A Feasibility Study on Water Conservation Measures in Kota Lama Site, Semarang, Indonesia

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SUMMARY

Worldwide population growth and economic development has increased freshwater demand, and at the same time has threatened its availability. Poor management of freshwater resources has caused freshwater demand to exceed its supply, which is known as freshwater scarcity in terms of quantity. Especially in developing countries, a lack of awareness has led to a decrease of freshwater quality – i.e., an increase of freshwater scarcity in terms of quality. Nowadays, freshwater scarcity is not only experienced by arid and semi-arid regions but also by tropical wet regions such as the region where Kota Lama Site, Semarang, is located. This small city called Kota Lama Site, has been suffering from freshwater scarcity for many years, yet this scarcity has not been acknowledged by local inhabitants and the city government of Semarang. The plan of Semarang's government to include Kota Lama Site on the list of UNESCO world heritage, made the city government initiate the Kota Lama Site revitalization plan in 2016. Since then, the city has attracted millions of visitors annually, and the number of commercial businesses has considerably increased (23 %). The economic growth of Kota Lama Site could lead to a more severe freshwater scarcity if Semarang's government remains idle in recognizing this issue. Throughout the world, especially in developed countries, the water conservation concept has been proven to reduce freshwater scarcity. This concept is primarily intended to preserve freshwater quality, to reduce freshwater demand, and to conserve freshwater for efficient uses.

Studies regarding water conservation measures for Kota Lama Site is lacking, although freshwater scarcity has become a pressing issue for this city. This study represents the first attempt in searching for the most feasible water conservation measures for Kota Lama Site by: analyzing characteristics of its freshwater scarcity, investigating potential water conservation measures based on its implementation challenges and freshwater scarcity characteristics of Kota Lama Site, and performing a scoring for selected potential water conservation measures to determine which measures are most feasible. The selection of feasibility criteria is conducted prior to the scoring. These criteria are determined in such a way that it represents vital elements that need to be considered by four different categories of freshwater users in Kota Lama Site, before implementing a water conservation measure. Because, although the city government of Semarang is responsible for the implementation and management of water conservation measures, the focus potentially shifts towards collective action and individual responsibility.

This study reveals that freshwater scarcity characteristics of Kota Lama Site relate to: (1) the lack of freshwater supply (-23.117.367,95 L/year) from the regional drinking water agency which is known to be of poor quality; (2) a supply deficit of groundwater (-255.104.525,09 L/year) in the confined aquifer; (3) the unusable supply excess of groundwater (188.172.656,36 L/year) in the unconfined aquifer; (4) unutilized annual high rainfall (above 2.000 mm/year); (5) ill-defined regulations; (6) weak laws and regulatory enforcement; and (7) unawareness of freshwater users regarding efficient freshwater use. Selected potential water conservation measures cover the need of Kota Lama Site's for: (1) strong laws and enforcement of regulations; (2) programs to raise the awareness of local inhabitants; (3) actions to strengthen institutional and community capacity; (4) funding and its allocation for water conservation; (5) an improvement of freshwater quality; and (6) a decrement of wasted freshwater. Finally, this study recommends that roof-water harvesting and educational incentives are the two most feasible water conservation measures for Kota Lama Site.

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List of Abbreviations

AMbO	Community Association Mbangun Oudestadt
AECOM	American Multinational Engineering Firm
APBD	Regional Revenues and Expenditures Budget
AWWA	American Water Works Association
BAPPEDA	Regional Planning and Development Agency
BBWS	River Basin Center Agency
BMKG	Meteorology, Climatology, and Geophysical Agency
BPK2L	Management Agency of Kota Lama Region
BPP Sima	Community of Sima Banger Polder Management Agency
BPS	Statistics Indonesia Agency
DWWT	Decentralized Wastewater Treatment System
DINKES	Public Health Agency
DISPERKIM	Housing and Settlement Agency
DISTARU	Spatial Planning Agency
DLH	Environmental Services Agency
DPC Projo	Branch Leadership Council Pro Jokowi
DPU	Public Works and Services Agency
ESDM	Ministry of Energy and Mineral Resources
ESP-PPC	Engineering Services Project - Project Preparation Consultant
FGD	Focus Group Discussion
IDR	Indonesian Rupiah
IUWASH	Indonesia Urban Water, Sanitation and Hygiene
Kemenkes	Ministry of Health
Kemenpu	Ministry of National Development Plan
KSM	People-based Community
KLS	Kota Lama Site
LIPI	Indonesia Institute of Sciences
MSL	Mean Sea Level
NRW	Non-Revenue Water
PDAM	Regional Drinking Water Agency
Perda	Regional Regulation
Permenkes	Ministry of Health Regulation
Permenpu	Ministry of National Development Plan Regulation
PP	Government Regulation
RISPAM	Master Plan of Drinking Water Provision
RPJMD	Regional Medium-Term Development Plan
RPJMN	National Medium-Term Development Plan
RTBL	Building and Environmental Planning
RTH	Open Green Spaces
Sarpras PKP	Housing and Settlement Infrastructure
SLHD	Regional Environmental Status
UN	United Nation
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIKA	Soegijapranata Catholic University
USAID	United States Agency for International Development
UU	Government Law
WHO	World Health Organization
WTP	Water Treatment Plant

Chapter 1: Introduction

1.1 Freshwater Scarcity in A Global Context

Freshwater is only a small portion (2,5 %) of all water on the earth. It is defined as non-saline surface water (lakes, rivers, and ponds) and groundwater which is useful for human needs (Patel & Shah, 2008). It comprises accessible surface freshwater (0,26 %), fresh groundwater (29,9 %), and ice caps as well as glaciers (68,7 %) (Patel & Shah, 2008). Freshwater is renewable through a hydrological cycle, but the demand for water has been increasing globally during the last decades due to a high population growth, the increase of economic activities, and dietary shifts (Mekonnen & Hoekstra, 2016; Liu et al., 2017; Postel, 2000; Jackson et al., 2001). Furthermore, it is predicted that climate change will become a serious threat to freshwater resources (Gosling & Arnell, 2016; Herrera-Pantoja & Hiscock, 2015; Krol et al., 2011; Jackson et al., 2001).

The worldwide increased water demand has threatened freshwater availability (Gosling & Arnell, 2016; Wyman, 2013; Van Beek et al., 2011; Mutikanga et al., 2009). In general, freshwater scarcity is known as the imbalance between freshwater demand and availability (Pereira et al., 2009; Jackson et al., 2001; Postel, 2000). The concept of freshwater scarcity is viewed in terms of both quantity and quality. Quantity is associated with freshwater availability that is useable for economic and social demands. Quality is linked to the value of parameters such as pH, total dissolved solids, calcium, and chloride which must fit the quality standard of World Health Organization (WHO) (Abbas et al., 2017). Freshwater only has a marginal benefit for humans if its quality keeps degrading (Pereira et al., 2009). Furthermore, freshwater scarcity negatively affects human health and economic activities (World Economic Forum, 2015; Pannirselvam, 2019). Approximately, three billion people will live in countries characterized as ‘water limited’ by 2025. Moreover, the amount of renewable freshwater resources will reduce to one third per capita (Postel, 2000).

About 40-60 % of the world population lives within 60-100 km from a coastline (UN, 2017; Surjan et al., 2016; Barragán & De Andrés, 2015; Pereira et al., 2009). Consequently, pressure on freshwater availability in coastal areas increases (Eslamian & Eslamian, 2017). Groundwater over-extraction, polluted freshwater due to the accumulation of greywater and solid waste disposal along rivers, degradation of freshwater bodies (rivers and wells) due to tidal flooding, seawater intrusion in aquifers, and limited access to freshwater have led to freshwater scarcity in coastal cities of developing countries (Abedin et al., 2019; Boretti & Rosa, 2019; WHO, n. d.). Semarang is one of Indonesia’s coastal cities that experiences this kind of pressure on the freshwater availability (Marfai & King, 2008; Bank, 2016; Chief Resilience Officer Team of Semarang, 2016; USAID, 2015).

1.2 Freshwater Scarcity in Semarang

1.2.1 Freshwater Scarcity in Semarang

According to the Government Regulation (PP) Number 82/2001, freshwater in Indonesia is defined as the natural non-saline sources of water located at and below ground level, such as springs, groundwater, rivers, swamps, and lakes. It is categorized into four classes which have different quality standards: (1) Class I for drinking water and potable uses; (2) Class II for recreational water facilities; (3) Class III for freshwater fisheries; and (4) Class IV for plant watering or irrigation.

Kodoatie et al. (2010) state that freshwater scarcity in Indonesia must be viewed in terms of both quality and quantity. We speak of scarcity when the demand for freshwater is higher than its supply, or when the groundwater recharge is less than the decrease of groundwater level due to extraction (Kodoatie et al., 2010; Kuwayama et al., 2017). Average annual freshwater availability in Indonesia has decreased to 15.500 m^3 per person (UN, 2004). This amount is not evenly distributed throughout the country, and it will keep decreasing due to the increase of freshwater demand (quantity) as well as the contamination of freshwater resources (quality) (UN, 2004). The National Medium-Term Development Plan (RPJMN) 2020-2024 (2019) states that the total area of Java island that is facing freshwater scarcity will increase to 9,6 % by 2045. Land conversion (from water infiltration to paved areas), high freshwater demand (from domestic and non-domestic sectors), and the increase of evaporation rates are the main causes of freshwater scarcity (RPJMN, 2019; LIPI, 2019). By 2040, the entire coastal area adjacent to the Northern Java Sea, including Semarang, will have changed into urban areas and will have to deal with freshwater scarcity (LIPI, 2019).

In Semarang, freshwater is sourced from wells, rivers, and springs (BAPPEDA, 2018). The amount of freshwater used daily for non-domestic sectors such as worship facilities (mosques, churches, temples), commercial sectors (hotels, restaurants), and health facilities (hospitals) ranges from 53,57 m^3 to 1.400,83 m^3, and the average domestic freshwater demand is about 0,144 m^3/person/day (BAPPEDA, 2018). Deep aquifers and rivers are the main freshwater resources for the Regional Drinking Water Agency (PDAM) Tirta Moedal, yet a significant amount of freshwater that has been produced is lost through leakages and never reaches the customers (BAPPEDA, 2018). In 2017, the Non-Revenue Water (NRW) in Semarang was about 39 % or 64.886 m^3/day (BAPPEDA, 2018). In addition, the high decrease of groundwater level forced the Semarang's government to shut down the city's wells; only eight production wells are owned by the government, in 2016. These wells are still used by PDAM as a freshwater resource for the whole of Semarang (BAPPEDA, 2018).

1.2.2 Freshwater Scarcity in Kota Lama Site (KLS)

Kota Lama Site or KLS is located in the northern part of Semarang. KLS has the potential for being highly valuable in economic terms, as it has many 18th century heritage buildings (Lokita, 2011; Dewantara, 2017). In 2016, the city government started conserving the buildings through a program called 'Revitalization'. The program is part of the Local Government Medium Term Development Plans (RPJMD) 2016-2021 (Gewati, 2019a). About 200 Billion Indonesian Rupiah (IDR) is invested by the central government for the revitalization (Gewati, 2019a). Furthermore, Kota Lama is expected to be recognized as one of the United Nations Educational, Scientific and Cultural Organization (UNESCO) Heritages in 2020 (Lukito et al., 2019; UNESCO, n. d.).

Despite KLS' immense value, more pressure on freshwater availability in KLS is inevitable. The high number of visitors and commercial businesses have increased since the revitalization. The total amount of visitors reached four million people in 2016 (Lukito et al., 2019). This number is remarkably higher than the number of residents; about 7.329 people in total (calculated from Statistics Indonesia Agency (BPS) of North, East, and Central Semarang Subdistricts 2019). Commercial sectors, which need high amount of freshwater (e. g. restaurants, cafes, and hotels), have increased up to 23 % (Harani et al., 2017).

The degradation of freshwater resources in KLS due to human activities and natural events are interrelated. Over-extraction of groundwater for economic activities (e.g. industries, commercial sectors) depletes the groundwater level far below Mean Sea Level (MSL) and forces the seawater-freshwater interface (transition zone) in the subsurface to continuously travel inland (Pereira et al., 2019; Supriyadi, 2019). Domestic waste disposal into open freshwater bodies, poor wastewater treatment, and sediment run-off (carried by river flow) from higher elevation also contribute in reducing freshwater quality (BAPPEDA, 2013). As a result, groundwater from shallow wells is unusable without treatment, and freshwater quality of PDAM gradually degrades (BAPPEDA, 2018). Consequently, residents only use these sources for non-potable purposes. To meet their potable demand, they rely on non-refillable (brand) and refillable bottled water, gallons, and jerrycans (Chief Resilience Officer Team of Semarang, 2016). Thus, KLS is not only already facing freshwater scarcity, due to economic growth the situation will worsen if it is not counteracted with water conservation measures. Although the water conservation concept is stated explicitly in the regulation regarding freshwater resources, its implementation is not the government's priority (Kodoatie et al., 2010).

Despite the urgency to investigate water conservation measures, recent studies about KLS have been limited to reviving the beauty of its heritage buildings (Lokita, 2011; Harani et al., 2017; Suskiyatno & Krisprantono, 2018), and have not focused on water conservation.

1.2.3 Site Description

Based on the Regional Regulation (Perda) on Building and Environmental Planning (RTBL) Number 2/2020, KLS is located between three subdistricts: Central Semarang, North Semarang, and East Semarang. KLS consists of a core zone (area inside red line) and a buffer zone (areas inside orange line) (Figure 1). According to Perda Number 2/2020, the total area of KLS is about 0,72 km^2.

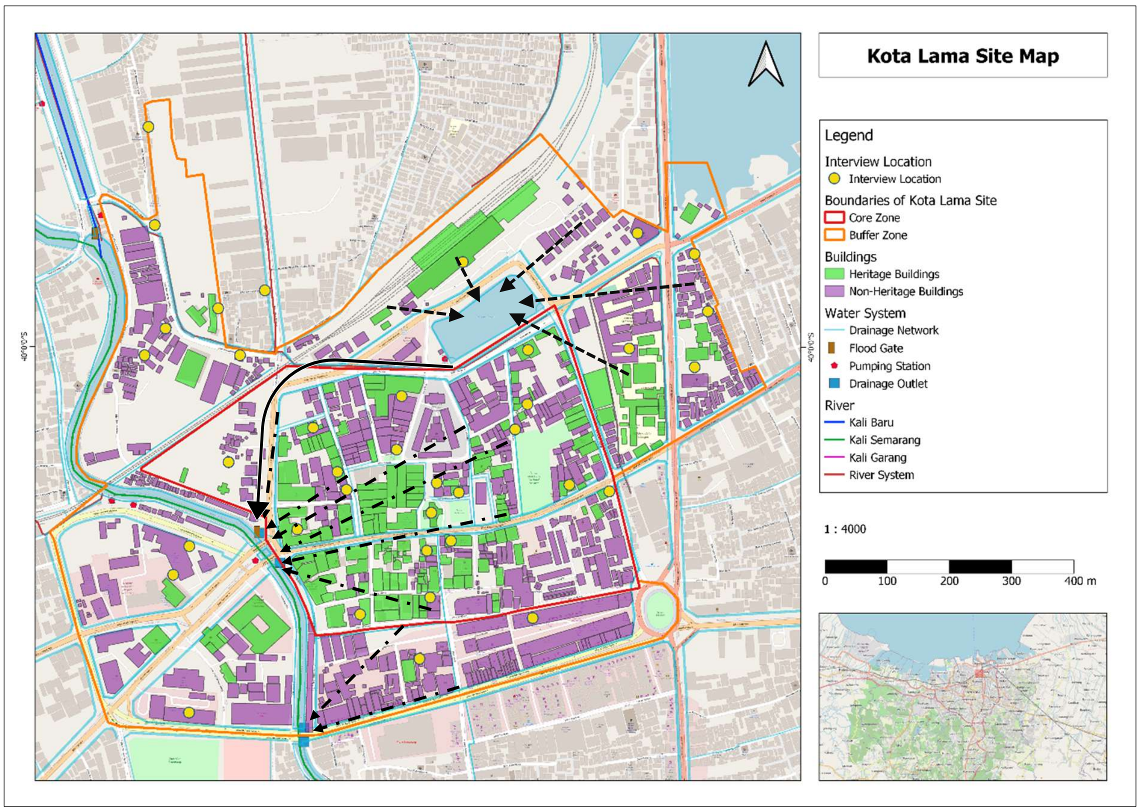

Figure 1. Map of KLS. Modified from RTBL (2020)

Kali Semarang is the main drainage in KLS (indicated as light blue meander in Figure 1) before water flows into the sea. Every drainage network in KLS is directed to Kali Semarang which has four drainage outlets (small blue square in Figure 1). The Tawang Retention pond, or Tawang pond in short (big light blue square at the northern part of KLS), is used to hold water which flows from the northern and eastern areas of the buffer zone. Then, water from the pond flows to Kali Semarang. Tawang pond has a drain with pumping capacity of 0,45 m^3/s (Perda Number 14/2011). Water from KLS is distinguished into three flows: (1) from drainage system to Kali Semarang (black dash-dot arrows); (2) from drainage system to the Tawang pond (black dash arrows), and (3) from the Tawang pond to Kali Semarang (curved black arrow).

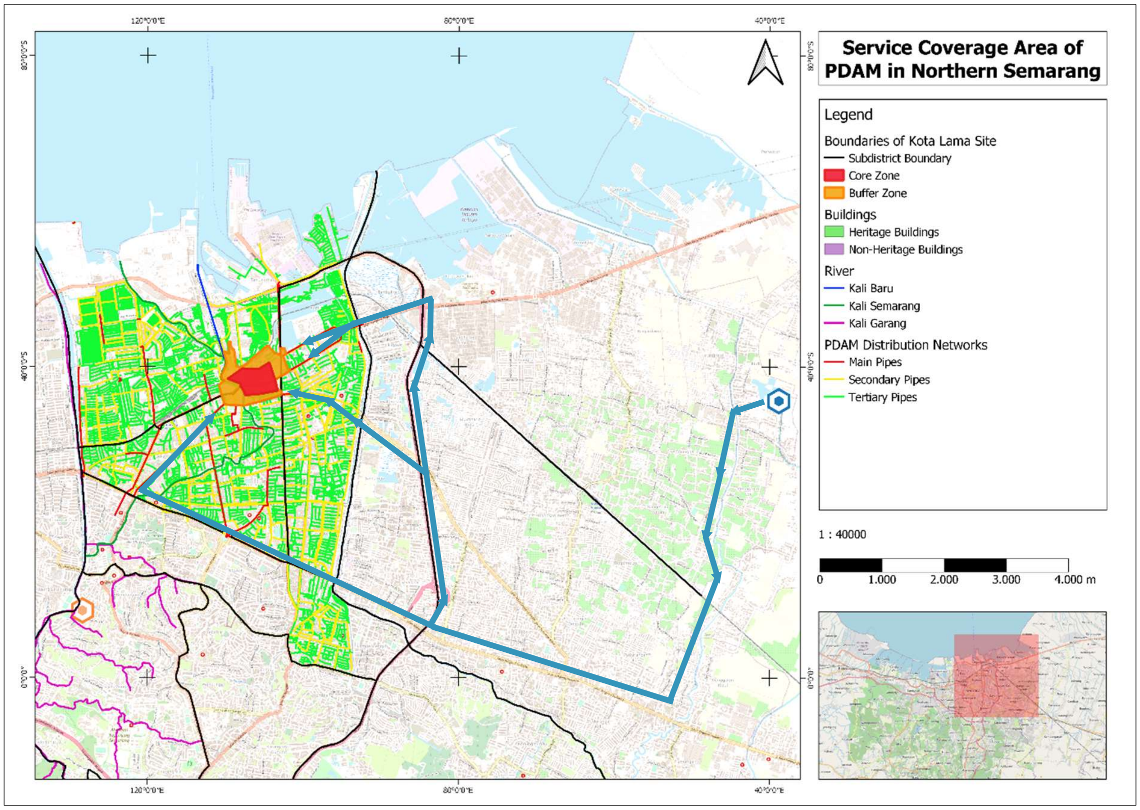

Figure 2. Freshwater sources from PDAM to KLS. Modified from Perda Number 2/2020, BAPPEDA (2018), and PDAM (2020).

