmental Sustainability*, 4 (1), 35-43.

Brown, L. R. (2001). *Eco-Economy: Building an Economy for the Earth*. United States of America: W. W. Norton & Company.

Brown, L. R. (2008). *Plan B 3.0: Mobilizing to Save Civilization*. United States of America: W. W. Norton & Company.

Carr, D. E. (1966). *Death of the Sweet Waters*. New York, NY: W. W. Norton & Company. Inc.

Costin, G., & Powell, B. (2004). *Timor Leste Situation Analysis Report*. Brisbane, Australia: International Water Center.

Da Costa, H. (2003). *The evolutions of agricultural policies in East Timor*. Retrieved on February 3, 2016 from: http://www.timoragri.fhost.com.au/ta100/ta108.pdf

Dai Nippon Construction. (2007). *Improvement of water supply in Dili*. Retrieved on May 4, 2016 from: http://www.dnc.co.jp/en/overseas/timor/project-05.html

Da Silva, D., & Valentin, G. S. (2004). *Plant Production*. Retrieved on February 3, 2016 from: http://gov.east-timor.org/MAFF/English/plant_production.htm

David, M. L., & Masten, S. J. (2004). *Principles of Environmental Engineering and Science*. New York, NY: The McGraw-Hill Companies, Inc.

Droste, R. L. (1997). *Theory and Practice of Water and Wastewater Treatment*. United States of America: John Wiley & Sons, Inc.

Falkernmark, M., & Molden, D. (2008). Wake up to realities of river basin closure. *International Journal of Water Resource Development*, 24 (2), 201-215.

Food and Agriculture Organization (FAO). (2007). *Coping with water scarcity, challenge of the twenty-first century*. Retrieved on May 4, 2016 from: http://www.fao.org/nr/water/docs/escarcity.pdf

General Directorate of Statistics. (2010). *Highlights of the 2010 Census Main Results in Timor-Leste*. Dili, East Timor: Government Printing Office.

General Directorate of Statistics. (2015). *Population and Housing Census 2015, Preliminary Results*. Dili, East Timor: Government Printing Office.

Geoscience Australia. (n.d). *Alluvial Aquifers*. Retrieved on May 4, 2016 from: http://www.ga.gov.au/scientific-topics/water/groundwater/groundwater-in australia/alluvial-aquifers#heading-1

Government of East Timor. (2010). *Timor-Leste Strategic Development Plan 2011-2030*. Dili, East Timor: Government Printing Office.

Government of East Timor. (2015). *History*. Retrieved on April 11, 2016 from: http://timor-leste.gov.tl/?p=29&lang=en

Government of East Timor. (n.d). *Administrative Division*. Retrieved on April 15, 2016 from: http://timor-leste.gov.tl/?p=91&lang=en

Idowu, O.A., Awomeso, J. A., & Martins, O. (2012). An Evaluation of Demand for and Supply of Potable Water in an Urban Center of Abeokuta and Environs, Southwestern Nigeria. *Water Resource Management,* vol. 26, 2109-2121.

Jansen, P., Jones, J., Kilchenmann, P., Meilhaut, V., Schmid, D., & Weiersmueller, M. (1999). *Dili (East Timor) Re-establishing the water supply after the events of September 1999*. Retrieved onMay 4, 2016 from: http://www.thirstycitiesinwar.com/wp content/uploads/2013/03/dili_final.pdf

Japan International Cooperation Agency (JICA). (2002). *The study on urgent improvement project for water supply system in East Timor*. Retrieved on May 4, 2016 from: http://open_jicareport.jica.go.jp/pdf/11643210_01.pdf

Japan International Cooperation Agency (JICA). (2010). *Project for the Development of a Water Supply Service in Dili*. Retrieved on May 4, 2016 from: http://www2.jica.go.jp/en/evaluation/pdf/2011_0400800_4.pdf

Joint Monitoring Programme (JMP). (2010). *Joint Monitoring Programme's Report 2010*. Retrieved on February 24, 2016 from: http://www.who.int/water_sanitation_health/monitoring/fast_facts/en/

Joint Monitoring Programme (JMP). (2011). *Progress on Sanitation and Drinking-Water, 2010 Update*. Geneva, Switzerland: World Health Organization (WHO) Press.

Joint Monitoring Programme (JMP). (2015a). *Improved and unimproved water sources and sanitation facilities*. Retrieved on February 3, 2016 from: http://www.wssinfo.org/definitions-methods/watsan-categories/

Joint Monitoring Programme (JMP). (2015b). *Estimates on the use of water sources and sanitation facilities, Timor-Leste*. Retrieved on February 3, 2016 from: http://www.wssinfo.org/documents/?tx_displaycontroller%5Bregion%5D=&tx_displaycontroller%5Bsearch_word%5D=timor-leste&tx_displaycontroller%5Btype%5D=country_files

Keenan, C. (2008). *A Precious Resource: Investing in the Fate of Fresh Water*. Retrieved on May 4, 2016 from: https://www.highbeam.com/doc/1G1-175549044.html

Klingel, P., & Nestmann, F. (2013). From intermittent to continuous water distribution: a proposed conceptual approach and a case study of Béni Abbès (Algeria). *Urban Water Journal*, 11 (3), 240-251.

