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Domestic water supply, residential water use behaviour, and household willingness to pay: The case of Banda Aceh, Indonesia after ten years since the 2004 Indian Ocean Tsunami

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ABSTRACT

In this study, we developed a preliminary assessment of current domestic water supply and use in Banda Aceh, Indonesia, a city that was hardest hit by the Indian Ocean Tsunami of 2004. The motivation was to develop understanding of the status and future direction for improvement of domestic water supply after 10 years of post-tsunami reconstruction. For this purpose, we collected primary and secondary information from both water utility and residential households. In particular, we conducted household survey to examine water use behaviour in relation to domestic water supply by local utility, public perception on water supply service, and household willingness to pay (WTP) for reliable water supply. Our study results show that domestic water supply in the city has been improving in service coverage but is subject to high percentages of non-revenue water, financial loss, and poor performance. Despite available tap water, residential households access multiple water sources differentially between drinking and non-drinking purposes. All survey respondents are willing to pay for reliable water supply service, with median WTP estimated at approximately 190% of current household monthly water bill. Most respondents have a concentrated WTP distribution whose mean depends mainly on household income, family size, and water use behaviour. The study findings fill in the knowledge gap in the literature while informing improvement of domestic water supply in Banda Aceh, Indonesia.

1. Introduction

On 26 December, 2004, a powerful Sumatra-Andaman earthquake of moment magnitude 9.1–9.3 occurred in the northern Indian Ocean about 250 km off the west coast of Sumatra, Indonesia (Lay et al., 2005). The earthquake generated a massive tsunami with the maximum wave height of up to 24–30 m, causing 230,000–280,000 fatalities while severely damaging coastal human settlements, properties and infrastructure, particularly in Indonesia, Thailand, Sri Lanka, India, and Maldives (Diacu, 2009). The total cost of damages was estimated at $15 billion at least (Farrell et al., 2015). The 2004 Indian Ocean Tsunami is by far the worst natural disaster of its kind in recorded human history (Athukorala, 2012).

Given the significance of the tsunami and its devastating impact, many studies have been developed surrounding the science and management aspects of the disaster as well as settlement reconstruction and restoration. For example, Röbke and Vött (2017) provided a thorough treatise on the tsunami phenomenon from a geoscientific point of view. Athukorala (2012) examined the nature and effectiveness of international humanitarian aid efforts after the tsunami disaster. Matsumaru (2015) compared the post-tsunami reconstruction process in Indonesia and Sri Lanka from the point of view of a "Build Back Better" philosophy. Yet, there is currently a knowledge gap in the literature that examines and documents urban water supply, one of the fundamental needs of urban society, in the disaster affected area, despite substantial aid poured in post-disaster to help reconstruct and restore urban settlements and public facilities including water supply system (e.g., The Guardian, 2014; Masyrafah and McKeon, 2008).

This study is dedicated to developing understanding of current domestic water supply and use behavior in Banda Aceh, Indonesia, the most affected city by the tsunami. It is intended to synthesize information from both water utility and residential water users in the urban area to examine specifically the below questions: 1) how is the current municipal water supply for domestic use? 2) what are major issues and challenges faced by domestic water supply? 3) how do urban households access and use water and perceive the water supply service of local utility? and 4) to what extent are urban households willing to pay (WTP) for reliable water supply? The study is expected to fill in the

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current knowledge gap while informing future development of water supply system in the area, promoting achievement of the sustainable development goal (SDG) for water - universal and equitable access to safe and affordable drinking water for all by 2030.

The paper is organized as follows. Section 2 describes the study area, the Banda Aceh city, encompassing its demographic background, tsunami impact, climate conditions and water resources. Section 3 summarizes the method used for collecting information and data, including questionnaire design for household survey, and the modelling approach to eliciting and analysing household WTP for reliable water supply. Section 4 presents the study results, covering the state of domestic water supply and challenges, characteristics of survey respondents, local perception on water supply service, residential water use behaviour, and household WTP for water supply service and underlying driving factors. Section 5 discusses the results and management implications. In the end, Section 6 concludes the paper.

2. The study area: Banda Aceh

2.1. Demographic background and tsunami impact area

The study area Banda Aceh is the capital city of the Province Aceh, Indonesia, located on the northern tip of the Sumatera Island (Fig. 1). The city occupies a total land area of about 61 km^2, with an average altitude of 0.8 m above the mean sea level (Badan Pusat Statistik, 2014a). Administratively, Banda Aceh is divided into 9 districts (i.e., Meuraxa, Jaya Baru, Banda Raya, Baiturrahman, Lueng Bata, Kuta Alam, Kuta Raja, Syiah Kuala, and Ulee Kareng) and 90 villages. According to Badan Pusat Statistik (2014a), land use in the city is dominated by residential land, which covered about 50% of the urban area in 2013 (see Table 1). As of 2013, Banda Aceh had a total population of approximately 250,000 (Badan Pusat Statistik, 2014a), and the occupations of citizens were mainly in the trade and service sector, which accounted for 84% of the population, followed by farmers at 4% (Badan Pusat Statistik, 2014b).