Kaligarang river is the main water input for the Water Treatment Plant (WTP) Kaligarang owned by PDAM (light orange hexagon icon in Figure 2) to produce freshwater for the northern part of Semarang. However, WTP Kudu (blue hexagon icon in Figure 2) is the only freshwater source from PDAM for KLS[1]. Its distribution pipe route from WTP Kudu to KLS is indicated by blue arrows. In general, freshwater in KLS is used for three main purposes depending on the source of the freshwater[2]: (1) freshwater from PDAM is used for bathing and flushing toilets; (2) bottled[3] water is used for drinking; and (3) groundwater (wells) is used for washing.

1.3 Water Conservation

Freshwater scarcity can be counteracted by implementing water conservation measures. Armitage et al. (2014) find that water conservation in South Africa is aimed to achieve sustainable urban water use and is linked to urban water infrastructure. In Egypt, water conservation is associated with water demand reduction (Nassar et al., 2017). La France (2016) mentions that the term 'water conservation' is interchangeable with demand management, water efficiency, and wise use. Water conservation within the household is linked to using freshwater wisely for drinking, laundry, washing, watering garden and other daily activities. For the industry, it is related to efficient freshwater use when producing goods (Kodoatie et al., 2010). Thus, water conservation is defined as the efficient use of freshwater through reduction of freshwater demand, preservation, and protection of freshwater resources (Kodoatie et al., 2010; Saurí, 2013; Hornberger et al., 2015; Maggioni, 2015).

[1] (M. Firdaus, personal communication, June 10, 2020)
[2] Interview with freshwater users, 2020.
[3] Non-refillable (brand) and refillable bottled water.

Water conservation measures are viewed from the interactions between hydrological and technical aspects to individual behavior analyses in using freshwater (Maggioni, 2015; Adams et al., 2013). Some studies link water conservation measures with political aspects (Hornberger et al., 2015; Hess et al., 2017). Various measures to conserve water are provided to mitigate and adapt to freshwater scarcity (Pereira et al., 2009).

Table 1. Examples of water conservation measures (Pereira et al, 2009; Nassar et al., 2017; Hess et al., 2017).

Type	Measures
Technical	Metering system at households Rainwater harvesting Water efficient fitting / water fixtures Greywater treatment and reuse Leak detection and repairment
Non-technical	Water pricing policies Water use education program Investments on water conservation implementation for low economic areas Creating a framework in a regulation about water conservation Penalties for violators of water conservation regulation

Table 1 shows examples of water conservation measures. Metering systems in every household in urban areas can provide information about the amount of freshwater used by costumers (Pereira et al., 2009). A rainwater harvesting system is beneficial to conserve surface run-off and to reduce the demand for freshwater produced by a water company (Nassar et al., 2017; Patel & Shah, 2008; Pereira et al., 2009). Creating a water conservation framework which is translatable to regulation is useful to force freshwater users to minimize their demand. Penalties for violators of regulations can discourage freshwater users from using water-wasting appliances (Pereira et al., 2009; Hess et al., 2017). Providing educational programs in school and communities about water conservation is important because a successful water conservation measure will require total support from freshwater users (Pereira et al., 2009; Nassar et al., 2017; Hess et al., 2017).

1.4 Research Objectives and Research Questions

Freshwater resource availability in KLS must be protected and maintained to reduce freshwater scarcity due to the future economic development of the city. This research focuses on exploring feasible water conservation measures for KLS as strategies to reduce freshwater scarcity. On top of that, this research will provide recommendations for Semarang's city administration to overcome its freshwater scarcity. Thus, the following research questions need to be answered to accomplish these objectives.

"What are the most feasible water conservation measures for Kota Lama Site to overcome its freshwater scarcity?"

Sub-questions:

1. What are the characteristics of freshwater scarcity in Kota Lama Site viewed from the physical, socio-economic, and regulatory aspects?
2. What are the potential water conservation measures to reduce freshwater scarcity in Kota Lama Site?
3. What are the feasible technical and non-technical water conservation measures for Kota Lama Site to overcome present and future freshwater scarcity?

Chapter 2: Materials and Methods

2.1 Data Collection

An extensive literature study and interviews with stakeholders have been conducted. Platforms such as World Catalogue, Scopus, Google Scholar, and other search engines provided by Utrecht University were accessed. Literature regarding regulatory measures and reports from PDAM, BAPPEDA, ESDM, DPU and other related city administration were gathered via official websites, or directly copied from its offices. Relevant data on socioeconomics, water-related and hydrological issues are regional (on city or subdistrict level) because data about KLS are limitedly available. To obtain additional facts for Subchapter 2.1.1 and 2.1.2, forty-four interviews were conducted (Table 2) to gather more information on freshwater scarcity and water conservation measures in KLS.

Unstructured interviews were held with key persons. Key persons were given opportunity to explain any information they know regarding freshwater scarcity and water conservation in KLS. Key persons were selected by the author using the snowballing technique, starting with local inhabitants in KLS who have insight on where to find the people with the most knowledge about freshwater issues. These key persons are considered as the role-models by locals in KLS. Semi-structured interviews were held with freshwater users, communities, and the environmental scientist using open questionnaires to get different perspectives and more detailed facts. The various interview purposes with different types of respondents are briefly explained in Table 2 below.

Table 2. List of interview respondents.

Type of interview	Respondent	Main Purpose
Unstructured	Key persons: - Vice chairman of Community Association Mbangun Oudestadt (AMbO) - Chairman of Branch Leadership Council Pro Jokowi (DPC Projo) of Semarang - Chief of North Semarang Subdistrict	To obtain descriptions about water management issues, and general conditions of KLS (SQ1).
Semi-structured	Freshwater users: - Sixteen households - Five offices - Eleven businesses - Five public facilities	To observe locals' perspectives about wastewater, freshwater quality issues, awareness to conserve freshwater, and willingness to pay (SQ1 & SQ3).
Semi-structured	Communities (representative): - Member of Community of Sima Banger Polder Management Agency (BPP Sima) - Secretary of Community Association Mbangun Oudestadt (AMbO) - Member of Management Agency of Kota Lama Region (BPK2L)	To obtain information about freshwater management issues, potential water conservation measures for KLS, the awareness of local inhabitants regarding freshwater saving (SQ2 & SQ3).
Semi-structured	Environmental scientist of Soegijapranata Catholic University (UNIKA): - (Dr. Ir. Djoko Suwarno, M.Si)	To obtain information about freshwater management issues and potential water conservation measures (its possibilities and difficulties) from a scientist perspective (SQ2 & SQ3).

2.1.1 Characteristics of Freshwater Scarcity (SQ1)

An extensive literature study was performed to gather data about the physical, socio-economic, and regulatory aspects which relate to freshwater scarcity in KLS. Data obtained for each aspect is shown in Table 3. These data were required to determine the characteristics of freshwater scarcity in KLS. Data on physical aspects was required to determine freshwater supply characteristics (quantity, quality, hydrological and geological conditions); socio-economic data was needed since it affects freshwater demand; and the regulatory aspect was required to study its effects on freshwater supply and demand in KLS.

Table 3. Physical, socio-economic, and regulatory aspects of water scarcity and associated data type and source.

Aspect	Data	Source
Physical (freshwater supply characteristics)	1. Rainfall, aquifer properties, sediment type	1. Regional Planning and Development Agency (BAPPEDA) of Semarang: Report on Master Plan of Drinking Water Provision (RISPAM) 2018; Meteorology, Climatology, and Geophysical Agency (BMKG)
	2. Freshwater quality and quantity	2. Environmental Services Agency (DLH) report; Regional Planning and Development Agency (BAPPEDA) of Semarang: Report on Master Plan of Drinking Water Provision (RISPAM) 2018; PDAM Tirta Moedal; academics reports (thesis, journals)
Socio-economic (freshwater demand characteristics)	1. Demographic	1. Statistics Indonesia Agency (BPS) of North, East, and Central Semarang Subdistrict 2019
	2. Amount of freshwater use	2. Regional Regulation (Perda) on Building and Environmental Planning (RTBL) Number 2/2020; PDAM Tirta Moedal on freshwater production data 2020; Interview with freshwater users
	3. Locals awareness regarding water use	3. Interview with freshwater users, communities, and an environmental scientist
Regulatory	Regulations which affects freshwater supply and demand	Government Law (UU) Number 17/2019; Regional Regulation (Perda) Number 2/2019; Government Regulation (PP) Number 16/2005; Regulation of Ministry of Health (Permenkes) Number 492/2010; Regional Regulation (Perda) Number 3/2018

2.1.2 Potential Water Conservation Measures (SQ2)

The data collection of water conservation measures found throughout the world were obtained via a literature review. Data on potential water conservation measures that are specifically about KLS were obtained from regulatory documents regarding spatial planning in Semarang, to explore the possible measures from the city government, community and academic perspectives. A meeting was held with representatives of DPU, BAPPEDA, and DLH, to discuss the identified water conservation measures (and get feedback on them), and to confirm if data obtained on KLS' freshwater supply, freshwater quality, and spatial planning are in line with the city government's knowledge.

Information coming directly from the community was required to consider the needs of local inhabitants regarding freshwater. The environmental scientist gave the author information regarding possible water conservation measures based on the environmental scientist perspectives. Gathering information from the community was done through interviews with representatives of BPK2L, AMbO, and BPP Sima. Information about the possibilities and difficulties regarding water conservation implementation was gathered during a meeting with the city administration and interviews with the community and environmental scientist.

2.1.3 Feasibility of Water Conservation Measures (SQ3)

To determine which water conservation measures are feasible for KLS, feasibility criteria (Table 4) were required. These criteria were chosen based on information gathered from Subchapter 2.1.1, Subchapter 2.1.2, and a field survey conducted in KLS. The criteria that have been selected, are selected because they are considered as important from the author’s perspective. In this research, feasible water conservation measures were investigated for the whole of KLS. Last but not least, feasible means that suggested water conservation measures for KLS can be implemented in the future (del Caño, 1992).

Regulations (technical and non-technical aspects)
A water conservation measure must be in line with regulations (del Caño, 1992; Kemenpu, 2017; PP Number 42/2008). This means that a measure is mentioned in a regulation, its implementation is in line with Regional Regulation (Perda) RTBL Number 2/2020, and in line with BAPPEDA’s development plan (RISPAM 2018).

Existing infrastructure (technical aspect)
Data on existing infrastructure was obtained through the website Open Street Map (OSM) Indonesia which was processed by the author using QGIS software and was confirmed with findings from the field survey. This data was needed to get an overview on whether technical measures which require space or must be retrofitted onto buildings or main drainages, are feasible. During the field survey, existing infrastructure such as available open spaces, roads, houses, offices, and drainages were observed.

Freshwater quality (technical aspect)
The quality of freshwater produced following a certain measure must be at least suitable for non-potable uses (meaning that it has a quality of class II or lower)[1,2] such as watering garden/plants, washing a car/bike, and mopping. Information about the quality was gathered through a literature study using institutional reports and research journals.

Water input (technical aspect)
An adequate amount of water is needed to ensure the existence of a water conservation measure. The amount of rainwater or greywater must be continuously available. This information was obtained from institutional reports and research journals.

Acceptance (technical and non-technical aspects)
Acceptance from locals (PP Number 42/2008) in KLS is important for a measure to be implemented. In terms of technical aspects, residents’ acceptance is linked to the assurance that a certain measure (e.g. freshwater savings) is beneficial to them (A. W. W. A., 2005). In terms of non-technical aspects, acceptance relates to the willingness of locals to obtain knowledge (via education[3]) about the importance of freshwater and good practices of saving water. This information was obtained through interviews with local inhabitants.

[1] Interview with freshwater users, 2020.
[2] Interview with communities, 2020.
[3] Interview with communities, 2020.

Cost (technical and non-technical aspects)

Technical feasibility is viewed from the cost of a measure (A. W. W. A., 2005; PP Number 42/2008; del Caño, 1992). The cost for a technical measure is viewed in terms of the installation costs only. Feasibility for technical and non-technical measures also depends on available funding from the city government. It has been found that the less expensive a measure is, the more the city government will prioritize it[1]. Non-technical feasibility also relates to the total cost of the program or campaign regarding water conservation practices[2]. This information has been obtained through a literature study (e. g. government reports, research journals, e-books, et cetera) and discussions with DPU and BAPPEDA.

Details on the feasibility criteria and its classification for technical and non-technical measures is shown in Table 4.

Table 4. Feasibility criteria used for water conservation measures in Kota Lama.

Type	Criteria	Classification
Technical	Regulations	Mentioned in a regulation
		In line with Perda on RTBL Number 2/2020
		In line with BAPPEDA's development plan (RISPAM 2018)
		Does not mentioned by or in line with any regulations or development plans
	Existing infrastructures	Possible to retrofit with existing infrastructure
		Require a small space
		Require more new space
	Freshwater quality	Has quality of class II or lower and usable for locals in KLS
		Has quality of class II or lower, but not usable for locals in KLS
	Water input	Freshwater input is continuously available
		Freshwater input is not continuously available
	Acceptance	Freshwater savings
		No freshwater savings, or only aesthetic
	Cost	Funded by city government
		Total cost
		Not funded by city government
Non-technical	Regulations	Mentioned in a regulation
		In line with Perda on RTBL Number 2/2020
		In line with BAPPEDA's development plan (RISPAM 2018)
		Does not mentioned by or in line with any regulations or development plans
	Acceptance	Locals' willingness to get education which relates to water conservation
	Cost	Funded by city government
		Total cost
		Not funded by city government

[1] Meeting with city government, March 4, 2020.

[2] Focus Group Discussion (FGD), March 5, 2020.

2.2 Data Analysis

2.2.1 Characteristics of Freshwater Scarcity (SQ1)

The information as described in Table 3 Subchapter 2.1.1 was used to determine characteristics of freshwater scarcity in KLS. First, every element of each aspect (Table 3) was explained. Second, brief conclusions of freshwater supply (physical aspects) and demand (socio-economic aspects) characteristics were derived. Third, regulations which are related to freshwater supply and demand were analyzed. Lastly, the freshwater scarcity characteristics (quantity and quality) in KLS were explained based on findings from prior steps.

2.2.2 Potential Water Conservation Measures (SQ2)

The data collection of water conservation measures found throughout the world were obtained via a literature review were selected by considering the findings from the meeting and interviews (Subchapter 2.1.2), and the characteristics of freshwater scarcity in KLS (Subchapter 2.2.1). This was performed to identify a longlist of potential water conservation measures. Afterwards, the longlist was discussed via a meeting with the city government (DPU, PDAM, BAPPEDA) (see Appendix I Table 22) and a Focus Group Discussion (FGD) to get information about the possibilities and difficulties of selected measures.

FGD was conducted to discuss the shortlist of potential water conservation measures that are applicable in KLS; to get feedback on existing conditions obtained from the literature about the area; and to get feedback on general freshwater problems such as its management, quality, and supply directly from relevant stakeholders (governmental and non-governmental perspectives). The FGD participants were selected based on the discussion with the chairman of the Housing and Settlement Infrastructure (Sarpras PKP) and BAPPEDA of Semarang (see Appendix I Table 20 and Table 21).

Findings from this Subchapter were listed as longlist options of potential water conservation measures in KLS.

2.2.3 Feasibility of Water Conservation Measures (SQ3)

The longlist of potential water conservation measures for KLS from Subchapter 2.2.2 was analyzed to investigate the feasibility of each measure using the criteria in Table 4. The measures were scored to determine which one is the most feasible—with the highest score meaning the highest feasibility. Detailed scoring criteria for technical and non-technical measures are shown in Table 6. The motivation for each criterion is explained in Subchapter 2.1.3. All criteria are equally weighted (weight = 1) because they are equally important based on author's perspective and because there is limited data available about which of the selected criteria are most likely to lead to a successful implementation of a water conservation measure. The total score per criteria must be normalized by comparing it with its maximum score. This is done by using the equation in the following. In addition, scoring for total cost (Table 6) is based on the cost categorization (Table 5).

Prior scoring of "total cost" criterion in Table 6 was performed. Gathered information about the total cost is sorted in ascending order. For technical measures, the lowest total cost belongs to category I (the least expensive), and it is given a highest point (1,00). The highest total cost belongs to category VI (the most expensive). Not enough information belongs to category N/A, and it is given a lowest point (0,00). For non-technical measures the lowest total cost belongs to category I (the least expensive), and it is given a highest point (1,00). The highest total cost belongs to category IV (the most expensive). Not enough information belongs to category N/A, and it is given a lowest point (0,00). For example, based on Table 5, the highest point (1,00) is given to buffer strip (technical measure) and water audits (non-technical measure) because the total cost of both measures are the lowest. The cost categorization of technical and technical measures is shown in Table 5.

Table 5. Total cost categorization of technical and non-technical measures.

Type	Category	Point	Total Cost (approximation)	Measure
Technical	I	1,00	IDR 7 Million*)	Buffer strips
	II	0,83	IDR 21 Million**)	Constructed wetlands
	III	0,67	IDR 171 Million***)	Water-saving fixtures
	IV	0,50	IDR 476 Million****)	Roof-water harvesting (RWH)
	V	0,33	IDR 1,7 Billion*****)	Retrofit greywater treatment
	VI	0,17	IDR 13 Billion******)	Non-Revenue Water (NRW) Reduction
	N/A	0,00	Not enough information	Optimization of open green spaces (RTH)
Non-technical	I	1,00	IDR 70 Million*******)	Water audits
	II	0,75	IDR 250 Million********)	Educational incentive
	III	0,50	IDR 500 Million*********)	Financial Incentive
	IV	0,25	IDR 17 Billion**********)	School incentive
	N/A	0,00	Not enough information	Regulatory incentive; Institution/community capacity building

N/A: Not enough information
*) IDR 7 Million per unit. Calculated from Melbourne Water (n. d.). If a buffer strip is installed on un-redesigned road at buffer zone.
**) IDR 21 Million per unit. Calculated from Melbourne Water (n. d.). If a constructed wetland is placed on Tawang pond.
***) IDR 700.000 per unit. Calculated from AECOM (2009). If all 245 buildings in KLS is installed with a water-saving faucet.
****) IDR 7 Million per unit (Abadi et al., 2018). If 68 of buildings which is owned by government are installed with RWH.
*****) IDR 7 Million per unit greywater treatment retrofit system. Calculated from Juan et al. (2016). If all 245 buildings in KLS is installed with the system.
******) Total cost for PDAM Northern Semarang service area. Averaging from the total cost of NRW reduction for the entire Semarang City, if it is shared equally among PDAM five branches. Calculated from BAPPEDA (2018).
*******) Calculated from A. W. W. A. (2005)
********) Calculated from A. W. W. A. (2005)
*********) Calculated from A. W. W. A. (2005)
**********) Calculated from AECOM (2009)

Moreover, the total score per criteria must be normalized by comparing it with its maximum score by using the equation below.

$$Normalized\ score\ per\ criteria = \frac{Total\ point\ per\ criteria}{Maximum\ point\ per\ criteria} \times weight$$

Table 6. Detail scoring of each criteria for technical and non-technical measures.