Michael, H. (2006). *Drinking-Water Quality Assessment and Treatment in East Timor, Case Study: Tangkae*. 2006. Retrieved on March 20, 2016 from: http://www.uwa.edu.au/__data/assets/pdf_file/0004/1637464/Michael_2007.pdf

Ministry of Agriculture and Fisheries. (2004). *Climate and Hydrology*. Retrieved on February 3, 2016 from: http://gov.east-timor.org/MAFF/English/climate_and_hydrology.htm

National Directorate of Local Administration. (2014). *Mapas dos sucos de Dili*. Retrieved on March 31, 2016 from: https://descentralizasaun.wordpress.com/distritos-2/dili/

National Geographic. (n.d). *Timor-Leste Map*. Retrieved on February 3, 2016 from: http://travel.nationalgeographic.com/travel/countries/timor-leste-guide/

Pacific Climate Change Science Program Partners. (2011). *Current and future climate of Timor-Leste*. Retrieved on February 3, 2016 from: http://www.pacificdisaster.net/pdnadmin/data/original/TL_PCCSP_2011_future_climate.pdf

Postel, S.L., Daily, G. C., & Ehrlich, P. R. (1996). Human appropriation of renewable fresh water. *Science*, 271 (5250), 785-788.

Renwick, D. A. V. (2013). *The Effects of an Intermittent Piped Water Network, and Storage Practice on Household Water Quality in Tamale, Ghana*. Retrieved on May 4, 2016 from:

http://web.mit.edu/watsan/Docs/Student%20Theses/Ghana/2013/Thesis_D_Vacs_Renwick_FINAL_5-31-13.pdf

Smith, A. H., Lingas, E. O., & Rahman M. (2000). *Contamination of drinking-water by arsenic in Bangladesh: a public health emergency*. Retrieved on March 17, 2016 from: http://www.who.int/bulletin/archives/78(9)1093.pdf

Solomon, Steven. (2010). *Water: The Epic Struggle for Wealth, Power, and Civilization*. United States of America: HarperCollins.

Tarfasa, Solomon & Brouwer, Roy. (2011). Estimation of the Public Benefits of Urban Water Supply Improvements in Ethiopia: A Choice Experiment. *Applied Economics*, 45 (9), 1099-1108.

United Nations Department of Public Information. (2002). *East Timor – UNTAET Background*. Retrieved on February 3, 2016 from: http://www.un.org/en/peacekeeping/missions/past/etimor/UntaetB.htm

United Nations Development Programme (UNDP). (2005). *Environment and Natural Resources Management*. Retrieved on February 3, 2016 from: http://undp.east-timor.org/undp/pdf_files/FACT_Sheets/english/ENVIRONMENT.pdf

United Nations Development Programme (UNDP). (2009a). *Capacity Development: A UNDP Primer*. Retrieved on May 4, 2016 from: http://unpcdc.org/media/129559/cdg_primerreport_web%5B1%5D.pdf

United Nations Development Programme (UNDP). (2009b*). Overcoming barriers: Human mobility and development*. New York, NY: Palgrave Macmillan.

United Nations Development Programme (UNDP). (2012). *About Timor Leste*. Retrieved on March 31, 2016 from: http://www.tl.undp.org/content/timor_leste/en/home/countryinfo.html

United Nations Development Programme (UNDP). (2015). *Human Development Index (HDI)*. Retrieved on February 3, 2016 from: http://hdr.undp.org/en/content/human-development-index-hdi

United Nations Fund for Population Activities (UNFPA). (2010). *Timor-Leste, Democratic republic of*. Retrieved on February 3, 2016 from: http://countryoffice.unfpa.org/timor-leste/2009/11/02/1482/timor-leste_democratic_republic_of/

United Nations International Children's Emergency Fund (UNICEF). (2013). *At a Glance: Timor Leste*. Retrieved on February 3, 2016 from: http://www.unicef.org/infobycountry/Timorleste_statistics.html

Wallingford, HR. (2003). *Handbook for the assessment of catchment water demand and use*. Retrieved on May 4, 2016 from: http://www.samsamwater.com/library/handbook_catchment_water.pdf

Weatherbee, D. E. (1966). Portuguese Timor: An Indonesia Dilemma. *Asian Survey*, 6 (2), 683-695.

World Bank Group. (2009). *Timor-Leste: Country Environmental Analysis*. Retrieved on February 3, 2016 from: http://siteresources.worldbank.org/INTRANETENVIRONMENT/3635842-1175696087492/22247462/TLCEAfinal4July09.pdf

World Bank Group. (2012). *Average Monthly Temperature and Rainfall for Timor-Leste from 1990-2012*. Retrieved on April 10, 2016 from: http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisRegion=Australia&ThisCCode=TLS

World Bank Group. (2015). *Timor-Leste Data*. Retrieved on February 3, 2016 from: http://data.worldbank.org/country/timor-leste

World Health Organization (WHO). (2011). Guidelines for Drinking-water Quality. Fourth edition. Retrieved on May 4, 2016 from: http://www.unicef.org/cholera/Chapter_4_prevention/01_WHO_Guidelines_for_drinkin_water_quality.pdf

World Health Organization (WHO). (2014). *Water Safety in Distribution System*. Geneva: World Health Organization.

Xin, K., Li, F., Tao, T., Xiang, N., & Yin, Z. (2014). Water losses investigation and evaluation in water distributiom system – the case of SA city in China. *Urban Water Journal*, 12 (5), 430-439.

Yadav, S. M., Singh, N. P., Shah, K. A., & Gamit, J. H. (2014). Performance Evaluation of Water Supply Services in Developing countries: A Case Study of Ahmedabad City. *Korean Society of Civil Engineers Journal*, 18 (7), 1984-1990.