Table 1
Land use classification in Banda Aceh in 2013.

Land Use	Area, ha	Percentage, %
1. Protected area		
a. Riparian area	179.9	2.93
b. Mangrove forest	434.38	7.08
c. Green open space	552.72	9.01
d. Reserved area	16.65	0.27
2. Cultivated area		
a. Residential area	3,042.63	49.59
b. Business area	522.23	8.51
c. Office area	149.56	2.44
d. Tourist area	51.31	0.84
e. Non-green open space	25.39	0.41
f. Fishery area	32.07	0.52
g. Public service area	293.86	4.79
h. Port area	11.76	0.19
i. Empty area	341.55	5.57
j. Open water	482.02	7.86

Source: Badan Pusat Statistik (2014a).

Banda Aceh was the most affected city and severely damaged by the 2004 tsunami due to its location at the forefront of the northwest coast of Indonesia that is the closest to the epicentre of the earthquake and tsunami (e.g., Cluff, 2007; Matsumaru et al., 2012). The tsunami inundation in the city travelled about 3–4 km inland, affecting nearly

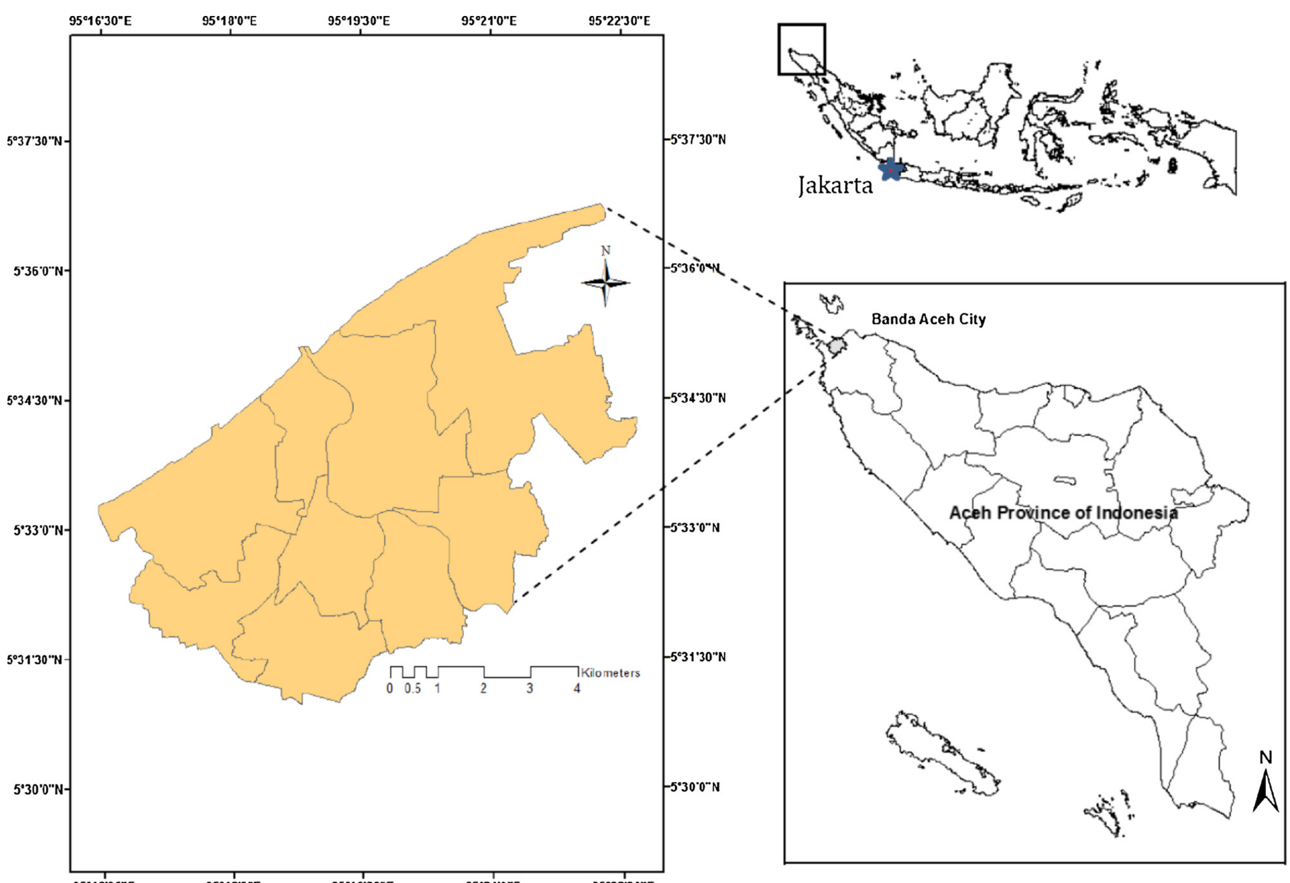

Fig. 1. Geographic location of the study area Banda Aceh, Indonesia.
Source: Achmad et al. (2014)

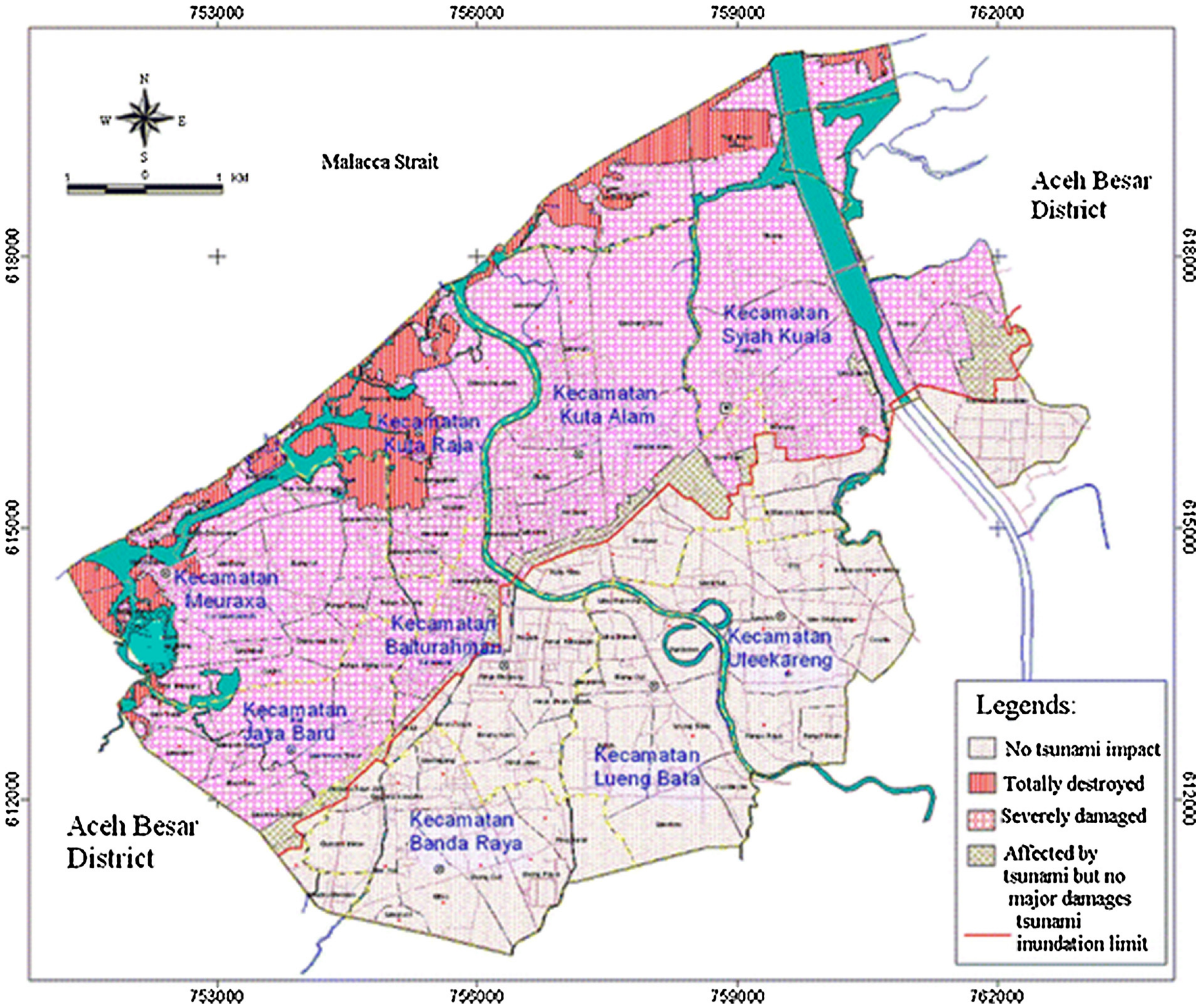

Fig. 2. Spatial distribution of the impact of the 2004 Indian Ocean Tsunami in Banda Aceh, Indonesia.
Source: Syamsidik et al. (2017)

50% of the urban area, with about 77,000 people killed and a large number of houses and infrastructure destroyed (Borrero, 2005; Ghobarah et al., 2006; Syamsidik et al., 2017). Fig. 2 shows the areas of the city that was affected by the tsunami.