Type	Criteria	Weight	Classification	Point	Maximum point per criteria	Normalized score per criteria
Technical	Regulations	1	Mentioned in a regulation	1,00	3,00	$\frac{3,00}{3,00} \times 1 = 1,00$
			In line with Perda on RTBL Number 2/2020	1,00		
			In line with BAPPEDA's development plan on RISPAM 2018	1,00		
			Does not mentioned by or in line with any regulations or development plans	0,00		
	Existing infrastructures	1	Possible to retrofit with existing infrastructure	1,00	1,50	$\frac{1,50}{1,50} \times 1 = 1,00$
			Require a small space	0,50		

Type	Criteria	Weight	Classification	Point	Maximum point per criteria	Normalized score per criteria
			Require more new space	0,00		
	Freshwater quality	1	Has quality of class II or lower and usable for locals in KLS	1,00	1,50	$\frac{1,50}{1,50} \times 1 = 1,00$
			Has quality of class II or lower, but not usable for locals in KLS	0,50		
	Water input	1	Freshwater input is continuously available	1,00	1,00	$\frac{1,00}{1,00} \times 1 = 1,00$
			Freshwater input is not continuously available	0,00		
	Acceptance	1	Freshwater savings	1,00	1,50	$\frac{1,50}{1,50} \times 1 = 1,00$
			No freshwater savings, or only aesthetic	0,50		
	Cost	1	Funded by city government	1,00	2,00	$\frac{2,00}{2,00} \times 1 = 1,00$
			Total cost	*)		
			Not funded by city government	0,00		
Non-technical	Regulations	1	Mentioned in a regulation	1,00	3,00	$\frac{3,00}{3,00} \times 1 = 1,00$
			In line with Perda on RTBL Number 2/2020	1,00		
			In line with BAPPEDA's development plan on RISPAM 2018	1,00		
			Does not mentioned by or in line with any regulations or development plans	0,00		
	Acceptance	1	Locals' willingness to get education which relates to water conservation	1,00	1,00	$\frac{1,00}{1,00} \times 1 = 1,00$
	Cost	1	Funded by city government	1,00	2,00	$\frac{2,00}{2,00} \times 1 = 1,00$
			Total cost	*)		
			Not funded by city government	0,00		
TOTAL SCORE						(total of normalized score)
*) Point for "Total cost" is given based on Table 5.						

As an example, the normalized score for "cost" criterion of roof-water harvesting (RWH) is calculated as follow. An RWH system is funded with Regional Revenues and Expenditures Budget (APBD) (BAPPEDA, 2018). Thus, point 1,00 is given for the "funded by city government" classification. Based on Table 5, the total cost of RWH belongs to category IV, hence the "total cost" point is 0,50. Therefore, the total point for "cost" criterion is 1,50. Since the maximum point for "cost" criterion is 2,00, then the normalized score for "cost" of RWH is 1,50/2,00 = 0,75.

Chapter 3: Results

3.1 Characteristics of Freshwater Scarcity in Kota Lama Site (KLS)

3.1.1 Physical Aspects

3.1.1.1 Hydrogeological and Geological Conditions.

KLS lies on a slope of less than 5 m (Bermana, 2006) and is set on young alluvium deposits (mixtures of clay, silt, and sand) with the aquifer thickness varying from 2 to over 60 m (BAPPEDA, 2018; Susanto, 2010; Marfai, 2003). Data on the groundwater level in Semarang is limitedly available because many monitoring wells need repairments[1]. Based on soil investigation in the Banger polder area (about 1,2 km North-East of KLS), the decrease in groundwater level is about 0,40 m/year for the confined aquifer (measured from -12 to -19 m and -65 to -75 m below MSL) and 0,10 m/year for the unconfined aquifer (measured from -1 to -2 m below MSL)[2]. The decrease of the unconfined aquifer is smaller but has a greater contribution to land subsidence due to its sediment type[3]. Total annual rainfall from 2008 to 2019 in KLS (Figure 3) is about 2.165 mm/year with 160 days of rain (Calculated from daily rainfall data of Badan Meteorologi, Klimatologi, dan Geofisika (BMKG) website). This data is obtained from the nearest BMKG station to KLS (Figure 4), namely: the Maritim Tanjung Emas station.

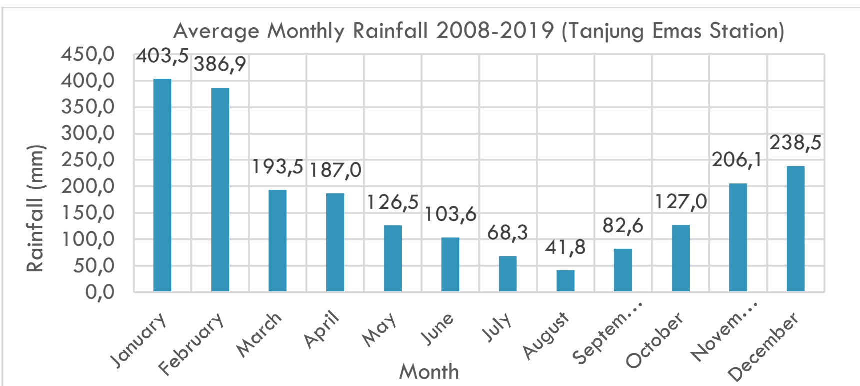

Figure 3. Average Monthly Rainfall 2008-2019 (BMKG, 2020).

3.1.1.2 Surface Freshwater and Groundwater Resources in KLS.

In subchapter 1.2.3, it is mentioned that the only freshwater source for KLS from PDAM is sourced from WTP Kudu. However, it is difficult to quantify how much freshwater is actually received by KLS because freshwater from WTP Kudu is also widely distributed through pipes to three different regions in Eastern Semarang[4] (Subchapter 1.2.3 Figure 2). In addition, there is no main water meter in KLS[5], and PDAM supply data is only available on a subdistrict level. Thus, PDAM supply for KLS in this thesis is calculated based on supply data of North, Central, and East Semarang subdistricts since KLS lies within all three of those (Figure 4). The calculated

[1] (M. A. Popang, personal communication, June 12, 2020)
[2] (M. A. Popang, personal communication, June 12, 2020)
[3] (M. A. Popang, personal communication, June 12, 2020)
[4] (M. Firdaus, personal communication, June 10, 2020)
[5] (M. Firdaus, personal communication, February 25, 2020)

annual PDAM freshwater supply for KLS (see Appendix II for the calculation) is about 655.939.515,23 L/year (Table 7).

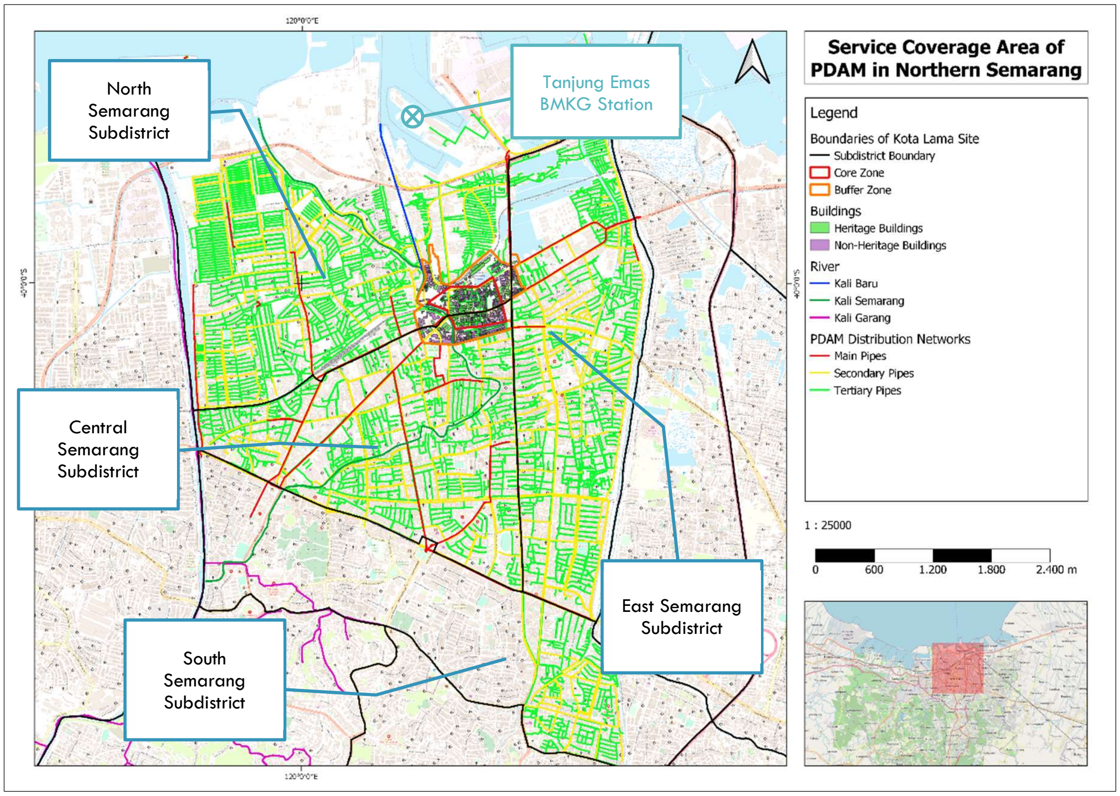

Figure 4. Service coverage area of PDAM in Northern Semarang and Tanjung Emas Climatology Station. Obtained from PDAM (2020) and modified from RTBL, 2020

Table 7. Calculated PDAM annual supply for KLS.

Subdistrict	Total supply within KLS (L/year)
North	425.768.712,38
Central	206.575.419,42
East	23.595.383,43
Total Supply	**655.939.515,23**

Non-Revenue Water (NRW) or freshwater loss—for example through pipes leakages or illegal connections—is a big problem for PDAM in Northern Semarang. In 2017 the NRW percentage in that area made up about 20 % (see Appendix II for calculation) of the total NRW of Semarang. From 2023 onwards, it was predicted that the NRW for the whole of Semarang will decrease. However, this can only be achieved if PDAM's plans of system monitoring and control, repairment of 30 % parcel pipes and leakages from secondary pipes (five leakages per km), optimization of PDAM water meters (production and costumers), and main water meters installation are executed and finished before 2023 (BAPPEDA, 2018).

Water produced by PDAM is primarily intended to be used as drinking water. However, its quality does not meet the standard for drinking water (class I). The quality has decreased over the years due to PDAM's poor water infrastructure (Senjaya, 2020). PDAM puts the blame on the freshwater inputs for the WTPs, claiming that these are severely polluted (Senjaya, 2020). The quality of Klambu river, which is the main freshwater input for WTP Kudu, is already degraded due to for example sedimentation, algae, domestic solid waste and wastewater (grey and black), and poisonous substance for fishing (Sasangka, 2018; Suseno et al., 2015). Quality of freshwater input for WTP Kudu and WTP Kaligarang are shown in Appendix III Table 31.

Many studies have found that PDAM quality is poor (Listanti et al., 2015; Devina, 2017; Jaya & Suharyanto, 2004; Kusumadewi & Prakoso, 2018). Moreover, PDAM never publishes any reports about its freshwater quality (BAPPEDA, 2013). This poor quality of PDAM has been confirmed by fourteen customers (Table 8). In addition, Tawang pond could be a potential freshwater source in KLS for non-potable purposes only[1]; which can add value to the pond's existing functions as a retention pond and recreational water facility[2]. The pond can store about 15.000.000 L of water with a pumping capacity of 450 L/s (BAPPEDA, 2018). Currently, water quality of Tawang pond is lightly polluted for all classes[3].

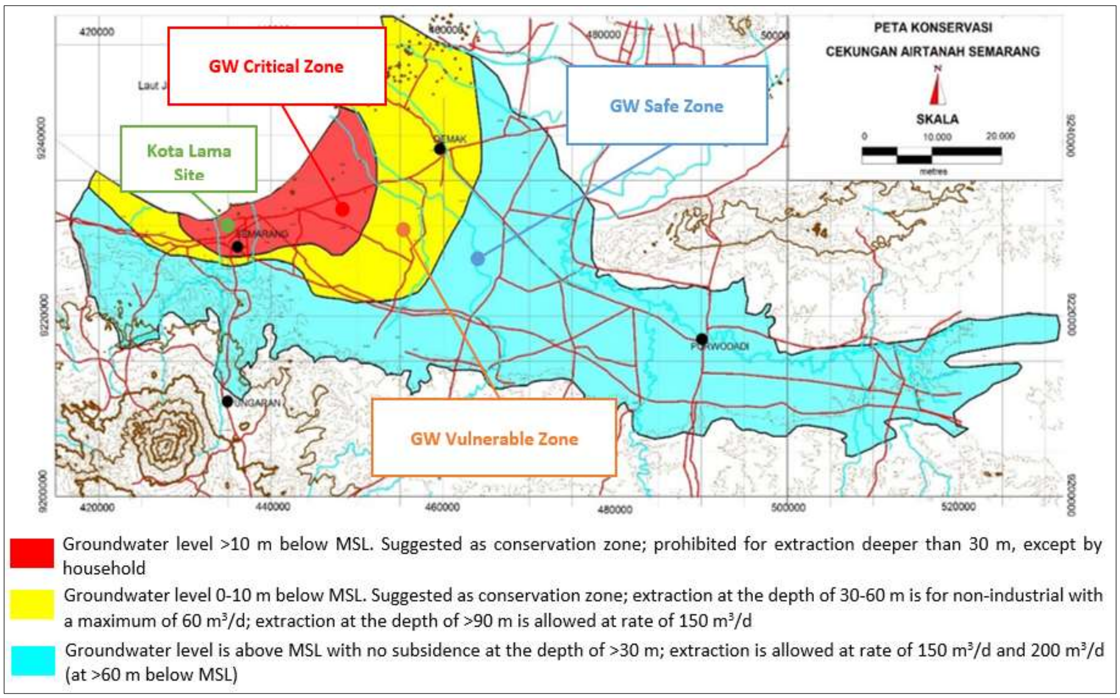

Figure 5. Approximate location of KLS within Semarang-Demak groundwater basin. Modified from BAPPEDA (2018).

KLS lies within the Semarang-Demak groundwater basin which has an area of 1.915 km^2 (Figure 5) (BAPPEDA, 2018; Susanto, 2010). The recharge rate for its unconfined aquifer is about 783.000.000 m^3/year and 91.000.000 m^3/year for its confined aquifer (Susanto, 2010). Putranto & Rude (2011) calculated that the annual increase of groundwater level in the basin for the unconfined aquifer is about 0,316 m. Based on the assumption that the surface area is equal for both aquifers and that they have a homogenous soil type, the increase of the Semarang-Demak groundwater level is about 0,36[4] m/year in the unconfined aquifer, and 0,05 m/year in the confined aquifer. Due to data availability issues, the quantity of groundwater supply in KLS is calculated from the amount of its annual recharge. Recharge rates for KLS are 260.546.754,96 L/year (unconfined) and 34.391.869,31 L/year (confined) (see Appendix II for the calculation).

[1] (J. Kalalo, personal communication, February 20, 2020)
[2] (D. Suwarno, personal communication, February 20, 2020)
[3] (W. Purwasih, personal communication, March 3, 2020)
[4] Averaging from (0,41 m + 0,316 m) / 2 = 0,36 m.

Groundwater contains high levels of iron, turbid, and saline at many locations in Northern Semarang (BAPPEDA, 2013). Exfiltration is found at three locations in the North Semarang subdistrict[1]. Twenty-four of thirty-seven respondents in KLS are well users[2] (active users), and two respondents used a well once. Low groundwater quality was confirmed by fourteen active users (Table 8). Two others closed the wells due to high salinity. Commercial sectors and two public facilities use it for drinking after having filtrated it themselves. Moreover, it is suspected that the distance between the septic tanks and wells is very close[3] (<10 m) causing wastewater from those septic tanks to infiltrate into the well[4].

Table 8. Freshwater quality in KLS based on interviews with freshwater users.

Respondent	Location		Quality*)	
			PDAM	Groundwater
Household	Bandarharjo	RT 1 / RW 10	a, b, c	
		RT 5 / RW 11	d	1
		RT 1 / RW 10	a, d	
		RT 3 / RW 11	*	
		RT 2 / RW 11	a, d	**
		RT 4 / RW 11	*	**
		RT 6 / RW 11	*	
		RT 1 / RW 11	a, e	
	Dadapsari	Representative of seven families of RT 1 / RW 9		*; 2**)
	Purwodinatan	Representative of seven families of RT 4 / RW 2		*; 1, 2**)
	Rejomulyo	RT 1 / RW 3	a, b, d	1
		RT 2 / RW 3	d	
	Tanjung Mas	RT 3 / RW 1	a	1, 2, 3
		RT 2/ RW 1		1, 3
		RT 1 / RW 1	a, b, c, d	
		RT 3 / RW 1	b	
Commercial	Purwodinatan	Pharmaceutical		1, 4
		Food & Beverages		** (after filtration)
		Food & Beverages		1, 2, 3
		Photocopy & courier	*	
	Kauman	Hotel (big)	d	1, 5
	Tanjung Mas	Café	a, c, f	
		Food & Beverage		** (after filtration)
		Hall for rent	*	1
		Cigarette factory		**
		Food & Beverages	a, c	
		Hotel (small)	*	**
Office	Dadapsari	Government office		** (quality monitoring every three months)
	Purwodinatan	Insurance office		**
		Bank office	*	1
	Tanjung Mas	Station		**
		Church office	*	1

[1] Field survey January – March 2020.
[2] Interview with freshwater users, 2020.
[3] (W. Purwasih, personal communication, March 3, 2020)
[4] (D. Suwarno, personal communication, February 20, 2020)

Respondent	Location		Quality*)	
			PDAM	Groundwater
Public Facility	Rejomulyo	Worship & educational facilities		6
	Purwodinatan	Social		**
	Tanjung Mas	Worship & educational facilities		1, 3, 5
		Worship facility	a, b, d	1
		Worship facility		2, 3
*: no issues; a: bad odor (soil or Calcium Hypochlorite/*kaporit* or feces odor); b: contains suspended sediment; c: taste like Calcium Hypochlorite (*kaporit*); d: turbid; e: stain after boil, f: sticky				
**: no issues; 1: saline; 2: bad odor; 3: turbid; 4: contains sediment; 5: high Manganese (Mn) or Iron (Fe); 6: contains high number of bacteria				
*) not for drinking; **) researcher experience				

3.1.1.3 Characteristics of Freshwater Supply.

The main freshwater sources in KLS are PDAM (surface water) and wells (groundwater). The total freshwater supply from PDAM is about 655.939.515,23 L/year. The amount of freshwater supply in KLS is affected by NRW[1]. However, it is not possible to quantify how much it is affected because there is no main water meter installed in the area. Groundwater recharge rates (supply) for unconfined and confined aquifers are 260.546.754,96 L/year and 34.391.869,31 L/year, respectively. Due to the data limitation regarding KLS, freshwater supply numbers (PDAM and wells) are only an approximation. Freshwater from wells is considered better than PDAM in terms of continuity (always available), while freshwater from PDAM is sometimes not available, for example during road constructions and repairment[2].