Yance, S. (2004). *Assessment of Water Availability and Water Demand in Timor-Leste River Basin Level* (unpublished document). Retrieved on February 3, 2016 from: http://www.timoragri.fhost.com.au/ta400/ta409%20Water%20Resources%20Report%20Draft_August04.pdf

Ysusi, M. A. (2000). System Design: An Overview. In Mays, L. W, *Water Distribution System Handbook* (3.1). New York. NY: The McGraw-Hill Companies, Inc.

APPENDIX A. WELL DATA FOR 2013 IN DILI, EAST TIMOR

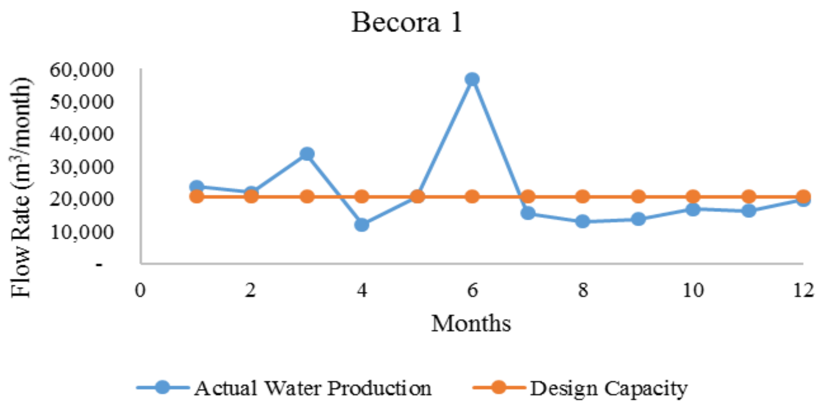
	Jan. (m^3)	Feb. (m^3)	Mar. (m^3)	Apr. (m^3)	May (m^3)	Jun. (m^3)	Jul. (m^3)	Aug. (m^3)	Sep. (m^3)	Oct. (m^3)	Nov. (m^3)	Dec. (m^3)	**Monthly Design Capacity (m^3)**
Becora 1	24,869	22,968	23,862	25,869	10,602	22,968	23,862	536,238	22,968	23,862	22,860	10,602	**20,736**
Becora 2	25,674	25,967	23,165	25,674	33,685	25,967	23,165	2,325	25,967	23,165	25,674	34,755	**90,720**
Comoro A	9,674	9,689	1,0620	8,696	8,417	8,452	8,512	8,587	8,682	8,572	8,822	9,172	**90,720**
Comoro B1	41,976	38,851	41,272	41,976	23,194	38,851	41,272	664,330	38,851	41,272	41,976	23,194	**132,192**
Comoro C	4,050	3,312	4,232	4,050	4,039	3,312	4,232	133,641	3,312	4,232	4,050	4,039	**46,656**
Comoro D	5,523	4,636	5,206	5,523	6,991	4,636	5,206	221,650	4,636	5,206	5,523	6,991	**57,024**
Comoro E	30,136	32,046	28,633	30,136	29,681	32,046	28,633	879,501	32,046	28,633	30,136	29,681	**67,392**
Bidau 2	32,417	42,926	56,262	33,479	51,957	42,926	56,262	670,280	42,926	56,262	33,479	51,598	**67,392**
Bidau 3	15,261	16,016	15,970	15,621	15,295	16,016	15,970	501,549	16,016	15,970	15,621	15,952	**20,736**
Bidau 4	4,677	4,983	4,925	4,778	3,112	4,983	4,925	2,814	4,978	4,925	4,677	3,221	**12,960**
Kuluhun A	3963	3924	4716	3963	9189	3924	4716	80352	3924	4716	3963	9189	**93,312**
Kuluhun B	73,817	71,931	68,524	73,817	72,116	72,958	68,524	2,235,906	72,958	68,524	73,817	72,116	**77,760**
Manleuana	15,375	14,528	14,879	15,375	14,956	14,528	14,879	14,563	14,528	14,879	15,375	14,956	**57,024**
Total Monthly	287,412	291,777	302,266	288,957	283,234	291,567	300,158	6,951,736	291,791	300,218	285,973	285,466	**834,624**

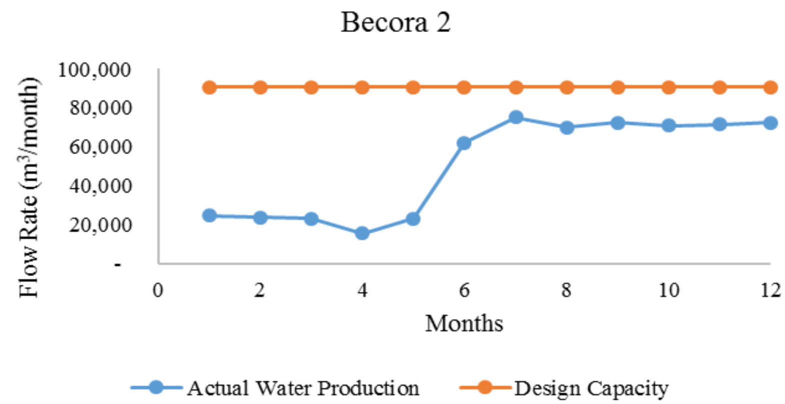
APPENDIX B. WELL DATA FOR 2014 IN DILI, EAST TIMOR