2.2. Climate and water resources

The natural condition of the city is characteristic of a tropical rainforest climate, with a nearly constant average temperature of 27 °C. Similar to other areas throughout Indonesia, Banda Aceh has two seasons: a dry season and a rainy season, with June through August being the driest months. In the year of 2013, the driest month was August, and the average precipitation in that month was 40.4 mm, which was in contrast to the rainfall amount of 283.3 mm in the wettest December. The annual average rainfall is about 1624 mm, spreading over 151 rainy days. As a humid area, Banda Aceh had an average humidity of 80.7% in 2013.

Banda Aceh is situated in the Krueng Aceh Watershed, which is one of the 15 watersheds in the Province of Aceh. The watershed has a total area of about 207,496 ha (Balai Penelitian Agroklimat dan Ekologi, 2006) and covers two administrative regions, namely the Banda Aceh City and the Aceh Besar Regency. Dominated by low-lying areas besides undulating hills and mountains, the watershed has a topography varying from flat to steep, with an altitude of 0–1710 m above the mean sea level (Balai Penelitian Agroklimat dan Ekologi, 2006). This watershed has an important role supplying water to Banda Aceh. Fig. 3 shows the 7 rivers in the Watershed (Krueng Aceh, Krueng Daroy, Krueng Doy, Krueng Neng, Krueng Lhueng Paga, Krueng Tanjong, and Krueng Titi Panyang).

The Banda Aceh city has highly productive aquifers with a wide distribution (Fig. 4). Groundwater in the city, however, is of different quality, which can be salty, brackish or fresh. Areas with salty groundwater are in the north and east of the city extending to the city center. Brackish water is in the central part of the city stretching from the east to the west. The region has fresh groundwater in the southern part of the city stretching from the Meuraxa district to the Baiturrahman district.

3. Method

3.1. Data collection approach

In this study, both primary and secondary information was collected. Primary information was obtained through household survey on water use, perception of water supply service, and WTP. The survey was implemented through face-to-face interviews based on a structured questionnaire. Before implementing the survey, the questionnaire was tested with a small sample of households across the city districts. The purpose of the testing was to make sure that the questionnaire was clear and understandable to local respondents. Based on feedbacks from the