Drinking water in KLS is mostly obtained from bottled[3] water due to the low quality of PDAM and groundwater. However, the exact amount of bottled water in KLS is difficult to quantify. Because to calculate the volume of bottled water, specific data will be needed, for instance, regarding bottled water distribution data in KLS from various private water companies.

Essentially, locals in KLS expect a class I freshwater quality from PDAM[4]. However, freshwater quality for the entire city of Semarang is in class II or lower (BAPPEDA, 2018). It is impossible for PDAM to produce class I freshwater (Senjaya, 2010). Poor quality of groundwater forced locals to close their wells. Moreover, because groundwater from some of the active wells contain a high amount of iron, manganese, chloride, and suspended solids, filtrations are needed in general to make the water usable for non-potable purposes.

3.1.2 Socio-economic Aspects

3.1.2.1 Profile of Freshwater Demand in KLS (PDAM and Wells).

There is no demographic data specifically for KLS[5]. Freshwater demand (PDAM) in KLS is calculated based on the maximum daily demand of North, Central, and East Semarang subdistricts, although generally total demand is calculated based on total population and volume of daily freshwater use. The calculated PDAM freshwater

[1] (M. Firdaus, personal communication, February 25, 2020)
[2] Interview with freshwater users, 2020.
[3] Non-refillable (brand) and refillable bottled water.
[4] Interview with freshwater users, 2020.
[5] (N. Sutiyani, personal communication, March 5, 2020)

demand for KLS (see Appendix II for the calculation) is about 679.056.883,18 L/year (Table 9). In addition, average daily demand for domestic use in Semarang is about 144 L/person/day (BAPPEDA, 2018) and the demand for non-domestics use in Semarang (Susanto, 2010) is shown in Table 10.

Table 9. PDAM annual demand for North, Central, and East Semarang Subdistricts.

Subdistrict	Total demand within KLS (L/year)
North	443.451.190,35
Central	210.181.445,85
East	25.424.246,99
Total Demand	**679.056.883,18**

Table 10. Freshwater average daily demand for non-domestic. Modified from Susanto (2010).

Non-domestics category	Demand (L/person/day)
Worship facility	
Mosque	30
Church	10
Buddhist Temple	10
Hindus Temple	10
Educational facility	
Basic school	10
Junior high school	20
Senior high school	25
Higher educational institution	50
Public facility	
Bus station	15
Hospital	250
Bank	25
Commercial	
Cinema	15
Restaurant	70
Store	20
Others	
Office	30
Jail	50

According to data from PDAM (2020), in 2017 the total PDAM connection in KLS was 211. This consist of 66 commercials, 119 households, and 26 offices. The total recorded freshwater usage in 2017 is about 56.446.909 L (about 18.030.553 L belongs to commercial sectors and offices). For households the total demand in 2017 is about 38.416.356 L or 221 L/person/day[1]. This amount is way more than the average daily use of freshwater (PDAM) in Semarang (144 L/person/day). This is most likely because the recorded number from water meters is inaccurate. There are 66 water meter units that are either broken or have problems (PDAM, 2020).

Groundwater extraction in Semarang is about 96 % by non-domestic sectors and 4 % by domestic sectors[2]. Data on the number of wells, their location, and extraction demand in KLS is scarcely available[3]. Thus, annual groundwater extraction is calculated from the decrease rate of the groundwater level in aquifers which are about 72.374.098,60 L/year (in unconfined aquifers) and 289.496.394,40 L/year (in confined aquifers) (see

[1] Four person per family. Calculated from Statistics Indonesia Agency (BPS) of North, East, and Central Semarang Subdistricts (2019).
[2] Meeting with Ministry of Energy and Mineral Resources (ESDM) Central Java Provincial, January 14, 2020.
[3] (D. Suwarno, personal communication, February 20, 2020)

Appendix II for the calculation). In addition, during the field survey there were twenty-four wells in total (Table 11).

Table 11. Wells users in KLS.

User	Well Type			
	Shallow (less than 30 m)		Deep (over 60 m)	
	Individual	Communal	Individual	Communal
Household	3	3**)		
Commercial	6		1	
Office	2		1	
Public Facility	6			
Other*)		2		
Total	**17**	**5**	**2**	**-**

*) Public shallow wells which are used by jerrycans seller and firefighter (to fill the water tank)
**) Communal shallow wells are used by forty-two families

During the field survey, the researcher classified freshwater users in KLS into four different categories (Table 12). Water from bottled[1] water is the main source for drinking water in all categories. For non-potable uses, PDAM is the main source for household usages and wells are the main source for the other categories. Freshwater from PDAM and wells is mainly used for bathing (households) and flushing toilets (commercial sectors, offices, and public facilities). A remarkably high volume of fresh groundwater for non-potable purposes was observed at a big hotel in KLS. It reaches over 1.500.000 L/month, while one-third of this amount covers the demand from all other smaller hotels, big restaurants and cafes. Hotel guests' demand for water from brand bottled water goes up to 500.000 L/month and more. A high demand for freshwater was also found at public facilities, ranging from 225.000 to 600.000 L/month. This amount is the demand from two big church complexes and a mosque. About 400.000 L/month of freshwater is used by a bank office. In addition, there are two big hotels and six smaller hotels in KLS and other commercial sectors such as restaurants, cafes, markets, and pharmaceuticals. The number of cafés and restaurants is predicted to increase, and about 19 vacant buildings are available to be sold and used for commercial purposes in KLS[2].

Table 12. Potable and non-potable uses per user category.

User category	Type of use	Freshwater source*)	Uses	Usage/demand range (L/month/unit)	Usage/demand range (L/day/unit)
Household	Potable	Refillable bottled water, brand bottled water	Drinking, cooking/food preparation	95 – 936	3 – 31
	Non-Potable	PDAM, wells	Bathing, washing, toilet, watering plant/garden	2.000 – 45.000	67 – 1.500
Commercial (cafes, hotel, and factory)	Potable	Brand bottled water, refillable bottled water, PDAM, wells	Drinking, cooking	570 – over 500.000	19 – over 16.667
	Non-Potable	Wells, PDAM	Toilet, washing, bathroom	1.500 – over 1.500.000	50 – over 50.000
Office (private and state-owned corporation)	Potable	Brand bottled water, refillable bottled water, wells	Drinking, pantry	532 – 2.375	18 – 79

[1] Non-refillable (brand) and refillable bottled water.
[2] (H. Ahmad, personal communication, February 27, 2020)

	Non-Potable	Wells, PDAM, refillable bottled water	Toilet, washing, bathroom, watering plant/garden	Not enough information	Not enough information
Public facility (mosque, church and social building)	Potable	Brand bottled water, wells, refillable bottled water	Drinking, cooking	225.000 – over 600.000 (both uses)	7.500 – over 20.000 (both uses)
	Non-Potable	Wells	Toilet, bathroom, watering plant/garden, washing		
*) *Type of freshwater source is based on freshwater sources classification determined by BPS and sorted from the most use sources to the least.*					

3.1.2.2 Characteristics of Freshwater Demand.

Freshwater from PDAM and wells are mostly used by locals for non-potable purposes. The need for water for potable uses (e.g. drinking and food preparation) is met by brand and refillable bottled water. Commercial sectors, offices, and public facilities use freshwater from wells for non-potable uses (e.g. toilet, car-washing, pantry, plant-watering or garden) whereas households use PDAM for non-potable daily needs.

The total demand for PDAM is about 679.056.883,18 L/year and the total demand for groundwater (wells) is 72.374.098,60 L/year (unconfined) and 289.496.394,40 L/year (confined). These are only approximate amounts because demographic- and freshwater usage data are currently not available. In addition, freshwater demand from the commercial category is the highest amongst other user categories.

Locals' awareness regarding freshwater-saving practices affects the amount of freshwater demand[1]. However, the awareness on effective water use practices in KLS is very low[2]. Locals tend to waste freshwater because they have no understanding of the importance of saving water. Examples of wasteful usages are households using "clean" freshwater to wash cars and motorbikes and a worship facility watering its garden for two hours daily using hoes that use "clean" freshwater. Only two respondents (household) reuse water from washing rice and fish to water their plants. There was also a program about greywater reuse in a worship facility, but the program ended years ago. The rest of the respondents, from all categories, assume that reusing water is inappropriate even for watering their garden.

3.1.3 Regulatory Aspects

According to Perda Number 2/2019, PDAM is a professional drinking water agency which has been formed by the regional government to produce and distribute freshwater so the need for clean freshwater of each Semarang citizen can be met. On top of that PDAM also plays a role as a source of income for the city. Water produced by PDAM is supposed to meet the quality criteria of drinking water (class I) (PP Number 16/2005; Permenkes Number 492/2010; BAPPEDA, 2013; BAPPEDA, 2018).

Any utilizations of freshwater resources (e.g. transportation, drinking water production, food company, fisheries, mining company) must follow UU Number 17/2019. This law prioritizes PDAM to use freshwater resources and gives the least priority to private businesses (national and international). However, PDAM must optimize the use of surface freshwater as their main source to fulfill citizen's daily basic needs of freshwater. Moreover, any activity regarding freshwater utilization must pay attention to the needs of water conservation and mitigation acts to prevent any environmental damage (PP Number 16/2005). In addition, society must

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[1] (D. Suwarno, personal communication, February 20, 2020)
[2] Interview with freshwater users, 2020.

participate in maintaining the quality of freshwater resources by, for example, not disposing solid waste into freshwater bodies (PP Number 16/2005).

Concerning the use of groundwater, private businesses/companies must request permission from the governor. Any commercial sectors which extracts groundwater for more than 50 L/s, must allocate at least 15 % of the maximum permissible withdrawal debit to be used by neighboring residents to meet their daily water needs (Perda Number 3/2018). Commercial sectors must also regularly record their groundwater extraction volume using a monitoring well (Perda Number 3/2018). The extraction of groundwater for non-commercial sectors does not need a permit if it is less than 9.000 L/day, it is withdrawn using a hand water pump and a drilling well (pipe diameter less than 5 cm), and it is used for public agricultural areas with a demand less than 2 L/s – when existing surface freshwater resources around cannot fulfill its demand (Perda Number 3/2018). In addition, according to Perda Number 3/2018 and BAPPEDA (2018), the groundwater zone for the whole of Semarang is considered critical (Figure 5). This means that groundwater in this zone must be conserved, that it is not allowed to extract the groundwater at more than 30 m depth from MSL, and that extraction from the confined groundwater is only allowed for domestic (household) use.

3.1.4 Characteristic of Freshwater Scarcity in KLS

Freshwater scarcity must be viewed in terms of quantity and quality (Subchapter 1.2.1). Scarcity in terms of quantity is related to the balance of freshwater supply and demand. When the demand exceeds the supply then there is scarcity. Table 13 shows freshwater supply and demand in KLS. Freshwater scarcity is also viewed in terms of quality because available freshwater resources are unusable if they are polluted (Kodoatie et al, 2010). For example, an annual surplus of fresh groundwater in an unconfined aquifer (Table 13) is not usable due to a high salinity and bad odor[1,2]. The river Klambu, which is the main input for WTP Kudu, has also been polluted (Subchapter 3.1.1.2).

Table 13. Freshwater supply and demand in KLS.

Resources		Supply (L/year)	Demand (L/year)	Supply – Demand (L/year)	Condition
Groundwater (wells)	Unconfined	260.546.754,96	72.374.098,60	188.172.656,36	Surplus
	Confined	34.391.869,31	289.496.394,40	-255.104.525,09	Scarcity
Surface water (PDAM)		655.939.515,23	679.056.883,18	-23.117.367,95	Scarcity

Drinking water in KLS is mostly sourced from brand and refillable bottled water due to a low quality of PDAM and wells. However, the exact amount (supply and demand) of brand and refillable bottled water in KLS is difficult to quantify because more information is needed about how many liters of bottled water is distributed by different private water companies and how often locals buy bottled water.

Enforcement of regulations concerning freshwater supply and demand is weak. Groundwater extraction from a depth above 30 m below MSL is not allowed except by households (PP Number 3/2018). However, despite the regulation, extractions at that depth do occur and are performed by non-domestic sectors[3]. Extracted groundwater volume monitoring is only obligatory for an extraction rate of over 50 L/s. This could mean that groundwater extraction data below 50 L/s is lacking. Moreover, surface freshwater contamination (such as by industry, households, and animal husbandries) is still a huge problem for the city government even though PP Number 16/2005 states that such contamination must be prevented.

[1] Interview with freshwater users, 2020.
[2] (D. Suwarno, personal communication, February 20, 2020)
[3] Field survey January – March 2020.

3.2 Potential Water Conservation Measures in KLS

Water conservation in Indonesia is needed to: (1) ensure protection of freshwater, (2) ensure a sustainable freshwater quantity, (3) ensure good quality of freshwater, and (4) to prevent freshwater contamination (UU Number 17/2019). Water conservation could be approached through technical and non-technical means. Based on a literature study and FGD, this study has identified potential water conservation measures for KLS which will be discussed in the following paragraphs.

3.2.1 Technical

3.2.1.1 Roof-Water Harvesting (RWH) (WANG H, ET AL., 2018; MATTO ET AL., 2017; PATEL & SHAH, 2008).

During the field survey, author found that almost every roof (excluding vacant buildings) had a gutter for carrying off rainwater. Existing buildings in KLS just have to place a rainwater storage tank which is installed with a tap and a simple filter (of charcoal crumble, sand, gravel, and/or coconut fiber) on top of the tank lid (Patel & Shah, 2008; Pereira et al., 2009), to have a complete RWH system. Currently, rainwater in KLS is directly discharged onto the streets or stored in semi-open squared cement structures before being discharged onto the streets and then drainage channel. Average rainfall in KLS is considerably high. Storing rainwater using a storage tank could be used for non-potable uses at the very least, so it can reduce freshwater demand from PDAM and wells. This measure is mentioned in Permenpu Number 11/2014, Permen LH Number 12/2009, and BAPPEDA development plan on RISPAM 2018. It is also in line with Perda Number 2/2020 regarding the adaptation of a building.

3.2.1.2 Water-Saving Fixtures (CITY OF VENETA, 2003; LEE ET AL., 2013; MATTO ET AL., 2017).

Water-saving fixtures such as low flow shower heads, -faucets, and -flush toilets can reduce wasting freshwater due to leakages and/or faucets that are left open. Since daily use of freshwater from faucets is considerably high in KLS, using such a water-saving fixture could be beneficial. Although these kind of fixtures are more suitable for new- or renovated buildings, and within current regulation it is only mandatory for new small buildings or houses to have it installed—water-saving faucets can be retrofitted and can be used for household usages, especially in the bathroom (for bathing and/or ablution) and in the kitchen (for washing dishes by hand, washing ones hands and preparing food). The implementation of water-saving faucets in cafés and restaurants in KLS is also important because it has many toilets and many faucets for ablution. Although water-saving faucets can be retrofitted, the implementation of the measure is only compulsory for new small buildings or houses (Perwal Number 24/2019). Moreover, APBD cannot fund the measure if it is implemented in private buildings (Gewati, 2019b). Only 68 of 245 buildings are owned by the city government.

3.2.1.3 Non-Revenue Water (NRW) Reduction (CITY OF VENETA, 2003; FGD; BAPPEDA, 2018; A. W. W. A., 2005; FGD).

NRW issues in Semarang comprise water loss in production and distribution stages, poor maintenance of water meters and distribution pipes, illegal pipe connections, and defect water meters (BAPPEDA, 2018). Improving PDAM infrastructures could reduce NRW by 1-6 % a year (BAPPEDA, 2018). PDAM’s strategy about installing main water meters in KLS could help monitoring the amount of distributed freshwater, and recording NRW. According to Pereira et al. (2009) reducing NRW is considered as important for freshwater scarce areas to cope with its scarcity. Moreover, household water meter repairment could be beneficial for PDAM to improve their calculations on freshwater usage in KLS. This measure is stated in the BAPPEDA development plan on RISPAM

2018 and is in line with Perda Number 2/2020. According to BAPPEDA (2018), NRW reduction will cost about IDR 65 billion and is funded from PDAM.

3.2.1.4 Retrofit Greywater Treatment (JUAN ET AL., 2016; FGD).

Since greywater is used freshwater, retrofit greywater treatment is another way of conserving freshwater. The basic principle of retrofit greywater treatment is adjusting the greywater treatment system within a domestic space and utilize the treated greywater for non-potable purposes such as watering plants and toilet flushing (Juan et al., 2016). Considering that greywater in KLS accounts for over 50 % of daily freshwater use[1], retrofit greywater treatment could help in reducing daily freshwater demand for non-potable purposes, or at least improve the quality of greywater before it goes to Kali Semarang. The system could be installed in cafes or houses and combined with a grease trap. When it comes to the food and beverage sector, 3 of 5 cafes in KLS already use a grease trap[2]. Greywater treatment is stated in Permenpu Number 4/2017, Perda Number 13/2006, Perda Number 2/2020, and is in line with BAPPEDA's development plan on RISPAM 2018. However, the implementation of the measure cannot be funded from APBD if it concerns private buildings (Gewati, 2019b).

3.2.1.5 Constructed Wetlands (PHILIP ET AL., 2019).

Constructed wetlands are ecosystems created in shallow basins (about <1 m deep) with plants (e.g., Macrophytes) saturated with water that comes from drainage channels (Philip et al, 2019). It is designed to improve water quality by treating parameters such as BOD_5, TSS, Phosphate, and Total Nitrogen (Philip et al, 2019). This system could be applied at Tawang pond (or at its inlet)[3] which could also make Tawang pond greener, aesthetically. This measure is in line with Permenpu Number 12/2014 and Perda Number 2/2020.

3.2.1.6 Buffer Strips (WANG H, ET AL., 2018).

Buffer strips are beneficial to improve freshwater quality by filtering sediment from runoff and by purifying rainwater (Wang et al., 2018) before it goes into drainage channels. It could also make KLS greener aesthetically. The measure is in line with Permenpu Number 12/2014 and Perda Number 2/2020 although currently there are no buffer strips placed in KLS. Thus, DPU should include buffer strips in future road construction plans in buffer zones and/or along Kali Semarang.