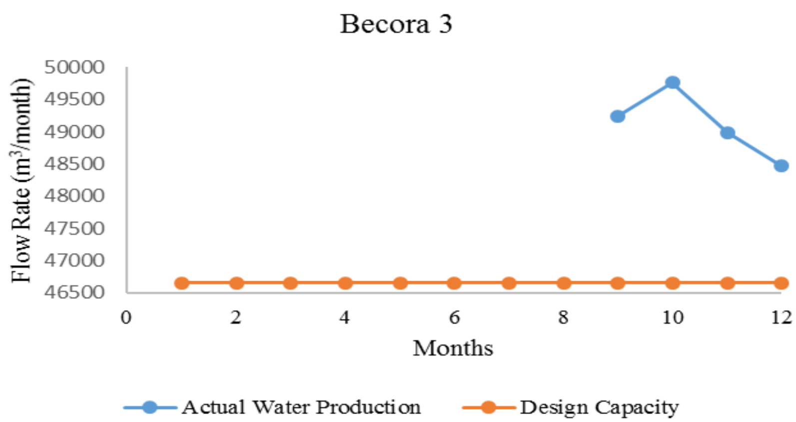
	Jan. (m^3)	Feb. (m^3)	Mar. (m^3)	Apr. (m^3)	May (m^3)	Jun. (m^3)	Jul. (m^3)	Aug. (m^3)	Sep. (m^3)	Oct. (m^3)	Nov. (m^3)	Dec. (m^3)	**Monthly Design Capacity (m^3)**
Becora 1	23,869	21,968	33,862	12,096	20,736	57,024	15,552	12,960	13,737	16,848	16,329	19,699	**20,736**
Becora 2	24,674	23,967	23,165	15,552	23,328	62,208	75,168	69,984	72,576	71,020	71,539	72,316	**90,720**
Becora 3									49,248	49,766	48,988	48,470	**46,656**
Comoro A	9,674	9,689	10,620	65,664	80,352	69,984	69,984	72,576	69,984	73,353	72,057	70,502	**90,720**
Comoro B1	41,976	38,851	41272	27,648	64,800	88,128	85,536	90,720	88,128	82,425	69,465	69,206	**132,192**
Comoro B2	14,175	13,689	13608	13,851	13,932	14,094	13,770	13,851	13,527	13,284	13,446	12,985	**38,880**
Comoro C	4,050	3,312	4232	31,104	31,104	44,064	44,064	38,880	44,323	44,582	45,360	43,545	**46,656**
Comoro D	5,523	4,636	5206	48,384	48,384	80,352	72,576	67,392	58,320	72,835	72,835	72,057	**57,024**
Comoro E	30,136	32,046	28633	31,104	46,656	49,248	49,248	44,064	33,955	34,992	34,473	33,736	**67,392**
Marconi	46,656	44,582	46396	44,064	44,064	54,432	46,656	41,472	44,323	43,804	41,990	43,804	**57,024**
Bairo Pite	49,248	48,470	47692	49,766	41,472	44,064	49,248	44,064	45,360	43,286	43,545	44,323	**57,024**
Mascarinhas	41,472	40,694	39657	40,435	54,432	85,536	82,944	85,536	86,054	85,795	83,721	78,278	**38,880**
Bidau 2	31,417	42,926	56262	32,832	49,248	49,248	44,064	44,064	45,619	44,582	45,619	44,841	**67,392**
Bidau 3	15,261	16,016	15970	20,736	20,736	20,736	46,656	20,736	21,254	20,476	19,699	20,995	**20,736**
Bidau 4	4,677	4,983	4925	4,320	7,257	5,184	5,961	5,184	4,924	4,406	4,665	5,961	**12,960**
Kuluhun A	67,132	3,924	4,716	58,968	61,776	72,576	77,760	72,576	73,612	72,057	66,873	68,428	**93,312**

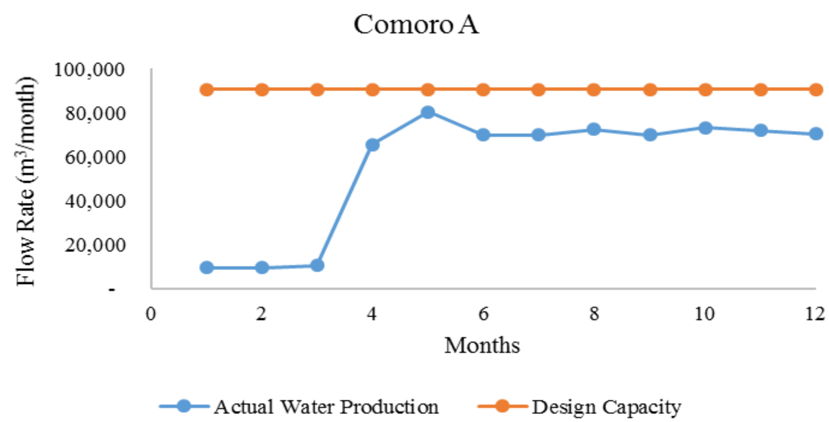
	Jan. (m^3)	Feb. (m^3)	Mar. (m^3)	Apr. (m^3)	May (m^3)	Jun. (m^3)	Jul. (m^3)	Aug. (m^3)	Sep. (m^3)	Oct. (m^3)	Nov. (m^3)	Dec. (m^3)	**Monthly Design Capacity (m^3)**
Kuluhun B	73,817	71,931	68,524	60,480	72,576	77,760	72,576	75,168	75,945	74,908	71,798	77,760	**77,760**
Manleuana	14,375	15,528	15,879	20,736	18,144	46,656	41,472	82,944	44,841	78,537	73,353	76,464	**57,024**
Total Monthly	498,132	437,212	460,619	577,740	698,997	921,294	893,235	882,171	885,730	926,956	895,755	903,370	**1,073,088**