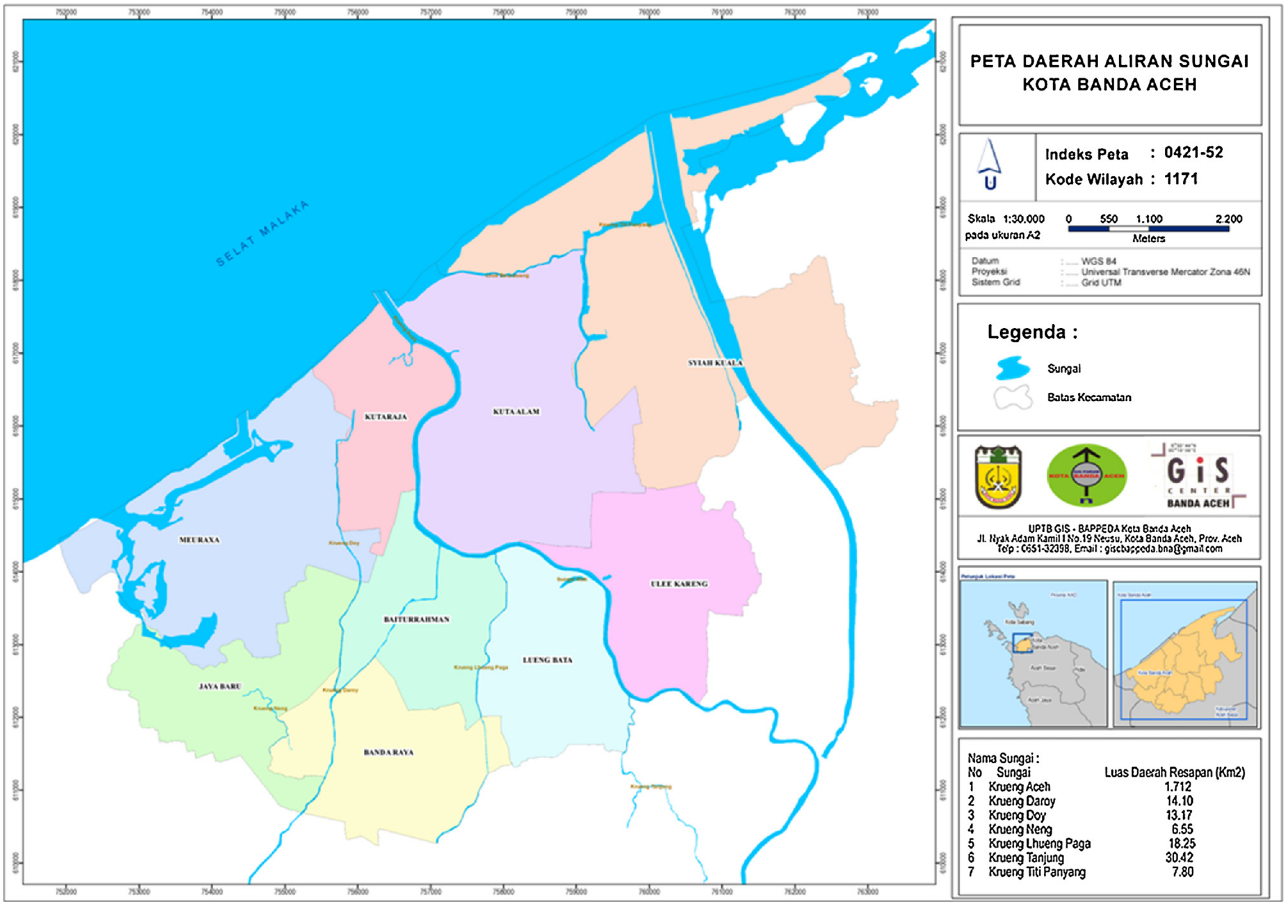

Fig. 3. The Krueng Aceh Watershed in Banda Aceh, Indonesia.
Source: UPTB-GIS Kota Banda Aceh (2014)