3.2.1.7 Optimization of Open Green Spaces (RTH) (FGD, MARCH 5, 2020).

The optimization of existing RTH in KLS could be done by planting plants or trees that do not require as much water. Thus, rainwater and runoff would be naturally filtered before it infiltrates unconfined aquifers and flows into drainage channels. The measure is mentioned in UU Number 26/2007 on spatial planning which strongly suggests that a city should have at least 30 % RTH which consists of 10 % owned by the private buildings and 20 % is for the public (P2KH, 2015). It is in line with Perda Number 2/2020 and BAPPEDA development plan on RISPAM 2018 and therefore possible to implement in vacant places such as the areas between Raden Patah and Ronggowarsito street. However, these vacant spaces need to be opened up and transformed into green spaces.

[1] (D. Suwarno, personal communication, February 20, 2020)
[2] Field survey January – March 2020.
[3] Meeting with city government, March 4, 2020.

However, because many vacant spaces in KLS are owned by the Indonesian Railways Company (PT KAI), the city government or DPU would need permission and might have to pay annual rent to PT KAI[1].

3.2.2 Non-Technical

3.2.2.1 Educational Incentives (A. W. W. A., 2005; CITY OF VENETA, 2003; AECOM, 2009; FGD, MARCH 5, 2020).

Educational incentives are aimed to increase adults' awareness. Distribution of information could be done through meetings/counseling/workshops, websites, pamphlets, and fliers (AECOM, 2009). The information could contain the importance and benefit of water saving practices and freshwater usage monitoring, and the importance to participate in improving freshwater quality. KLS is one of the most visited tourist destinations in Semarang. Simply putting a sign saying "Save Water" in a public toilet at Srigunting park, cafés, restaurants, and/or worship facilities in KLS would therefore already reach a lot of people. This incentive is in line Perda Number 2/2020 and with BAPPEDA development plan on RISPAM 2018. Moreover, it could be picked up from the smallest administrative division up to subdistricts within KLS[2].

3.2.2.2 School Education Program (AECOM, 2009).

School education about the importance of water conservation is aimed at elementary, junior, and senior high school students. It could significantly change the younger generation's outlook on water use and therefore raise awareness in general in KLS. Raising awareness on effective water use should not only be done at schools within KLS but also at schools nearby KLS—since there are only a few schools in KLS itself. Education on water use could be done, for instance, by inviting PDAM representatives to give presentations, or by PDAM inviting junior and senior high school students to its office to show and explain how drinking water is produced.

3.2.2.3 Financial Incentives (CITY OF VENETA, 2003; SAURI, 2013; AECOM, 2009).

Financial incentives could motivate freshwater users to conserve water. Examples of financial incentives are free installments of water-saving fixtures, and rebate- and reward programs (AECOM, 2009; City of Veneta, 2003). Apart from water bill discounts, rebate programs can be in the form of a reduction on the price of installing water-saving fixtures. Free installment of water-saving fixtures such as low flow faucets can be started by the city government of Semarang in low income residential. A voucher can be given by PDAM to commercial sectors that can reduce their monthly freshwater demand. Later, the voucher can be used to cut the price of the water bill. However, the programs are currently not mentioned in any regulations nor are they in line with Perda Number 2/2020 and BAPPEDA development plan on RISPAM 2018—making it quite challenging to implement.

3.2.2.4 Regulatory Incentives (CITY OF VENETA, 2003; FGD, MARCH 5, 2020).

Whereas financial incentives are a type of 'positive incentive' promoting certain choices/actions, regulatory incentives are a type of 'negative incentive' whereby making specific choices or taking certain actions is (financially) punished. Often this punishment is in the form of fines (City of Veneta, 2003). Fines can be forced upon commercial sectors in KLS which extract more groundwater than allowed. The incentive also relates to strengthening regulations on water conservation. In 2021, every village administration area will receive a budget

[1] Meeting with city government, March 4, 2020.
[2] FGD, March 5, 2020.

of one billion IDR to develop their infrastructure (Maarif, 2020) and this fund could be allocated for water conservation programs. However, the official regulation must be published and explicitly mentions this fund allocation.

3.2.2.5 Water Audits (AECOM, 2009).

The objective of water audits is to reduce freshwater use by educating residents to monitor the monthly amount of freshwater use and to stimulate residents to perform water saving practices (AECOM, 2009). Water audits for commercial sectors must be performed because the amount of freshwater use depends on the sector's scale (AECOM, 2009). An inventory of freshwater use characteristics from visiting commercial sectors can be used to suggest different solutions on efficient freshwater use. This program is in line with PP Number 3/2018 regarding the obligation to install a monitoring well for commercials (Subchapter 3.1.3).

3.2.2.6 Institution and Community's Capacity Building (KODOATIE ET AL., 2010; FGD, MARCH 5, 2020)

The role of communities in KLS must be strengthened so they can optimally participate in educating locals regarding water conservation[1]. Creating a community that has water conservation as its point of departure is another possibility. The members could be residents who are concerned about freshwater quality and quantity, or city government representatives, academia, and more. Successful capacity building requires effective coordination and partnership between the city government and communities. For instance, by exchanging information regarding water conservation between communities and city the government. Village administrations can also be a part of information distribution regarding water conservation and freshwater issues[2]. This measure is in line with BAPPEDA development plan on RISPAM 2018. The cost to form and uphold a (new) community depends on the number of persons involved.

3.3 Feasibility of Potential Water Conservation Measures in KLS

An overview of potential water conservation measures (Subchapter 3.2) and detailed scoring of its feasibility criterion (Table 6 Subchapter 2.2.3) were presented to determine the highest feasibility (highest cumulative score) of potential technical and non-technical measures. The cumulative score per type of measure is shown in Table 14 and Table 15 in the following. The most feasible measure for both technical and non-technical are indicated in green and the least feasible are indicated in red.

[1] FGD, March 5, 2020.
[2] FGD, March 5, 2020.

Table 14. Scoring of potential technical water conservation measures for KLS.

Criteria	Classification	Max. point	RWH			Water-savings fixtures			NRW-Reduction		
			Point	Total point per criteria	Normalized score	Point	Total point per criteria	Normalized score	Point	Total point per criteria	Normalized score
Regulations	Mentioned in a regulation	3,00	1,00	3,00	1,00	1,00	1,00	0,33		2,00	0,67
	In line with Perda on RTBL Number 2/2020		1,00						1,00		
	In line with BAPPEDA's mid-term development plan on RISPAM 2018		1,00						1,00		
	Does not mentioned by or in line with any regulations or development plans										
Existing infrastructures	Possible to retrofit with existing infrastructure	1,50	1,00	1,00	0,67	1,00	1,00	0,67	1,00	1,00	0,67
	Require a small space										
	Require more new space										
Freshwater quality	Usable for non-potable purposes (quality of class II or lower)	1,50	1,00	1,00	0,67	1,00	1,00	0,67	1,00	1,00	0,67
	Has quality of class II or lower, but not usable for locals in KLS										
Water input	Freshwater input is continuously available	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	Freshwater input is not continuously available										
Acceptance	Freshwater savings	1,50	1,00	1,00	0,67	1,00	1,00	0,67	1,00	1,00	0,67
	No reduction on freshwater demand, or only aesthetic										
Cost	Funded by city government	2,00	1,00	1,50	0,75		0,67	0,34	1,00	1,17	0,59
	Total cost		0,50			0,67			0,17		
	Not funded by city government					0,00					
TOTAL SCORE					**4,75**			**3,67**			**4,25**

Table 14 (continued).

Criteria	Classification	Max. point	Retrofit Greywater Treatment			Constructed Wetlands			Buffer Strips			Optimization of RWH		
			Point	Total point per criteria	Normalized score	Point	Total point per criteria	Normalized score	Point	Total point per criteria	Normalized score	Point	Total point per criteria	Normalized score
Regulations	Mentioned in a regulation	3,00	1,00	3,00	1,00	1,00	2,00	0,67	1,00	2,00	0,67	1,00	3,00	1,00
	In line with Perda on RTBL Number 2/2020		1,00			1,00			1,00			1,00		
	In line with BAPPEDA's mid-term development plan on RISPAM 2018		1,00									1,00		
	Does not mentioned by or in line with any regulations or development plans													
Existing infrastructures	Possible to retrofit with existing infrastructure	1,50	1,00	1,00	0,67	1,00	1,00	0,67		0,50	0,33		0,50	0,33
	Require a small space								0,50			0,50		
	Require more new space													
Freshwater quality	Usable for non-potable purposes (quality of class II or lower)	1,50	1,00	1,00	0,67		0,50	0,33		0,50	0,33		0,50	0,33
	Has quality of class II or lower, but not usable for locals in KLS					0,50			0,50			0,50		
Water input	Freshwater input is continuously available	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	Freshwater input is not continuously available													
Acceptance	Freshwater savings	1,50	1,00	1,00	0,67		0,50	0,33		0,50	0,33		0,50	0,33
	No reduction on freshwater demand, or only aesthetic					0,50			0,50			0,50		
Cost	Funded by city government	2,00		0,33	0,17	1,00	1,83	0,92	1,00	2,00	1,00	1,00	1,00	0,50
	Total cost		0,33			0,83			1,00			0,00		
	Not funded by city government		0,00											
TOTAL SCORE					**4,17**			**3,92**			**3,67**			**3,50**

Table 15. Scoring of potential non-technical water conservation measures for KLS.

Criteria	Classification	Max. point	Educational Incentives			School education program			Financial Incentives		
			Point	Total point per criteria	Normalized score	Point	Total point per criteria	Normalized score	Point	Total point per criteria	Normalized score
Regulations	Mentioned in a regulation	3,00		2,00	0,67		0,00	0,00		0,00	0,00
	In line with Perda on RTBL Number 2/2020		1,00								
	In line with BAPPEDA's development plan (RISPAM 2018)		1,00								
	Does not mentioned by or in line with any regulations or development plans					0,00			0,00		
Acceptance	Locals' willingness to get education which relates to water conservation	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Cost	Funded by city government	2,00	1,00	1,75	0,88		0,25	0,13		0,50	0,25
	Total cost		0,75			0,25			0,50		
	Not funded by city government					0,00			0,00		
TOTAL SCORE					**2,54**			**1,13**			**1,25**

Table 15 (continued).

Criteria	Classification	Max. point	Regulatory Incentives			Water Audits			Institution/Community Capacity Building		
			Point	Total point per criteria	Normalized score	Point	Total point per criteria	Normalized score	Point	Total point per criteria	Normalized score
Regulations	Mentioned in a regulation	3,00	1,00	1,00	0,33	1,00	1,00	0,33		1,00	0,33
	In line with Perda on RTBL Number 2/2020										
	In line with BAPPEDA's development plan (RISPAM 2018)								1,00		
	Does not mentioned by or in line with any regulations or development plans										
Acceptance	Locals' willingness to get education which relates to water conservation	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Cost	Funded by city government	2,00	1,00	1,00	0,50		1,00	0,50	1,00	1,00	0,50
	Total cost		0,00			1,00			0,00		
	Not funded by city government					0,00					
TOTAL SCORE					**1,83**			**1,83**			**1,83**

3.3.1 Technical

As shown in Table 16, RWH is the most feasible technical measure in KLS because all criteria for RWH are met. It is specifically mentioned in regulation; in line with both regional regulations regarding buildings and environmental planning and infrastructure of freshwater provision. The only drawback of RWH is the cost (IDR 476 million). The least feasible of technical measures is RTH optimization. Although it is mentioned in regulations and in line with development plan, not only must vacant spaces be transformed into green areas, the measure also does not result in freshwater savings. The measures RWH and NRW reduction are in line with development plan and/or mentioned in regulations and are in the top two of potential feasible technical measures. Both measures are funded by the city government, and the freshwater it produces is usable for locals. The bottom two measures are water-saving fixtures and RTH. Water-saving fixtures score higher than RTH optimization because freshwater can be saved by implementing the measure, while RTH optimization can only improve the freshwater quality and has an aesthetic value. Although water-saving fixtures installation is supported by Perwal Number 24/2019, there is no statement about providing funds (from city government) for the implementation.

Table 16. Feasibility of the potential water conservation of technical measure for KLS (ranked from the most feasible to the least).

Measure	Total Score	Description
RWH	4,75	The most feasible
NRW Reduction	4,25	
Retrofit greywater treatment	4,17	
Constructed wetlands	3,92	
Buffer strips	3,67	
Water-saving fixtures	3,67	
RTH Optimization	3,50	The least feasible

3.3.2 Non-technical

As shown in Table 17, educational incentives are the most feasible non-technical water conservation measure for KLS. It is in line with BAPPEDA's development plan on RISPAM. The total cost of an educational incentive is considerably low (IDR 250 Million) and funded by the city government. The least feasible of non-technical measure is the school education program. This program is not in line with any regulations, and its approximate cost is the highest (IDR 17 Billion). The educational incentives and regulatory incentives are in line with development plan or mentioned in a regulation, and are in the top two of the potential feasible non-technical measures. Moreover, both measures are funded by either BAPPEDA or PDAM. The two least feasible measures—school education program and financial incentives—are either costly or cannot be funded by city government. On top of that, the measures are not related or mentioned in any regulation or development plan. In addition, regulatory incentives, water audits, and institutional/community capacity building all three obtained the same score. These measures are either in line with a regulation or with BAPPEDA's development plan.

Table 17. Feasibility of the potential water conservation of non-technical measure for KLS (ranked from the most feasible to the least).

Measure	Total Score	Description
Educational incentives	2,54	The most feasible
Regulatory incentives	1,83	
Water audits	1,83	
Institution/community capacity building	1,83	
Financial Incentives	1,25	
School education program	1,13	The least feasible

Chapter 4: Discussion

4.1 Limitations

4.1.1 Methods Limitation and Results Reliability

At its most basic, there is freshwater scarcity—in terms of quantity—when freshwater demand (or extraction) exceeds freshwater supply (or recharge). The deficit between supply and demand is used as the parameter to indicate that a region is in need of water conservation measures. However, data for a new, somewhat special city as Kota Lama Site are not yet available. Thus, data from a 'higher' level of administrative units have been used, and assumptions were used to calculate the annual amount of supply and demand from PDAM to KLS. Surface water (PDAM) supply and demand data on the level of subdistrict were considered. The volume of groundwater recharge (supply) has been approximated by considering groundwater recharge data on a basin scale. The groundwater extraction amount (demand) is approached by using the decrease rate of groundwater level data.

Prior scoring for total cost classification was performed. It is difficult to quantitatively categorize the total cost; in a way to determine which of the costs are the most and least expensive. In addition, total cost information for some technical measures are based on the cost per unit. Thus, the number of units that is potentially needed were assumed based on the conditions of KLS. Moreover, the total cost for RTH optimization, institutional/community capacity building, and regulatory incentives were considered as zero due to lack of information. Total cost for the mentioned measures exclusively depend on the number of people involved in creating a new regulation and community (City of Veneta, 2003), the cost of converting land from paved into green spaces, the rent cost if the land is not owned by city government, and the number of plants/trees that needs to be planted in KLS. If these are known, the total score for each measure will be different and its rank on feasibility could also change.

Although data about KLS specifically is scarcely available, the procedure of translating information that has been gathered into the results of the feasibility of water conservation measures, is considered as reliable. It provides a general picture about the reality of freshwater scarcity in KLS and offers conservation measures that are appropriate for KLS. As shown in Table 168 and Table 1719, RWH and educational incentives are the most feasible measures for the city.

RWH is beneficial to reduce locals' freshwater demand (for freshwater from PDAM and wells) by collecting the currently unutilized rainwater for non-potable purposes in KLS. According to BAPPEDA (2018), simple RWH is being implemented in other regions in Semarang (BAPPEDA, 2018; Abadi et al., 2018). The authorities agree on its importance. Thus, RWH has become the most discussed measure regarding freshwater provision programs in Semarang (BAPPEDA, 2018).

The educational incentive is exclusively intended to raise awareness of adults (residents and visitors) in KLS about water-saving practices. J. Setiawati (personal communication, January 23, 2020) from AMbO community mentioned that "*[…] the information which relates to water conservation practices has never been communicated before. Thus, locals in KLS are not aware about either freshwater scarcity or the benefits from water-saving practices, including me. There is a high possibility that locals will integrate water-saving practices or support any water conservation measure, if locals can witness its real benefits. Because in principal, locals in KLS are open to any positive advice. What is needed now is just initiating a pilot project and/or starting a dissemination of knowledge regarding these matters. […]*". Along with J. Setiawati, representatives of BPK2L and BPP Sima community share a similar thought.

4.1.2 Implication of Different Weighing

There is little data and information available that can give insights on which of the selected criteria is the most important. This study therefore applied equal weighing for each criterion to score the most feasible water conservation measures in KLS. However, insufficient funds and a weak enforcement of regulations are considered as the main culprits hindering improvements to water management and its infrastructures in Indonesia (Drosou et al., 2019; Rahmasary et al., 2019). To observe the implication of different weighing to the feasibility scoring, a weight of 2 is given to the cost and regulations criteria, while the weighing for other criteria stays the same. The result of this different weighing and its comparison to the equal weighing is shown in Table 18 and Table 19.

Table 18. Results comparison between different and equal weighing for technical measures.

Different weighing	Total Score	Equal weighing	Total Score	Description
RWH	6,50	RWH	4,75	The most feasible
Constructed wetlands	5,83	NRW Reduction	4,25	
Buffer strips	5,67	Retrofit greywater treatment	4,17	
NRW Reduction	5,50	Constructed wetlands	3,92	
Retrofit greywater treatment	5,33	Buffer strips	3,67	
RTH Optimization	5,00	Water-saving fixtures	3,67	
Water-saving fixtures	4,34	RTH Optimization	3,50	The least feasible

Different weighing resulted in a different feasibility rank of the potential technical measures. However, the RWH is still the most feasible technical measures for both scoring systems. The least feasible technical measure changed to water-saving fixtures.

Table 19. Results comparison between different and equal weighing for non-technical measures.

Different weighing	Total Score	Equal weighing	Total Score	Description
Educational incentives	4,08	Educational incentives	2,54	The most feasible
Regulatory incentives	2,67	Regulatory incentives	1,83	
Water audits	2,67	Water audits	1,83	
Institution/community capacity building	2,67	Institution/community capacity building	1,83	
Financial Incentives	1,50	Financial Incentives	1,25	
School education program	1,25	School education program	1,13	The least feasible

The change of weighing did not affect the rank of the feasible non-technical water conservation measures. More criteria are potentially needed to observe the change in the feasibility rank for both scenarios. For both scenarios, the educational incentive is the most feasible measure and the school education program is the least feasible (Table 19).

4.2 Comparing the Feasibility of Different Measures Throughout the World

The selection of water conservation measures is different between developing and developed countries, depending on the issues faced by a country. In India, the most appropriate technical water conservation measures to combat its freshwater usage issues are similar with KLS, that is, implementation of RWH, wastewater reuse, and NRW reduction (Matto et al., 2017). This is because the efficient freshwater use practices in India and KLS are challenged by identical “unconscious” water-wasting practices such as unutilized rainwater and its run-off, excessive use of freshwater during bathing and toilet flushing, and water waste from leakages due to poor maintenance of water infrastructures or NRW (Matto et al., 2017). Raising people’s awareness through educational incentives is also the most feasible non-technical water conservation method for India (Matto et al., 2017). When compared to Brazil, the feasible water conservation measures are different. For KLS, implementing water-saving fixtures is considered as one of the least feasible measures, while the use of water-saving fixtures and/or appliances in Brazil are proven to be the most feasible measures. (Sant'Ana, 2011). Sant'Ana (2011) found that people in Brazil are already aware about the importance of water-savings practices, and about 74,4 % of locals are willing to privately invest for the retrofitting of water-saving fixtures for their dwelling. While on the contrary, locals in KLS are not yet aware about the importance of water-saving practices, let alone about water-saving fixtures. Locals in KLS tend to waste water because they assume that KLS still has a lot of rainfall, and when there is no or less supply of freshwater from PDAM and wells they can always buy freshwater from other areas, for example, by calling a supplier in Ungaran to deliver freshwater using a water tank truck[1].