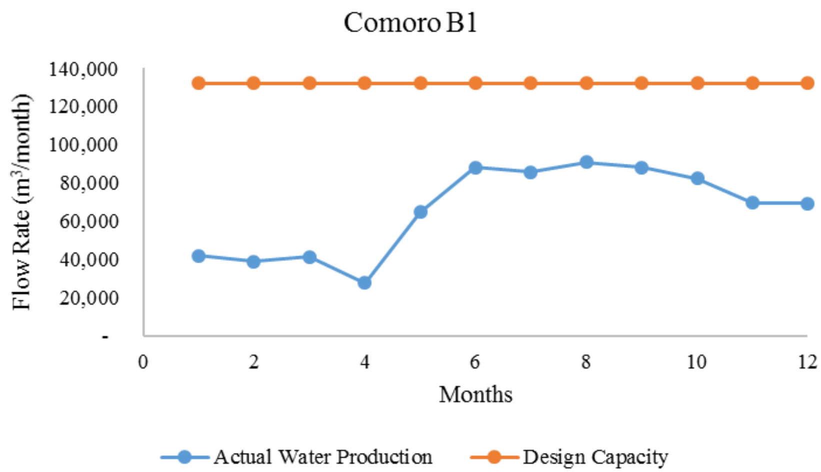
APPENDIX C. MONTHLY WATER PRODUCTION OF EACH WELL IN 2014 IN DILI, EAST TIMOR

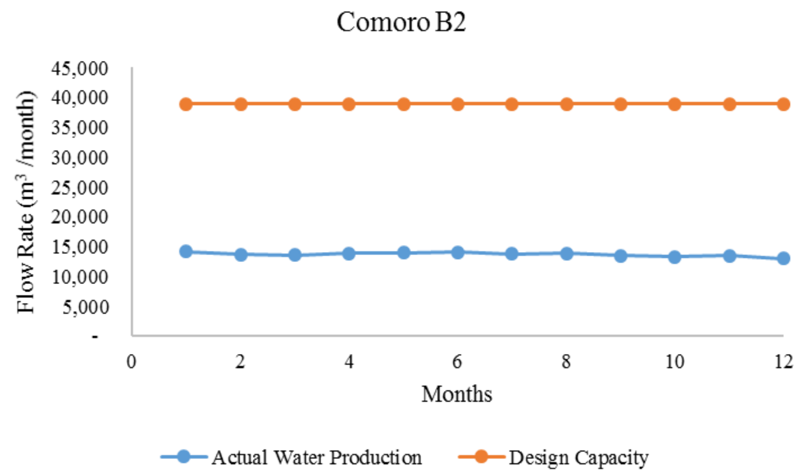

Becora 1
Flow Rate (m3/month)
60,000
50,000
40,000
30,000
20,000
10,000
-
0
2
4
6
8
10
12
Months
Actual Water Production
Design Capacity

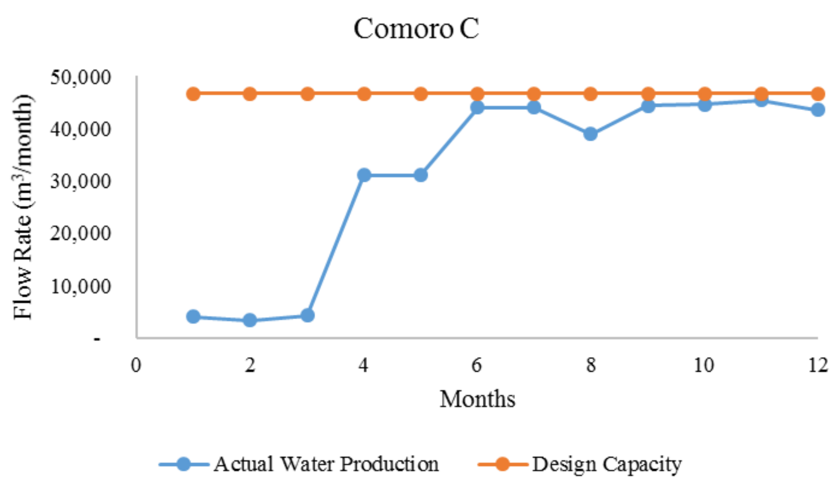

Becora 2
Flow Rate (m3/month)
100,000
80,000
60,000
40,000
20,000
-
0
2
4
6
8
10
12
Months
Actual Water Production
Design Capacity