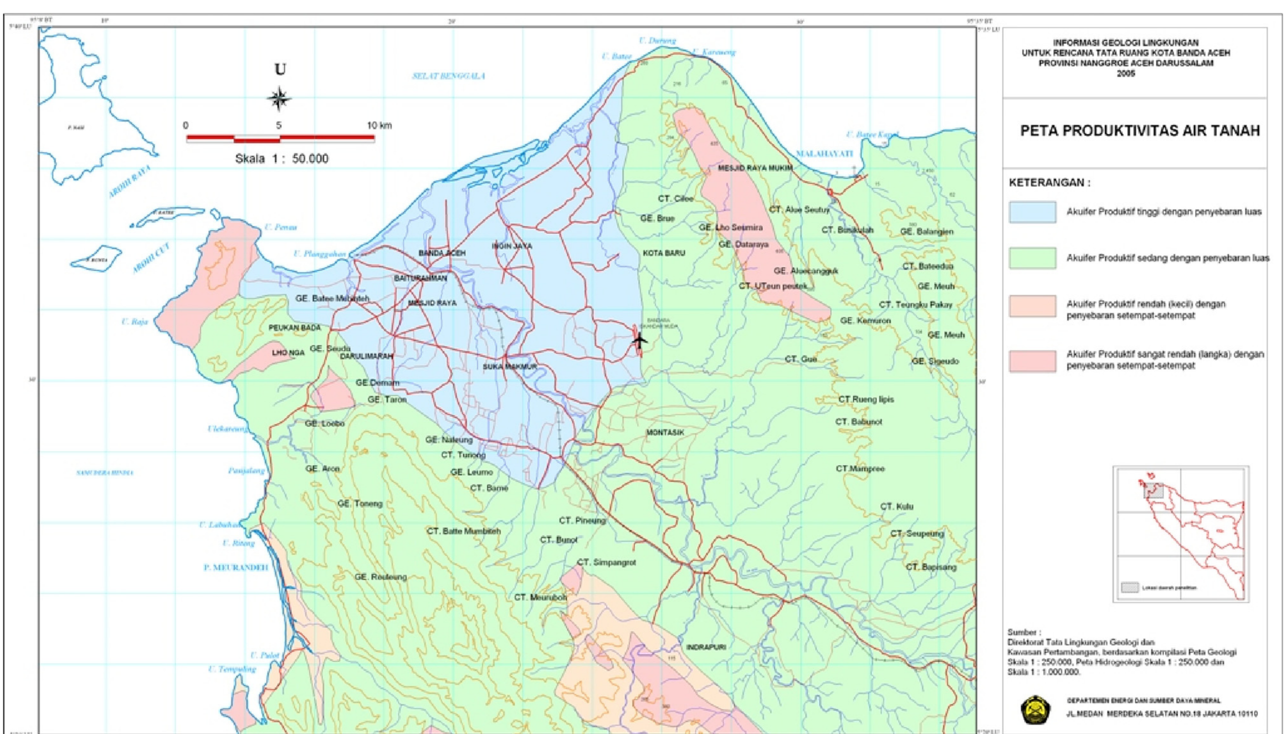

Fig. 4. Map of groundwater productivity in Banda Aceh, Indonesia in 2005.
Source: UPTB-GIS Kota Banda Aceh (2014) [adapted from Ministry of Energy and Mineral Resources (2005)]

testing, the questionnaire was modified and finalized. The survey was conducted in the period 24 November–7 December 2014. A sample of 120 households was randomly selected across the 9 districts of the city for interviews.

Secondary information was gathered from the local water utility on water supply and use. Information sources included company profile, financial reports, business plans, and network maps. Note that during the data collection period in December 2014, the most recent information was from 2013 which may actually reflect the state of 2012.

3.2. Survey questionnaire design

The survey questionnaire was composed of both close- and open-ended questions divided into three sections. The first section collected questions on the demographic characteristics of the survey respondents, such as gender, marital status, education level, occupation, household size, household income, house material, and house and land ownership. The second section covered household water use and perception of water supply service. For household water use, information collected included water sources for drinking and non-drinking uses, existing water use problems encountered, and monthly water expenditure. In this section, questions were also raised asking respondents to evaluate and compare current water supply service with the situation before the 2004 tsunami if applicable.

The last section was dedicated to eliciting household WTP for reliable water supply service. We adopted the contingent valuation method (CVM) to identify household WTP. CVM is a survey-based tool for collecting preference information through appropriately designed and structured questions that help reveal the monetary tradeoff people would make concerning the value of goods or services (Carson, 2012). Within the CVM framework, our survey questionnaire first presented the scenario of reliable water supply as described below:

> "The local water utility (or PDAM Tirta Daroy) provides to its customers reliable tap water supply with satisfying pressure and good quality 24 h per day."

This scenario defined the good or service for which the WTP of households was elicited.

In our survey, the WTP question was formulated in the format of multiple bounded dichotomous choice (MBDC), allowing for statement of respondents on their uncertainty towards different pre-specified WTP amounts (Wang and He, 2010). Specifically, the questionnaire presented a set of pre-specified WTP bids for access to reliable water supply service, and for each WTP bid, respondents were required to indicate their certainty level for paying the listed bid amount on a five-level scale in the following range: *definitely yes, probably yes, not sure, probably no,* and *definitely no* (see Table A1 in Appendix I for an example of the WTP question formulated as MBDC).

The pre-specified WTP bids were in two formats, accommodating different household water supply conditions. For respondents with their households receiving tap water from PDAM, the WTP bids presented were based on household monthly water bill, and measured in percentages of household average monthly payment for water, ranging from 0% up to 400% by an increment of 20% after the first 3 levels at 0%, 5%, and 10%. In relation to the survey instrument used, a question was raised, before the start of the bidding process on WTP, on household monthly payment for water levied by local utility in the last 3 months. For each household, the monthly water payments or water bills were used to calculate the average monthly expenditure for water use that served as the base for converting the different pre-specified WTP bids in percentage into absolute monetary values presented to respondents. Such design would allow respondents to get a clear sense of the monetary values implied by the specified bids.

The bidding process was set to start from the low of 0% and continuously increase to the next higher level unless the respondent indicated a certainty level of *definitely no* for the considered WTP bid. It is worth noting that while the WTP bids in percentage were uniform for all respondents, the absolute monetary values implied as household WTP amounts could be different among respondents depending on their household average monthly water bill.

For respondents with their households not subscribed to the water distribution network of PDAM or receiving no water from PDAM, the same WTP question and elicitation method were used except a different set of WTP bids used. This set of WTP bids was expressed in absolute monetary values, starting from 0 to 500,000 IDR with the increment of: 1) 25,000 IDR for WTP bids below 100,000 IDR except the first three bids of 0 IDR, 10,000 IDR, and 25,000 IDR, 2) 50,000 IDR for WTP bids below 400,000 IDR, and 3) 100,000 IDR for bids beyond 400,000 IDR.