There are also clear differences in the feasibility of water conservation measures between the United States (US) and KLS. Whereas in KLS financial incentives, school education program, and water-saving fixtures are among the least feasible measures; these are precisely the measures that have been proven to work in the US. In the US, the most feasible water conservation measures include rebate programs for a replacement of inefficient water appliances, rebates for installation and retrofitting of water-saving fixtures, and school education program on water conservation (A. W. W. A., 2005).

According to A. W. W. A (2005), water agencies throughout the US recognize the importance of water conservation measures. Throughout various states, city governments such as Fort Collins, Town of Cary, and Austin have actively formed partnerships with water retailers/companies to disseminate the importance and benefits of water-saving practices. Many rebate programs for water-saving fixtures installation, replacement, and retrofitting such as for household and commercial sectors, are funded by regional water agencies and/or the city government.

In the US, financial incentives receive funding from partnerships between the city government and private or regional water companies, while this is not the case for KLS. According to BAPPEDA (2018), although Semarang's city government is aware of the significance of forming partnerships, its primary goal is to cover the needs of funding for the development of water provision infrastructures.

Although educating children about water conservation from primary school onward will have a great positive impact in facing the even more challenging freshwater scarcity in the future (Zhan et al., 2019), school education program is the least feasible measure in KLS. School education program is difficult to implement since it is not mentioned in any regulation/policy nor is it in line with any development plan for KLS. Thus, the city government does not have the financial obligation to allocate funds for the implementation of the program. Moreover, the APBD fund is only prioritized for physical infrastructures such as roads and buildings, not for enhancing society's knowledge[2]. In addition, the role of society in water conservation (Article 63 UU Number 17/2019) does not include the citizens' right to get education about water conservation.

To integrate the water conservation topic in school curricula, the national curriculum needs to be updated following the agenda of PP Number 32/2013 about national education standards. Updating the curriculum in Indonesia is challenging because it will involve many discussions between various governmental personnel, and it has to be done in stages (Hadijaya, 2017). When the water conservation topic is included in the curriculum, new teaching materials on the topic will be needed. Consequently, a relatively large budget is needed in order to implement the school education program.

[1] (H. Ahmad, personal communication, February 27, 2020)
[2] (H. Ahmad, personal communication, February 27, 2020)

4.3 Implications of the Study

4.3.1 Policy/Management

Essentially, the implementation of water conservation in developing countries is delayed by weak and fragmented regulations as well as weak law enforcement on water conservation, poor maintenance of water infrastructures causing a high number of Non-Revenue Water (NRW), and a lack of incentives regarding efficient freshwater use (Sharma & Vairavamoorthy, 2009). In addition to this, the importance of water conservation practices to resolve freshwater scarcity in Indonesia, including KLS, is acknowledged by merely a few scientists. On top of that, the implementation of the measures is seen as a less promising investment in terms of its profit[1]. Moreover, A. S. Winarto (personal communication, January 28, 2020) states that *"[…] the important thing for any proposed conservation measure is that it can give a significant high profit to investors. […] And, it is a guarantee that, in general, households in KLS will not implement any measure that will cost them money because they simply cannot afford for it. […]"*.

Water infrastructure development in KLS must in line with Perda Number 2/2020, but it is only limited to improving PDAM water distribution pipes. Whereas according to UU Number 17/2019, any development that is related to spatial planning of any region in Indonesia must refer to water conservation rules and actions which are mentioned in the UU. Although water conservation is mentioned in UU Number 17/2019 (Article 24 to 27), the explanation about the importance of water conservation measures to cope with freshwater scarcity is not. Moreover, many regulations which relate to the implementation of water conservation measures (such as Permenpu Number 11/2014, Permen LH Number 12/2009, and Perwal Number 24/2019) are only intended to be implemented to buildings with certain criteria (e.g. new buildings, building areas of 300 m^2, etc.) and not for all existing buildings.

Taking these challenges into consideration, it becomes clear that to successfully integrate the water conservation concept for reducing freshwater scarcity, the city of Semarang needs to:

1) strongly enforce UU Number 17/2019 because it contains laws about punishing violations (Article 68 and 69);
2) strongly enforce PP Number 3/2018 about groundwater management because the existence of usable fresh groundwater is very important considering that commercial sectors, offices, and public facilities are the largest users of groundwater in KLS;
3) create a guideline on assessing the feasibility of water conservation measures which are appropriate for coastal city like KLS. In addition, this study could contribute by functioning as the first step for the city government of Semarang to perform the feasibility assessment;
4) create a specific and well-defined policy or regional regulation (Perda) regarding water conservation measures. It must clearly state the responsibility of city governments to allocate funds for water conservation measures implementation, for both the technical and non-technical ones;
5) focus on the implementation of roof-water harvesting and strengthen the role of existing communities and village administrations (*kelurahan*) to disseminate information on water-saving practices and its benefits;
6) enhance partnerships on water conservation with private companies from co-funding to profit sharing;
7) publicly share all data and information so that future research on water conservation measures can produce more accurate results;
8) involve the role of experts and scientists in the field of water sciences and management during the drafting of a policy or regulation about freshwater resources management;
9) integrate water conservation topic in school curricula starting from primary level (elementary school); and

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[1] (D. Suwarno, personal communication, February 20, 2020)

10) conduct primary surveys to get a complete picture regarding the actual amount of freshwater usage from PDAM and wells, the exact amount of brand (non-refillable) and refillable bottled water usage, and the number of populations (residents and visitors) of KLS.

4.3.2 Scientific

This study investigates the most feasible potential water conservation measures as an attempt to counteract freshwater scarcity in coastal cities such as KLS. This investigation considers the perspectives of four different freshwater users regarding their water conservation needs. In terms of water conservation, this study has:

1) identified the feasibility criteria of water conservation measures that are perceived as important requirements for four different freshwater users (household, office, commercial, and public facility) in order to implement a water conservation measure in a coastal city such as KLS;
2) offered a better understanding of freshwater supply and demand characteristics in a city such as KLS, which is being developed economically; and
3) offered a better understanding of how different freshwater users in KLS cope with the "unconscious" freshwater scarcity.

This study suggests that the freshwater demand "footprint" between regions is important to be included as an additional element in determining freshwater scarcity in coastal cities of developing countries. During less or no supply from PDAM and wells, freshwater users in KLS usually buy water from other regions outside KLS. This means that freshwater quantity in another region decreases. Having a dependency on freshwater supply from other regions could make other regions become more vulnerable to freshwater scarcity or even exacerbate its freshwater scarcity problems. For example, when locals in KLS buy water from Ungaran region to meet its demand during scarcity, it also means that freshwater resources in Ungaran are depleting. D. Suwarno (personal communication, February 20, 2020) states that *"[…] I live in the mountain range area near Kopengan. I witnessed it myself that my private well is empty for two years. We (residents) have been facing this scarcity long enough. We are having difficulties to fulfill our daily needs of freshwater. When I checked the nearby springs, it is empty, until now. Nearest wells are also empty. Later I found that all the water is directed to commercial husbandry and other commercial sectors in Semarang and Salatiga. […]"*. Therefore, by taking the freshwater demand "footprint" aspect into consideration, a more accurate overview of the freshwater scarcity characteristics of a region could be provided. Hence, more suitable water conservation measures could be investigated. This could also lead to finding solutions on how a region can fulfill its own freshwater demand without moving their scarcity burden to other regions.

Lastly, the results of the study could be used as a follow-up action for the city government of Semarang in the future, to reduce freshwater scarcity in KLS. This study could also be useful for universities in Semarang to conduct future studies regarding feasible water conservation measures specifically in KLS and Semarang's city in general.

Chapter 5: Conclusion

Over the years, freshwater scarcity has become the invisible problem for the inhabitants of Kota Lama Site. The scarce supply of freshwater sourced from the regional drinking water agency, its poor quality, and the fact that brackish groundwater is found almost everywhere in Kota Lama Site have not alerted the locals nor Semarang government that this freshwater scarcity issue exists. In 2016, the city government of Semarang initiated the revitalization project of Kota Lama Site so it could be on the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage list. This revitalization has increased the number of visitors and the commercial sector in Kota Lama Site; exacerbating its freshwater scarcity. Thus, this scarcity needs to be counteracted with water conservation measures that fit Kota Lama Site. To resolve this matter, this study provides answers to the following research question: *"What are the most feasible water conservation measures for Kota Lama Site to overcome its freshwater scarcity?"*

The study identifies the most feasible water conservation measures in Kota Lama Site, first by investigating the characteristics of its freshwater scarcity. Second, by exploring potential water conservation measures that suit Kota Lama Site. Lastly, by scoring the selected potential measures based on feasibility criteria. The study results show that implementation of roof-water harvesting and educational incentives are highly feasible for Kota Lama Site to cope with its freshwater scarcity. With implementing roof-water harvesting, the abundant amount of rainfall in Kota Lama Site can be conserved and used to minimize the demand for freshwater from groundwater (well) and the regional drinking water agency. The extreme lack of knowledge in adults (residents and visitors) regarding efficient freshwater use practices can be overcome with educational incentive measures, considering that residents in Kota Lama Site are very welcome to constructive advice and information.

There is a great confidence that Kota Lama Site will be able to overcome its freshwater scarcity, if the implementation of roof-water harvesting and educational incentives are collectively combined with well-defined regulations, a vigorous law enforcement, and a solid funding from Semarang's city government.

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Appendix I FGD and Meeting Information

Table 20. FGD Group 1 (City administration).

No.	Name	Organization
1.	Fajar Hartawan	BAPPEDA
2.	Nur Wachid	DPU
3.	Ligis Tri Novaldi	DPU
4.	Mila S.	DISTARU
5.	Herdias R.	PDAM
6.	Ngadiyono	PDAM
7.	R. Magut Ari	PDAM
8.	Pratiwi	DLH
9.	Dwi S.	DLH
10.	Hanu Ardiyanto	DISPERKIM
11.	Yusi Kurniasih	DINKES

Table 21. FGD Group 2 (Semarang Subdistrict, counterpart consultant, and communities).

No.	Name	Organization
1.	Eko Supriadi	Head of Central Semarang Subdistrict
2.	Dwi Rahmi	BPK2L
3.	Tjahjono Rahardjo	BPK2L
4.	Jessi Setiawati	AMbO
5.	Purnomo	ESP-PPC
6.	S. Suwono	ESP-PPC
7.	Uyat S.	ESP-PPC

Figure 6. FGD documentation on March 5, 2020.

Table 22. Attendance list of city government officers in the coordination meeting at BAPPEDA

No.	Name	Organization
1.	Danang	DPU
2.	Fajar Hartawan	BAPPEDA
3.	Yuni Hastuti	Head of planning and evaluation of DLH
4.	Putri	BAPPEDA
5.	Wiwik	DLH

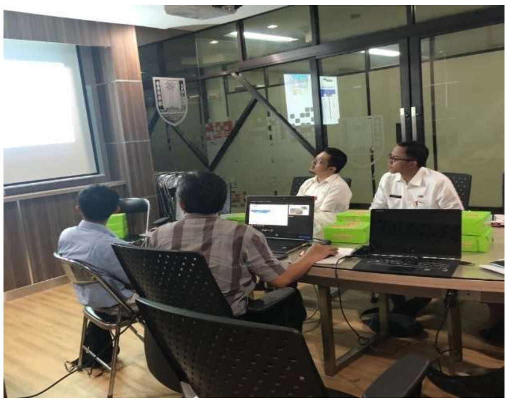

Figure 7. Meeting documentation at BAPPEDA on March 4, 2020.

Appendix II Supply, Demand, and NRW Calculations

A. Calculation of total annual PDAM freshwater supply in KLS.

Using an assumption that PDAM supply is evenly distributed throughout the North, Central, and East Semarang Subdistricts, hence the total annual supply in KLS can be calculated as follow.

Table 23. Freshwater supply from PDAM in North, Central, East Semarang Subdistricts, and calculated freshwater supply for KLS.

Subdistricts	Area*) (m^2)	Area KLS**) (m^2)	Total supply***) (m^3/s)	Total supply per subdistrict (m^3/year)	Total supply per subdistrict within KLS (m^3/year)	Total supply per subdistrict within KLS (L/year)
North	10.970.000,00	469.181,04	0,32	9.954.969,12	425.768,71	425.768.712,38
Central	6.140.000,00	220.781,94	0,18	5.744.913,12	206.575,42	206.575.419,42
East	7.700.000,00	33.778,00	0,17	5.378.780,16	23.595,38	23.595.383,43
Total	**24.810.000,00**	**723.740,99**	**0,67**	**21.078.662,40**	**655.939,52**	**655.939.515,23**

*) Total area per subdistrict (BAPPEDA, 2018)

**) Total area per subdistrict within KLS. Calculated from Open Street Map (OSM) Indonesia (n. d.).

***) Calculated from Regional Planning and Development Agency (BAPPEDA) (2018)

Total supply within KLS (m^3/year):

$$TSsub1KLS = \frac{TSsub1 \times PASub1}{TASub1}$$

$$TSsub2KLS = \frac{TSsub2 \times PASub2}{TASub2}$$

$$TSsub3KLS = \frac{TSsub3 \times PASub3}{TASub3}$$

$$TSKLS = TSsub1KLS + TSsub2KLS + TSsub3KLS$$

Where,

TSSUb1KLS	: total supply in North Semarang Subdistrict within KLS (m^3/year)
TSSUb2KLS	: total supply in Central Semarang Subdistrict within KLS (m^3/year)
TSSUb3KLS	: total supply in East Semarang Subdistrict within KLS (m^3/year)
TSSUb1	: total supply in North Semarang Subdistrict (m^3/year)
TSSUb2	: total supply in Central Semarang Subdistrict (m^3/year)
TSSUb3	: total supply in East Semarang Subdistrict (m^3/year)
PASub1	: portion of KLS area within North Semarang Subdistrict (m^2)
PASub2	: portion of KLS area within Central Semarang Subdistrict (m^2)
PASub3	: portion of KLS area within East Semarang Subdistrict (m^2)
TASub1	: total area of North Semarang Subdistrict (m^2)
TASub2	: total area of Central Semarang Subdistrict (m^2)
TASub3	: total area of East Semarang Subdistrict (m^2)
TSKLS	: total supply of KLS (m^3/year)

B. Calculation of total annual PDAM freshwater demand in KLS.

Due to the fluctuation of daily demand in a year, hence maximum daily demand data were used. And, using an assumption that PDAM demand is evenly distributed throughout the North, Central, and East Semarang Subdistricts, hence the total annual demand in KLS can be calculated as follow.

Table 24. Freshwater demand (PDAM) in North, Central, East Semarang Subdistricts, and calculated freshwater demand for KLS.

Subdistricts	Area*) (m^2)	Area KLS**) (m^2)	Total demand***) (m^3/s)	Total demand per subdistrict (m^3/year)	Total demand per subdistrict within KLS (m^3/year)	Total demand per subdistrict within KLS (L/year)
North	10.970.000,00	469.181,04	0,33	10.368.406,08	443.451,19	443.451.190,35
Central	6.140.000,00	220.781,94	0,19	5.845.197,60	210.181,45	210.181.445,85
East	7.700.000,00	33.778,00	0,18	5.795.686,08	25.424,25	25.424.246,99
Total	**24.810.000,00**	**723.740,99**	**0,70**	**22.009.289,76**	**679.056,88**	**679.056.883,18**

*) Total area per subdistrict (BAPPEDA, 2018)

**) Total area per subdistrict within KLS. Calculated from Open Street Map (OSM) Indonesia (n. d.).

***) Calculated from Regional Planning and Development Agency (BAPPEDA) (2018)

Total demand within KLS (m^3/year):

$$TDsub1KLS = \frac{TDsub1 \times PASub1}{TASub1}$$

$$TDsub2KLS = \frac{TDsub2 \times PASub2}{TASub2}$$

$$TDsub3KLS = \frac{TDsub3 \times PASub3}{TASub3}$$

$$TDKLS = TDsub1KLS + TDsub2KLS + TDsub3KLS$$

Where,

TDSUb1KLS	: total demand in North Semarang Subdistrict within KLS (m^3/year)
TDSUb2KLS	: total demand in Central Semarang Subdistrict within KLS (m^3/year)
TDSUb3KLS	: total demand in East Semarang Subdistrict within KLS (m^3/year)
TDSUb1	: total demand in North Semarang Subdistrict (m^3/year)
TDSUb2	: total demand in Central Semarang Subdistrict (m^3/year)
TDSUb3	: total demand in East Semarang Subdistrict (m^3/year)
PASub1	: portion of KLS area within North Semarang Subdistrict (m^2)
PASub2	: portion of KLS area within Central Semarang Subdistrict (m^2)
PASub3	: portion of KLS area within East Semarang Subdistrict (m^2)
TASub1	: total area of North Semarang Subdistrict (m^2)
TASub2	: total area of Central Semarang Subdistrict (m^2)
TASub3	: total area of East Semarang Subdistrict (m^2)
TDKLS	: total demand of KLS (m^3/year)

C. Calculation of total annual recharge (supply) of unconfined and confined aquifers in Semarang-Demak and KLS.

Using assumptions that sediment type for unconfined and confined aquifers is homogenous and the surface area of unconfined aquifer is equal to area of the confined aquifer, hence the annual increase of Semarang-Demak groundwater basin for both aquifers can be calculated. Total area is 1.915.000.000 m^2; annual recharge volume for the unconfined aquifer is 783.000.000 m^3/year; and annual recharge volume for the confined is 91.000.000 m^3/year (Susanto, 2010).

$$AIU = \frac{ARVU}{TA} \qquad AIC = \frac{ARVC}{TA}$$

Where,

AIU : Semarang-Demak annual increase of groundwater level in the unconfined aquifer (m/year)
AIC : Semarang-Demak annual increase of groundwater level in the confined aquifer (m/year)
ARVU : Semarang-Demak annual recharge volume of the unconfined aquifer (m^3/year)
ARVC : Semarang-Demak annual recharge volume of the confined aquifer (m^3/year)
TA : total area of Semarang-Demak groundwater basin (m^2)

Based on Putranto & Rude (2011), annual increase of Semarang-Demak groundwater level is 0,316 m in its unconfined aquifer. By averaging results of *AIU* and Putranto & Rude (2011), hence the annual increase of Semarang-Demak groundwater level is 0,36 m/year for the unconfined aquifer. Next, using the same assumptions, annual recharge rate in KLS for unconfined and confined aquifers can be calculated as follow.

$$ARU = AIU\ average \times KLSA \qquad ARC = AIC \times KLSA$$

Where,

ARU : KLS annual recharge in the unconfined aquifer (m^3/year)
ARC : KLS annual recharge in the confined aquifer (m^3/year)
KLSA : KLS area; 723.740,99 (m^2)

Table 25. Calculated annual increase groundwater level of Semarang-Demak and annual recharge (supply) of KLS.