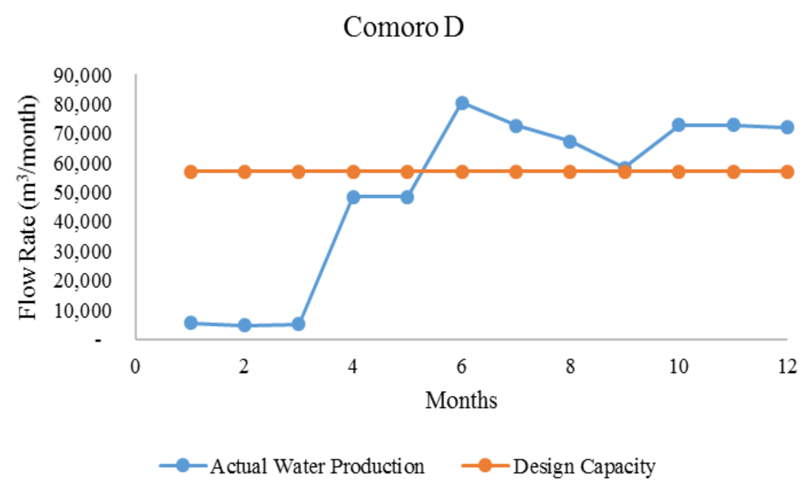

Becora 3
Flow Rate (m3/month)
50000
49500
49000
48500
48000
47500
47000
46500
0
2
4
6
8
10
12
Months
Actual Water Production
Design Capacity

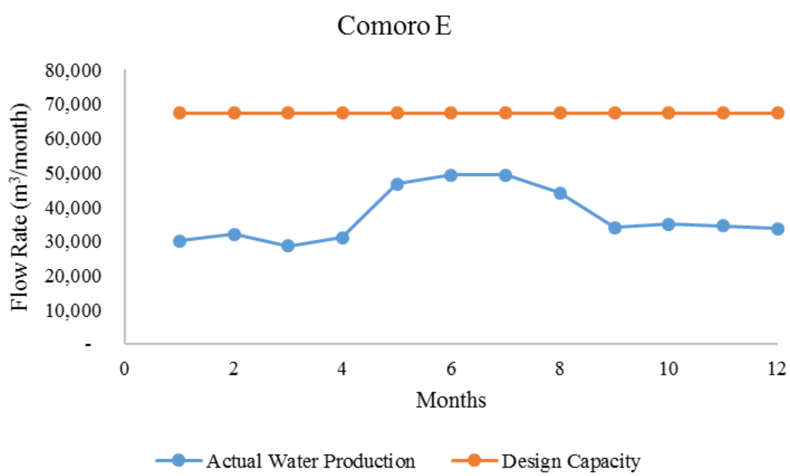

Comoro A
Flow Rate (m3/month)
100,000
80,000
60,000
40,000
20,000
-
0
2
4
6
8
10
12
Months
Actual Water Production
Design Capacity

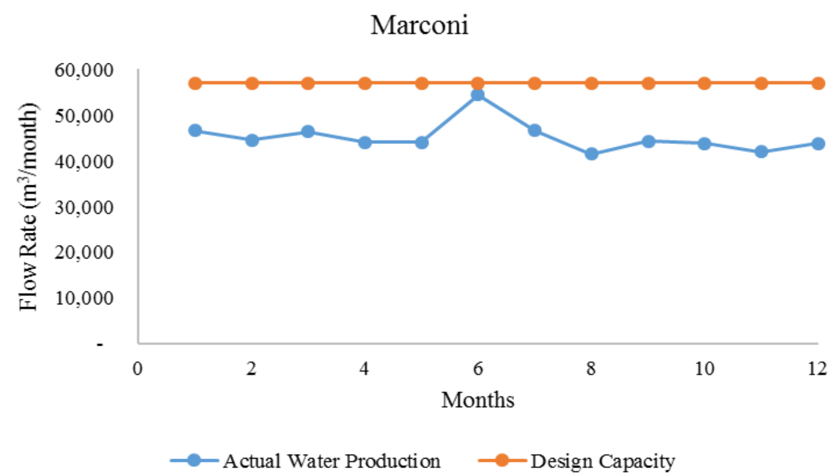

Comoro B1
Flow Rate (m^3/month)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
-
0 2 4 6 8 10 12
Months
Actual Water Production
Design Capacity

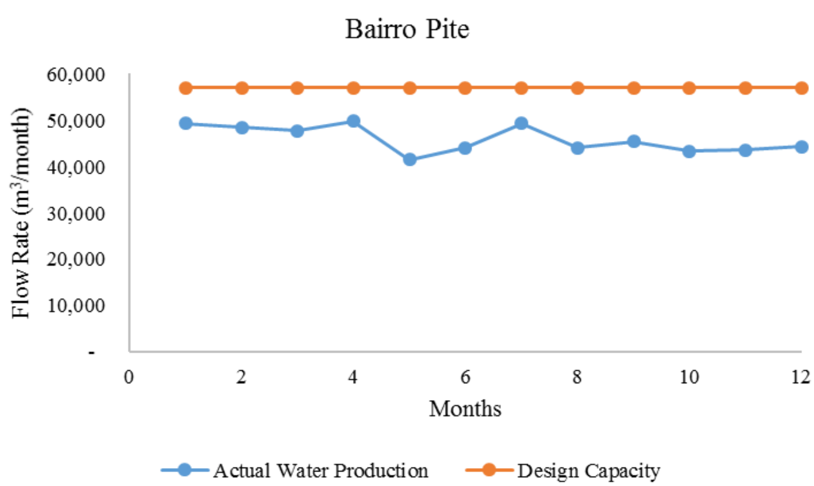

Comoro B2
Flow Rate (m^3 /month)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
0 2 4 6 8 10 12
Months
Actual Water Production
Design Capacity