3.3. Estimating individual WTP distribution

In our survey, respondents' household WTP information was collected through the MBDC question. To estimate household WTP of survey respondents, we adopted the approach proposed by Wang and He, (2010) that was developed for analysing MBDC data. The conceptual model for generating MBDC data that motivated the development and application of the modelling approach is characterized by randomly distributed WTP of individuals or survey respondents for a considered good or service. Under this model, individuals are allowed to be uncertain about their true WTP as precisely estimated single values but may be able to indicate their certainty level or probability for paying the specified price for the considered good or service. This conceptualization seems plausible and desirable by reflecting the likely data generation process when individuals attempt to generate their WTP information in response to structured eliciting questions. If the certainty levels or probabilities of an individual for paying different prices can be quantified or parameterized, then the probability distribution of the individual's WTP, if specified, may be statistically estimated.

Consider an individual i's WTP denoted as WTP_i. Under the conceptual model for MBDC data, the individual i's WTP_i is considered a random variable, which can be expressed as below:

$$WTP_i = M_i + \varepsilon_i$$

where M_i represents the mean of the random variable WTP_i and ε_i captures the random error with its mean equal to zero. Suppose the cumulative distribution of the random variable WTP_i is described by a cumulative distribution function (CDF) $F_i(t)$. For a given value t, $F_i(t)$ quantifies the probability that WTP_i is less than the value t, which can be regarded as measure of the certainty of the individual i towards not willing to pay for the specified amount t. Denote $P_{ij}(WTP_i < t_j)$ as the probability that individual i is unwilling to pay a specified amount t_j. Therefore, $P_{ij}\ (WTP_i < t_j) = F_i(t_j)$.

In our study, the uncertainties (or probabilities) of each respondent for different elicited WTP amounts were obtained by household survey, which were qualitatively measured at the predefined ordinal level ranging from *definitely yes*, *probably yes*, *not sure*, *probably no*, and *definitely no*. If the above certainty levels as indicated by individuals for different WTP amounts are quantified, the CDF $F_i(t)$ of WTP_i for any individual i can be estimated for a specified distribution. In this study, our empirical estimation of $F_i(t)$ followed the below steps including: 1) assigning different statistical values to the predefined certainty levels: 1% for *definitely yes*, 25% for probably yes, 50% for *not sure*, 75% for *probably no*, and 99% for *definitely no*, 2) assuming the random error ε_i of WTP_i be subject to a normal distribution with its mean equal to zero, and 3) estimating the CDF $F_i(t)$ of WTP_i for each individual i by

Table 2
Description of variables used in regression analysis of respondents mean WTP.

Variables	Description
Dependent variable	
Log_WTP	Continuous variable denoting the natural log value of the mean WTP of each respondent
Independent variables	
Constant	Constant equal to 1 capturing the intercept of the regression function
Log_Income	Continuous variable denoting the natural log value of the household monthly income in 10 thousand IDR of each respondent.
Num_Adults	Discrete variable denoting the number of adults (age ≥ 19) in the household of each respondent
Num_Children	Discrete variable denoting the number of children (age < 19) in the household of each respondent
D_Male	Dummy variable equal to 1 for male and 0 for female
D_Married	Dummy variable equal to 1 for the married status and 0 otherwise including single and widow/widower
D_University	Dummy variable equal to 1 for education up to university and 0 otherwise
D_Government	Dummy variable equal to 1 for government employee and 0 otherwise
D_Bottled	Dummy variable equal to 1 if the respondent's drinking water is from bottled water only and 0 otherwise
D_WQGood	Dummy variable equal to 1 for the perception of water quality being good and 0 otherwise
D_WSSatisfied	Dummy variable equal to 1 if the respondent is satisfied with the water supply service and 0 otherwise

maximum likelihood estimation of normal curve fitting. With the estimated CDF, the mean WTP of each individual can be derived.

3.4. Regression analysis of individual mean WTP

We further conducted a regression analysis to examine factors affecting individual mean WTP. Denote $M = [M_1, M_2, \ldots, M_k]'$ as the vector of mean WTP estimates for k individuals. Denote $X = [X_1, X_2, \ldots, X_k]'$ as the matrix of independent variables affecting household mean WTP M, where $X_i = [x_{i1}, x_{i2}, \ldots, x_{in}]$ is a vector collecting n independent variables specific to an individual i. Thus, for individual mean WTP M, we specified the below regression function:

$$\mathbf{M} = \mathbf{X}\boldsymbol{\beta} + \mathbf{e}$$

where $\boldsymbol{\beta}$ represents the vector of coefficient parameters to be estimated by the regression analysis.