Aquifer type	Semarang-Demak annual recharge (m3/year)	Semarang-Demak annual increase of groundwater level (m/year)	KLS annual recharge (m^3/year)	KLS annual recharge (L/year)
Unconfined	783.000.000,00	0,36*)	260.546,75	260.546.754,96
Confined	91.000.000,00	0,05	34.391,87	34.391.869,31
*) Averaging from: (0,41 m (*AIU*) + 0,316 m) / 2 = 0,36 m (*AIU average*)				

D. Calculation of total annual extraction (demand) of unconfined and confined aquifers in KLS.
Using the assumptions from previous part (C), hence the annual extraction in KLS can be calculated.

Table 26. Calculated annual decrease of groundwater level of Semarang-Demak and annual extraction (demand) of KLS.

Aquifer type	Semarang-Demak annual decrease of groundwater level (m/year)	KLS annual extraction (m^3/year)	KLS annual extraction (L/year)
Unconfined	0,10	72.374,10	72.374.098,60
Confined	0,40	289.496,39	289.496.394,40

$$AEU = ADU \times KLSA \qquad AEC = ADC \times KLSA$$

Where,

AEU	: KLS annual extraction in unconfined aquifer (L/year)
AEC	: KLS annual extraction in confined aquifer (L/year)
ADU	: KLS annual decrease of groundwater level in unconfined aquifer (m/year)
ADC	: KLS annual decrease of groundwater level in confined aquifer (m/year)
KLSA	: KLS area; 723.740,99 (m^2)

E. Calculation of total NRW (%) according to BAPPEDA (2018).

Table 27. NRW of North, Central, and East Semarang Subdistricts 2017-2038 compared to Semarang City (BAPPEDA, 2018).

Subdistrict	NRW (L/s)					
	2017	2018	2023	2028	2033	2038
North	71,61	75,77	87,71	80,52	72,44	63,26
Central	38,16	42,72	42,77	37,44	32,06	26,60
East	37,83	42,35	47,30	41,26	35,21	29,09
Semarang	750,71	829,54	1.049,28	1.012,59	962,14	891,9

$$\% \, NRWsub1 = \frac{Vsub1 \, NRW}{Vsem \, NRW} \times 100 \, \%$$

$$\% \, NRWsub2 = \frac{Vsub2 \, NRW}{Vsem \, NRW} \times 100 \, \%$$

$$\% \, NRWsub3 = \frac{Vsub3 \, NRW}{Vsem \, NRW} \times 100 \, \%$$

$$\% \, T.NRW = \% \, NRWsub1 + \% \, NRWsub2 + \% \, NRWsub3$$

Where,

% NRWsub1	: NRW in North Semarang Subdistrict (%)
% NRWsub2	: NRW in Central Semarang Subdistrict (%)
% NRWsub3	: NRW in East Semarang Subdistrict (%)
% T.NRW	: total NRW in three subdistricts (%)
Vsub1 NRW	: NRW in North Semarang Subdistrict (L/s)
Vsub2 NRW	: NRW in Central Semarang Subdistrict (L/s)
Vsub3 NRW	: NRW in East Semarang Subdistrict (L/s)
Vsem NRW	: NRW for the entire Semarang City (L/s)

Table 28. NRW percentage of North, Central, and East Semarang Subdistricts 2017-2038 compared to Semarang City. Obtained and calculated from (BAPPEDA, 2018).

Region	NRW (%)					
	2017	2018	2023	2028	2033	2038
North	9,54%	9,13%	8,36%	7,95%	7,53%	7,09%
Central	5,08%	5,15%	4,08%	3,70%	3,33%	2,98%
East	5,04%	5,11%	4,51%	4,07%	3,66%	3,26%
North + Central + East	19,66%	19,39%	16,94%	15,72%	14,52%	13,34%
Semarang City	39,14%	38,23%	33,67%	29,11%	24,56%	20,00%

Appendix III Freshwater Quality

Groundwater quality in Semarang, freshwater quality inputs of WTP Kudu and Kaligarang, and freshwater quality standard of WHO and PP Number 82/2001.

Table 29. Groundwater quality in Semarang and freshwater quality standards (Putranto & Rüde, 2011; PP Number 82/2001).

Parameter	Measurement	Class I	Class II	Class III	Class IV
Sediment type	Quaternary marine	no information	no information	no information	no information
TDS (mg/l)	817	1000	1000	1000	2000
pH (-)	7,34	6 – 9	6 – 9	6 – 9	6 – 9
EC (μS/cm)	1200	no information	no information	no information	no information
K^+ (mg/l)	10,6	no information	no information	no information	no information
Ca^{2+} (mg/l)	42,6	no information	no information	no information	no information
Mg^{2+} (mg/l)	13,4	no information	no information	no information	no information
Na^+ (mg/l)	168	no information	no information	no information	no information
SO_4^{2-} (mg/l)	79,5	400	(-)	(-)	(-)
Cl^- (mg/l)	215,4; 794,8$^{*)}$	600	(-)	(-)	(-)
HCO_3^- (mg/l)	253,2	no information	no information	no information	no information
$^{*)}$ Suhartono et al., 2013 (-) not required					

Table 30. WHO standard of freshwater quality (Abbas et al., 2017).

Parameters	WHO
pH	6,5 – 8,5
EC (mS/cm)	1500
TDS (mg/l)	1000
TH as CaCO3 (mg/l)	500
Ca2+ (mg/l)	75 – 200
Mg2+ (mg/l)	30 – 150
Na+ (mg/l)	200 – 400
K+ (mg/l)	12
SO4 (mg/l)	200 – 400
Cl- (mg/l)	200 – 600
NO3- (mg/l)	10 – 45
PO4- (mg/l)	5

Table 31. Freshwater input quality for WTP Kudu and WTP Kaligarang. Restructured and modified from (PP Number 82/2001; DLH Grobogan, 2011; Aprillia, 2018).

Parameter	Results		Quality standards			
	Input for WTP Kudu	Input for WTP Kaligarang**)	Class I	Class II	Class III	Class IV
Total Dissolved Solids (mg/L)	150*) – 298**)	135	1000	1000	1000	2000
Total Suspended Solids (mg/L)	0*) – 48,5**)	< 5	50	50	400	400
pH (-)	6,42**) – 8,8*)	9,3	6 – 9	6 – 9	6 – 9	5 – 9
Iron (mg/L)	0,085**)	0,07	0,3	(-)	(-)	(-)
Mangan (mg/L)	0,301**)	0,03	0,1	(-)	(-)	(-)
Cadmium (mg/L)	< 0,002**)	0,006	0,01	0,01	0,01	0,01
Zinc (mg/L)	< 0,001**)	0,02	0,05	0,05	0,05	2
Lead (mg/L)	< 0,005**)	0,03	0,03	0,03	0,03	1
Copper (mg/L)	< 0,004**)	0,01	0,02	0,02	0,02	2
Chromium Hexavalent (mg/L)	< 0,003**)	0,008	0,05	0,05	0,05	1
Nitrate (mg/L)	0,742**) – 2,10*)	0,02	10	10	20	20
Ammonia (mg/L)	0,01**) – 0,05*)	0,11	0,5	(-)	(-)	(-)
Phosphate (mg/L)	0*) – 0,336**)	1,43	0,2	0,2	1	5
Chemical Oxygen Demand (mg/L)	14,13**) – 54*)	16	10	25	50	100
Biological Oxygen Demand (mg/L)	8,14**) – 14*)	5	2	3	6	12
Chloride (mg/L)	0*) – 19,29**)	14	600	(-)	(-)	(-)
Phenol (μg/L)	0,003*)	360	1	1	1	(-)
Grease & Fat (μg/L)	0*)	4000	1000	1000	1000	(-)
Detergent (mg/L)	270*)	-	200	200	200 (-)	

(-) not required
- no information
*) Regional Environmental Status (SLHD) Grobogan (2012)
**) Aprillia (2018)

Appendix IV Freshwater Users Perspectives in KLS (Based on Interview Results)

Following graphs are resulted from interviews with freshwater users in KLS and are presented to provide insight to readers (not intended for a statistical analysis) regarding freshwater sources and usage, PDAM and well quality, reusing greywater practices, freshwater scarcity (shortage) in the last five years, and a necessity to have a freshwater saving system or device. Freshwater sources include sources for potable (Figure 9 and Figure 16) and non-potable uses (Figure 10 and Figure 17). Freshwater quality of PDAM and well (Figure 11 and Figure 18) are presented to show if freshwater from PDAM and well are in a need of quality improvement or both sources are acceptable to be directly utilized for non-potable uses only. Greywater reuse practices (Figure 12 and Figure 19) relate to existing of greywater reuse which are performed by local inhabitants in KLS. Freshwater scarcity in the last five years (Figure 13 and Figure 20) relates to the supply freshwater from the regional water company (PDAM), when it is not available or has a small debit (insufficient amount of freshwater for daily non-potable uses). Necessity to have a freshwater saving system or device (Figure 14 and Figure 21) relates to local inhabitants' opinions about their needs to use a freshwater saving system or device in the future.

Freshwater usage relates to monthly amount of freshwater which is used by households, offices, public facilities, and commercials. The amount of 17.280 L (Figure 8) is the average daily of freshwater use by a household (144 L/person/day x 4 persons x 30 days). The amount of 150.000 L (Figure 15) is the upper limit of daily freshwater consumption by non-domestic sectors. According to Human Resources Development Agency (BPSDM) (n. d.), the daily freshwater use of non-domestic sectors is ranging from 600 L to 5.000 L. Thus, the amount of 5.000 L per day is used to distinguish the total monthly freshwater use amongst non-domestic sectors.

A. Household

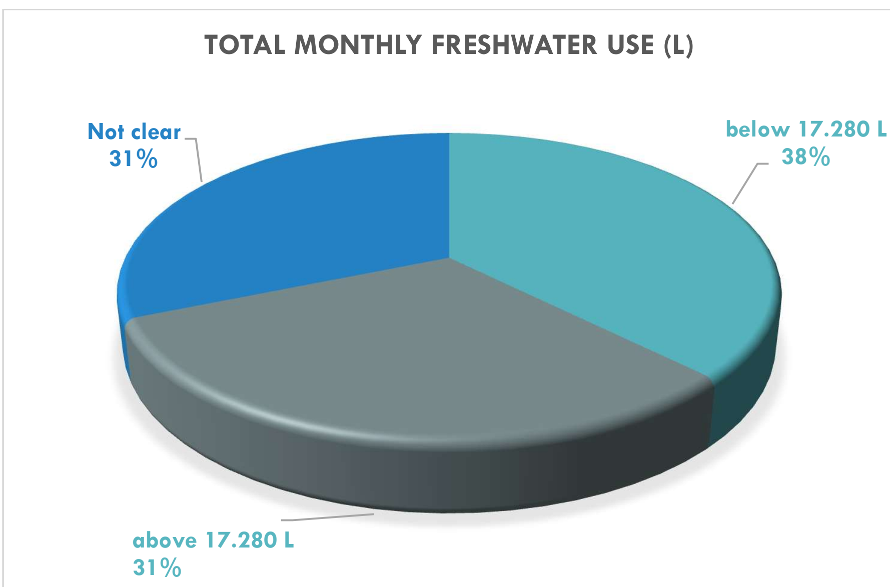

Figure 8. The total monthly freshwater use (household).

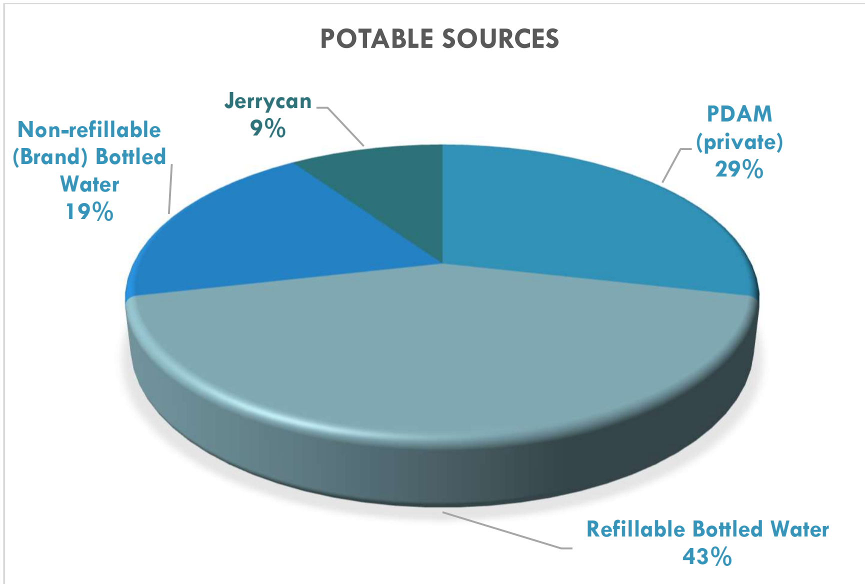

Figure 9. Potable freshwater sources (household).

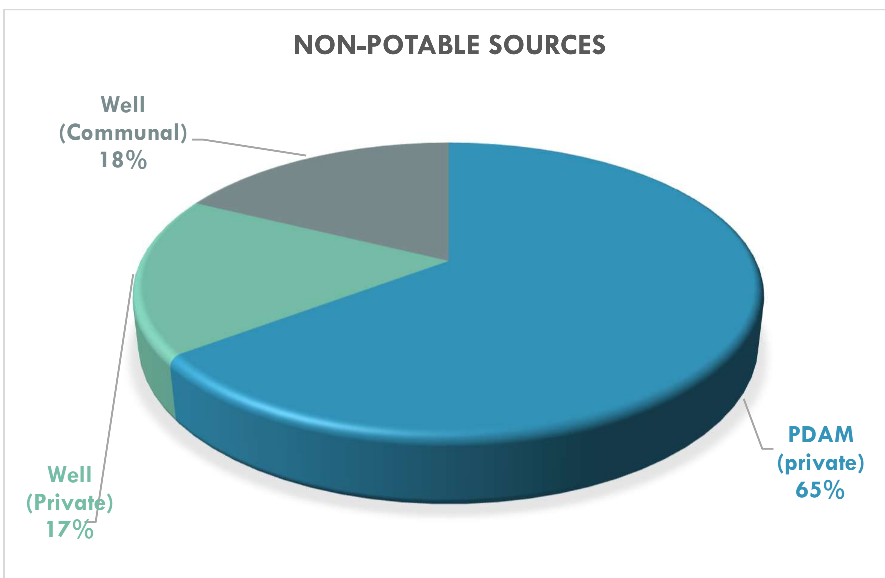

Figure 10. Non-potable freshwater sources (household).

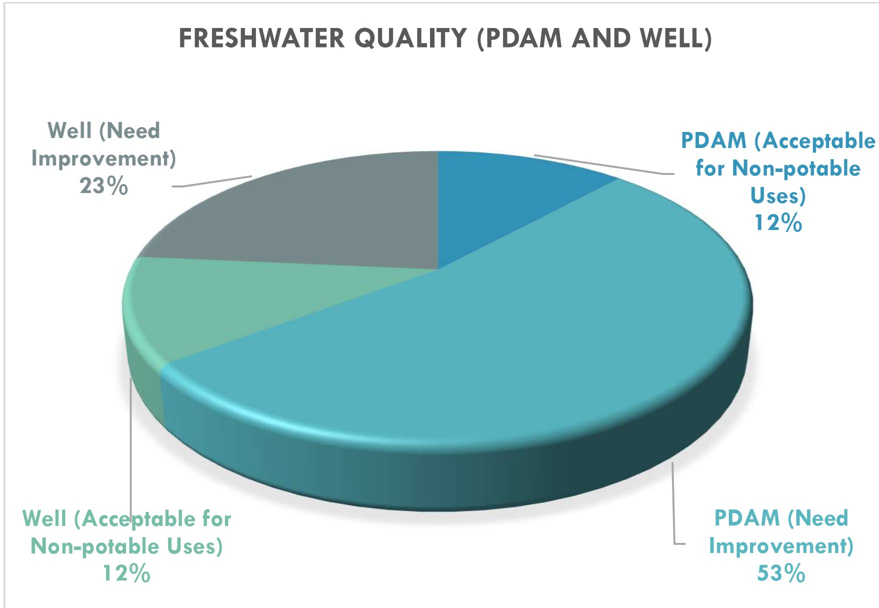

Figure 11. Freshwater quality of PDAM and well (household).

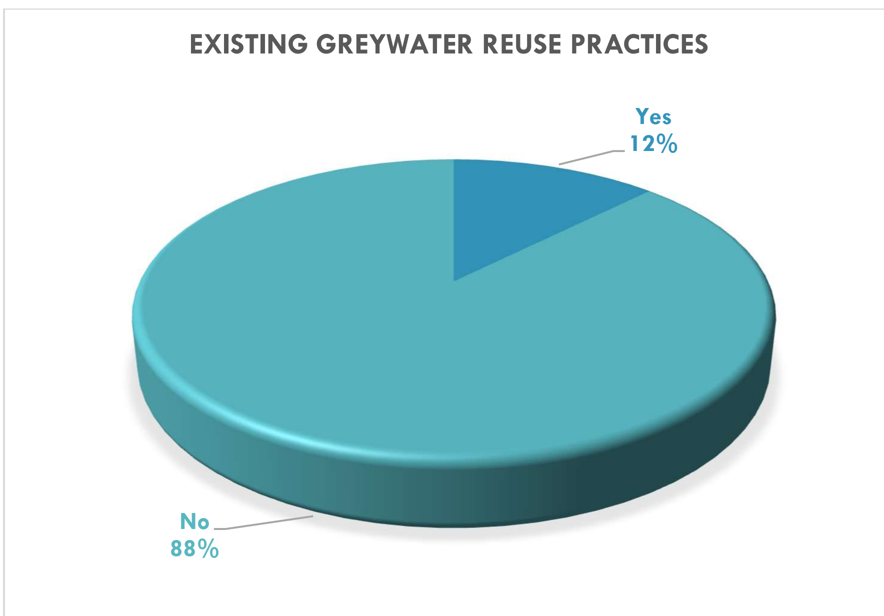

Figure 12. Existing greywater reuse practices (household).