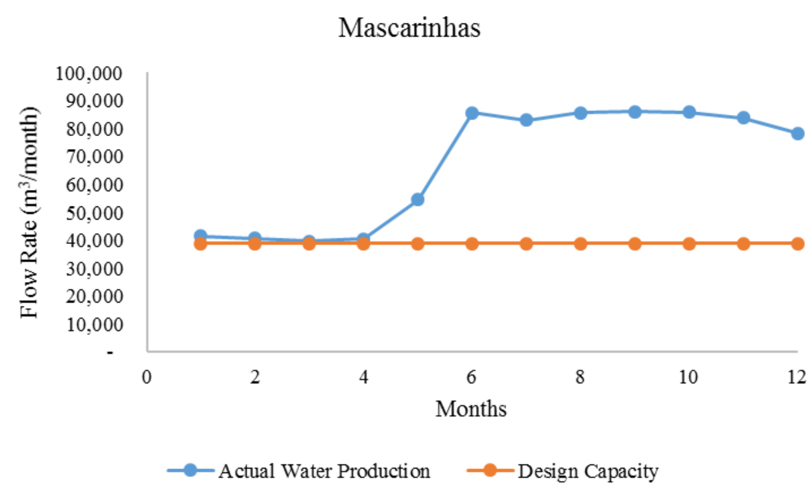

Comoro C
Flow Rate (m^3/month)
50,000
40,000
30,000
20,000
10,000
-
0 2 4 6 8 10 12
Months
Actual Water Production
Design Capacity

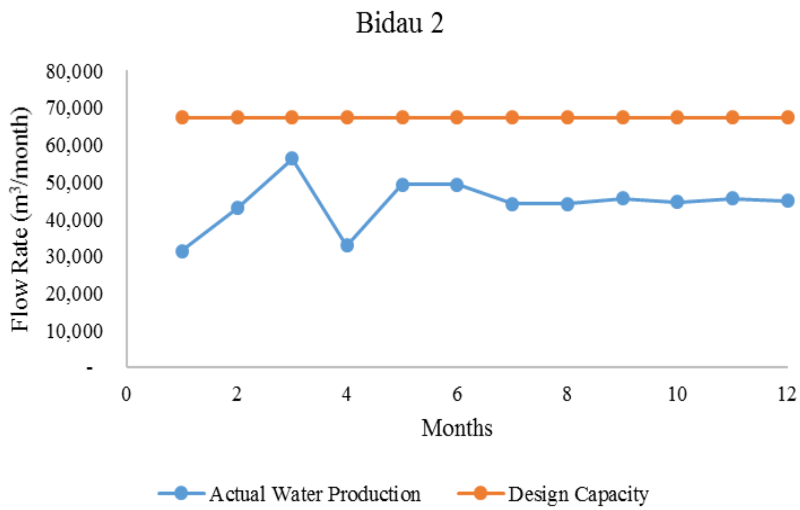

Comoro D
Flow Rate (m^3/month)
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
0 2 4 6 8 10 12
Months
Actual Water Production
Design Capacity

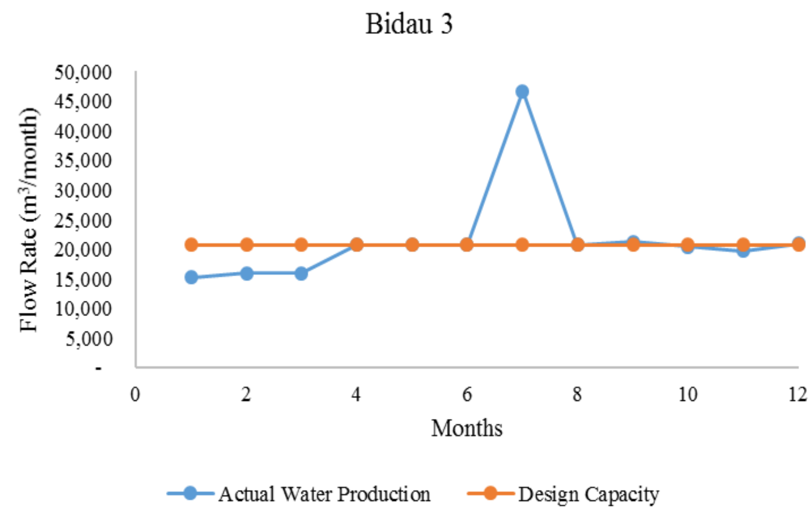

Comoro E
Flow Rate (m3/month)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
0
2
4
6
8
10
12
Months
Actual Water Production
Design Capacity

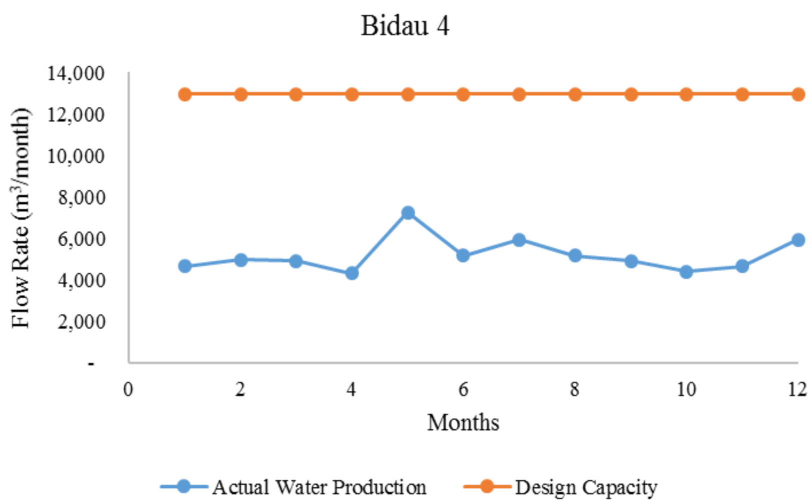

Marconi
Flow Rate (m3/month)
60,000
50,000
40,000
30,000
20,000
10,000
-
0
2
4
6
8
10
12
Months
Actual Water Production
Design Capacity

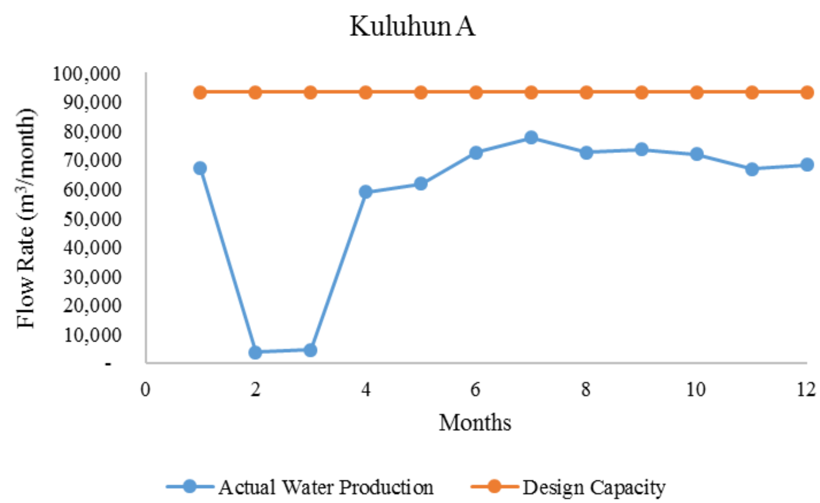

Bairro Pite
Flow Rate (m3/month)
60,000
50,000
40,000
30,000
20,000
10,000
-
0
2
4
6
8
10
12
Months
Actual Water Production
Design Capacity

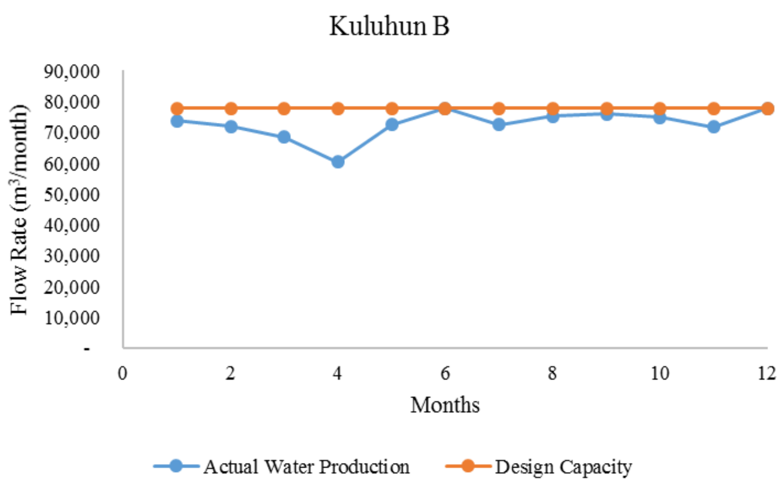

Mascarinhas
Flow Rate (m3/month)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
0
2
4
6
8
10
12
Months
Actual Water Production
Design Capacity

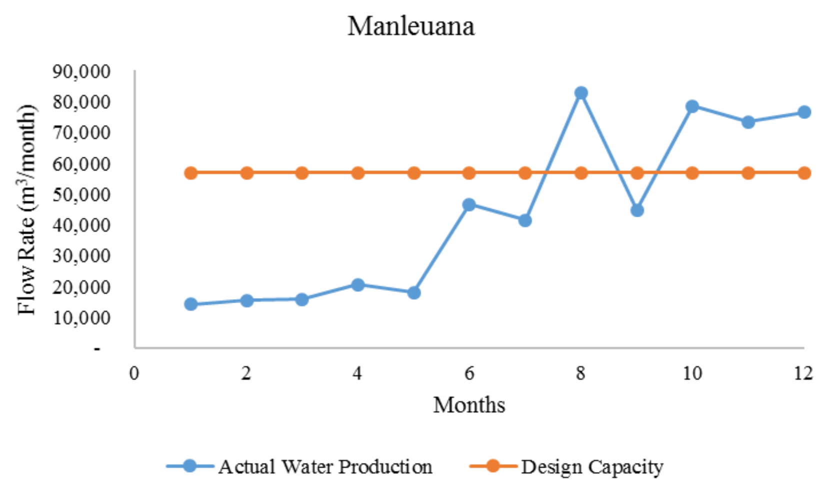

Bidau 2
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
0
2
4
6
8
10
12
Flow Rate (m^3/month)
Months
Actual Water Production
Design Capacity


Bidau 3
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
0
2
4
6
8
10
12
Flow Rate (m^3/month)
Months
Actual Water Production
Design Capacity


Bidau 4
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
0
2
4
6
8
10
12
Flow Rate (m^3/month)
Months
Actual Water Production
Design Capacity


Kuluhun A
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
0
2
4
6
8
10
12
Flow Rate (m^3/month)
Months
Actual Water Production
Design Capacity


Kuluhun B
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
Flow Rate (m³/month)
0
2
4
6
8
10
12
Months
Actual Water Production
Design Capacity


Manleuana
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
-
Flow Rate (m³/month)
0
2
4
6
8
10
12
Months
Actual Water Production
Design Capacity