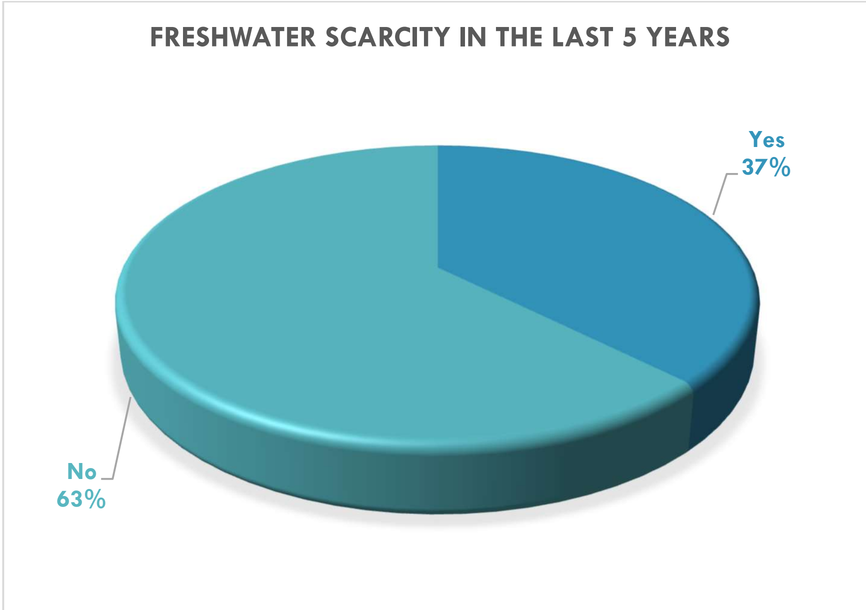

Figure 13. Freshwater scarcity experienced by households in the last five years.

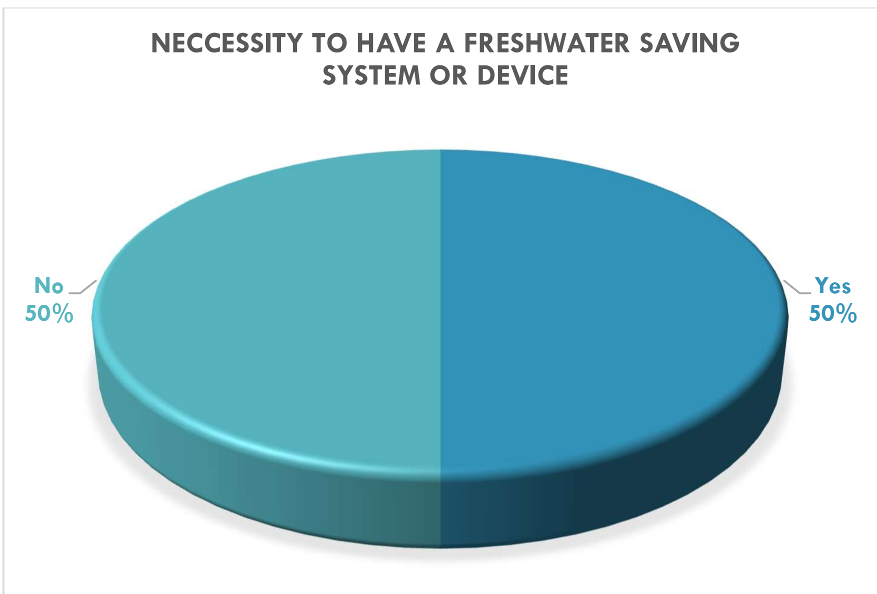

Figure 14. The necessity from households' perspective to have a freshwater saving system or device.

B. Commercial, Office, and Public Facility (Non-domestic Sectors)

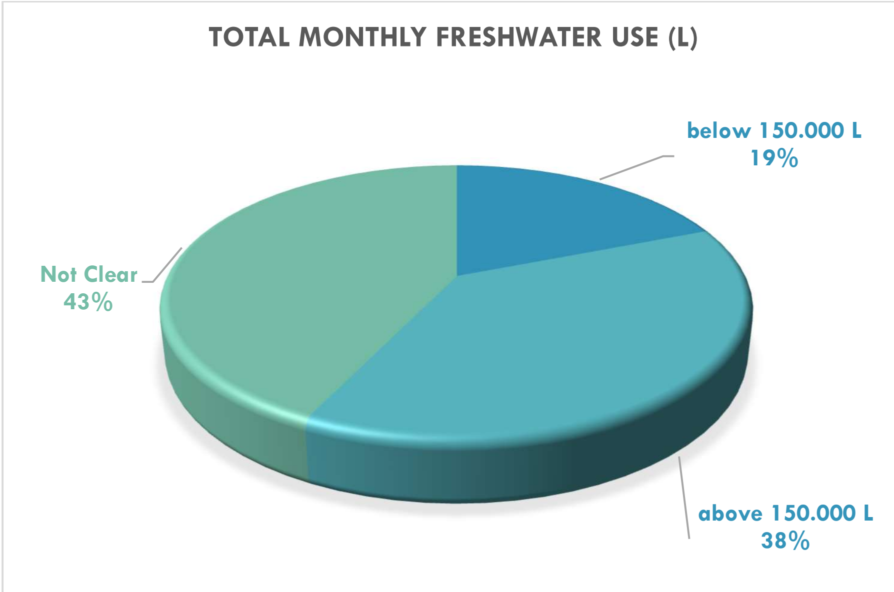

Figure 15. The total monthly freshwater use (non-domestic sectors).

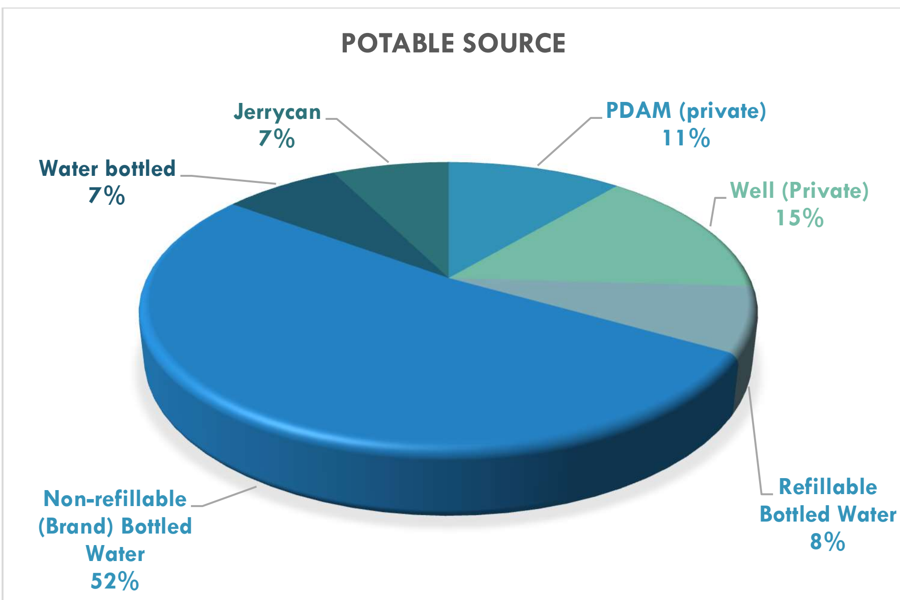

Figure 16. Potable freshwater sources (non-domestic sectors).

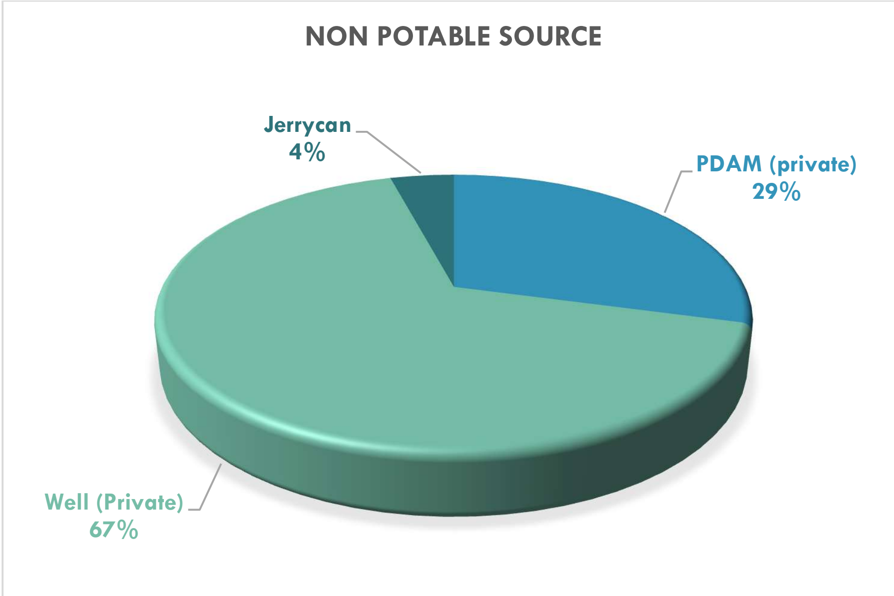

Figure 17. Non-potable freshwater sources (non-domestics sectors).

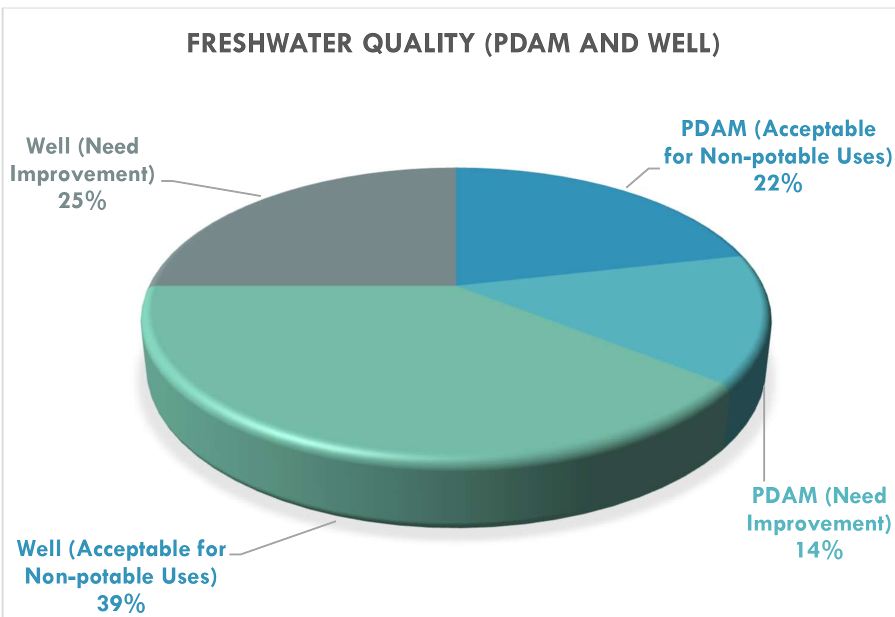

Figure 18. Freshwater quality of PDAM and well (non-domestic sectors).

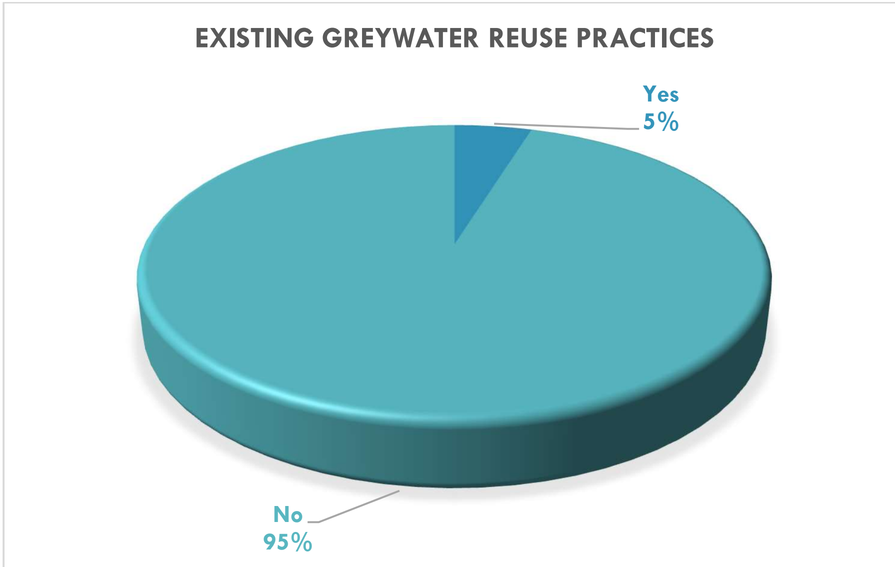

Figure 19. Existing greywater reuse practices (non-domestic sectors).

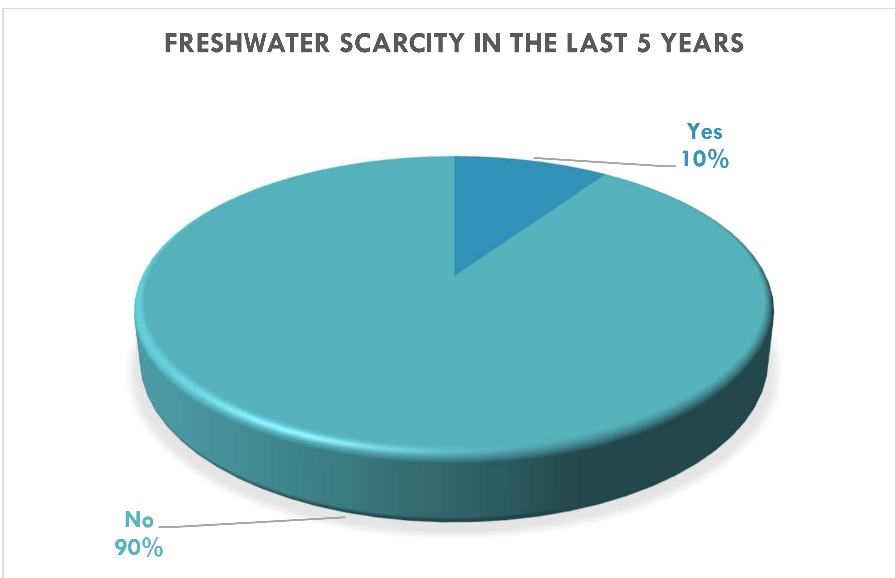

Figure 20. Freshwater scarcity experienced by non-domestic sectors in the last five years.

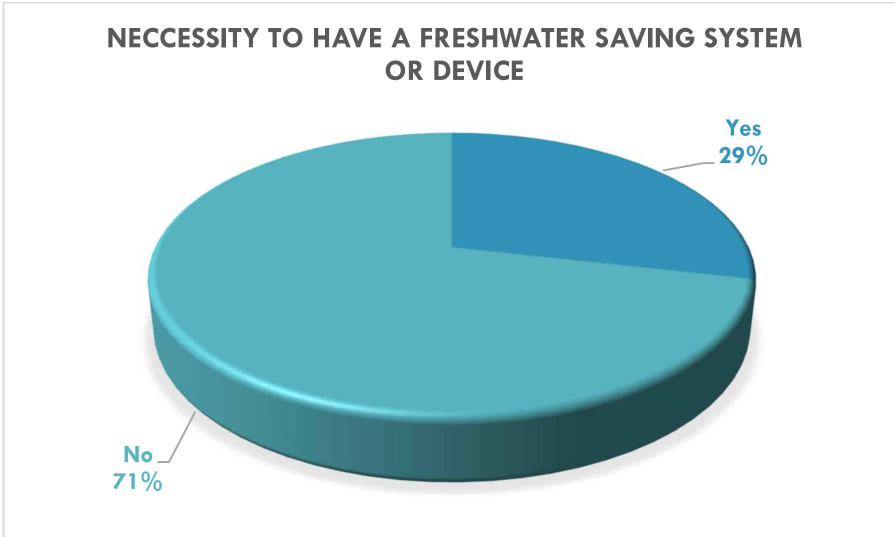

Figure 21. The necessity from non-domestic sectors' perspective to have a freshwater saving system or device.

Appendix V List of Respondents and Key Persons

Table 32. Important key persons and interviewees.

No.	Name	Role	Organization	Date
1.	Arwita Mawarti	Head of Planning	Sarpras PKP – BAPPEDA	March 2, 2020
2.	Djoko Suwarno	Environmental scientist	UNIKA	February 20, 2020
3.	Hakim Ahmad	Community member	BPK2L	February 27, 2020
4.	Jessie Setiawati	Secretary	AMbO	January 26, 2020
5.	Monika Aprianti Popang	Geotechnical & geo-environmental engineer	Witteveen+bos	June 12, 2020
6.	Mukhammad Firdaus	Head of planning division	PDAM Tirta Moedal	February 25, 2020 June 10, 2020
7.	Jenny Kalalo	Community member	BPP Sima	February 20, 2020
8.	Nik Sutiyani	Head of planning division	Distaru – BAPPEDA	March 5, 2020
9.	Wita Purwasih	Water and sanitation specialist	RHDHV	March 3, 2020
10.	Agus Suryo Winarto	Chairman	DPC Projo Semarang	January 28, 2020
11.	Caecilia Isti Sumiwi	Vice chairman	AMbO	January 21, 2020

Table 33. Household respondents.

No.	Respondent Name (Household)	RT / RW	Village	Subdistrict
1.	Nurhayati	001/010	Bandarharjo	North Semarang
2.	Sugiyanto & Dwi Lestari	001/010	Bandarharjo	North Semarang
3.	Lilik	002/011	Bandarharjo	North Semarang
4.	Slamet	002/011	Bandarharjo	North Semarang
5.	Musridah	003/011	Bandarharjo	North Semarang
6.	Sripudjiastuti	004/011	Bandarharjo	North Semarang
7.	Slamet Supriyadi	005/011	Bandarharjo	North Semarang
8.	Lipiarso	006/011	Bandarharjo	North Semarang
9.	M. Rosidi	001/009	Dadapsari	North Semarang
10.	Hantoro	004/002	Purwodinatan	Central Semarang
11.	Dini	001/003	Rejomulyo	East Semarang
12.	Asih	002/003	Rejomulyo	East Semarang
13.	Agus	001/001	Tanjung Mas	North Semarang
14.	Lis	002/001	Tanjung Mas	North Semarang
15.	Mihastiyono	003/001	Tanjung Mas	North Semarang
16.	Haryono	003/001	Tanjung Mas	North Semarang

Table 34. Commercial respondents.

No.	Commercial	RT / RW	Village	Subdistrict
1.	Hotel	-	Kauman	Central Semarang
2.	Pharmaceutical	002/005	Purwodinatan	Central Semarang
3.	Food and beverages	003/005	Purwodinatan	Central Semarang
4.	Stationary	004/005	Purwodinatan	Central Semarang
5.	Food and beverages	005/002	Purwodinatan	Central Semarang
6.	Food and beverages	001/001	Tanjung Mas	North Semarang
7.	Food and beverages	001/001	Tanjung Mas	North Semarang
8.	Auditorium	002/001	Tanjung Mas	North Semarang
9.	Cigarette factory	002/001	Tanjung Mas	North Semarang
10.	Motel	003/001	Tanjung Mas	North Semarang
11.	Food and beverages	004/001	Tanjung Mas	North Semarang

Table 35. Office building respondents.

No.	Office	RT / RW	Village	Subdistrict
1.	State-owned enterprises	001/009	Dadapsari	North Semarang
2.	Insurance	005/002	Purwodinatan	Central Semarang
3.	Bank	001/001	Tanjung Mas	North Semarang
4.	Church administration office	003/001	Tanjung Mas	North Semarang
5.	Station	009/001	Tanjung Mas	North Semarang

Table 36. Public facility respondents.

No.	Public Facility	RT / RW	Village	Subdistrict
1.	Social building	003/001	Purwodinatan	Central Semarang
2.	Church complex	001/003	Rejomulyo	East Semarang
3.	Church	003/001	Tanjung Mas	North Semarang
4.	Mosque	006/001	Tanjung Mas	North Semarang
5.	Nunnery complex	005/001	Tanjung Mas	North Semarang