Table 2 describes the dependent and independent variables used in our regression analysis of individual mean WTP. The independent variables included are mainly attributes characterizing respondents and their households, which may affect the household mean WTP of individual respondents. These variables can be divided into three categories: 1) demographic and socio-economic attributes, 2) source of drinking water used in households, and 3) perception and attitude toward household tap water supply.

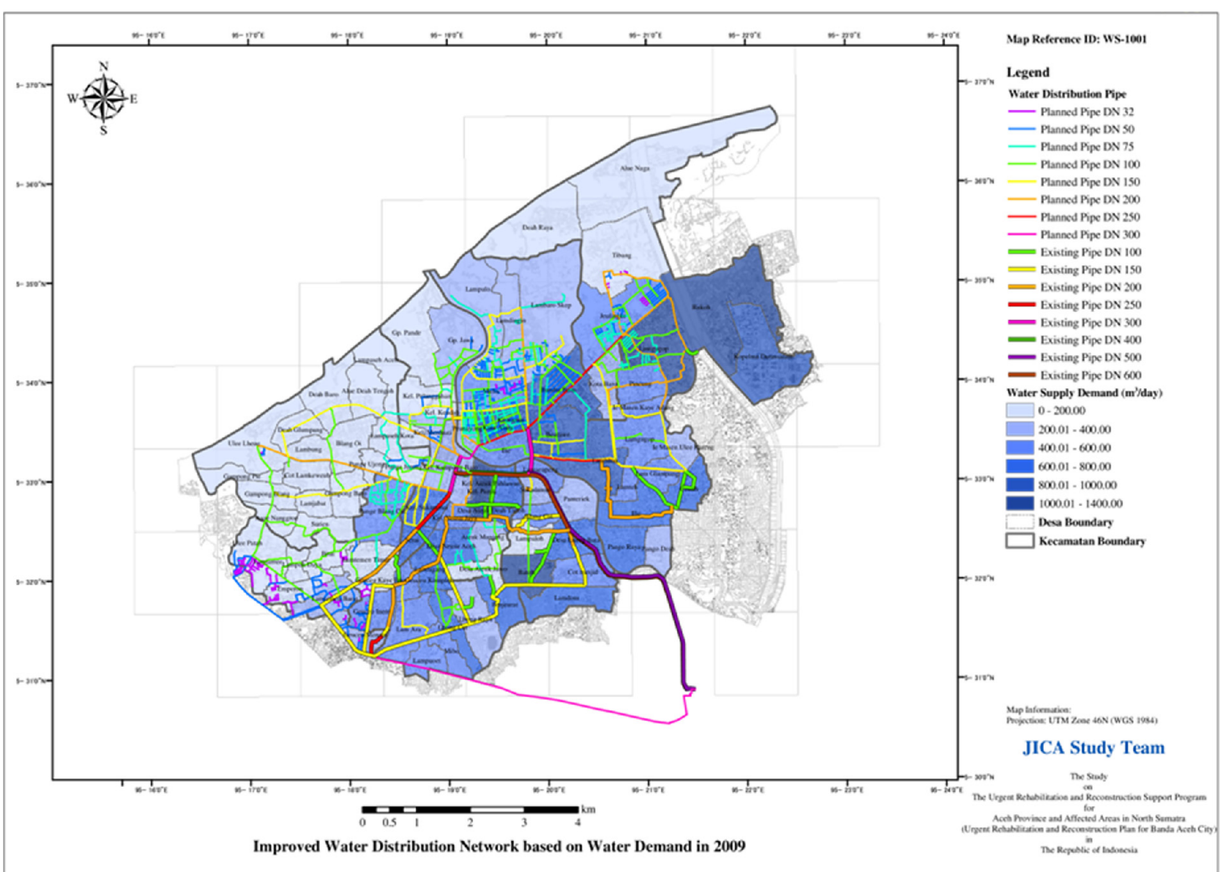

Fig. 5. Water distribution network in Banda Aceh in 2009.
Source: UPTB-GIS Kota Banda Aceh (2014).

Table 3
Coverage of domestic water supply by user type in Banda Aceh in 2012.

Type of installed connection	Number of connection (%)
Residential	39,343
Business	7,273
General social	47
Special social	138
Total	46,801

Source: PDAM Tirta Daroy (2013).

Table 4
Percentage of households covered by water supply service in Banda Aceh in 2010–2012.[a]

Year	Households water service coverage, %	
	Target	Achieved
2010	81.5	74.2
2011	85.0	81.1
2012	88.0	85.0

Source: PDAM Tirta Daroy (2013).
[a]The rates of service coverage were estimated based on the PDAM assumption of an average household size of 5 people, active household connections to the PDAM water service, and the total population of the city from Badan Pusat Statistik (2014b).

4. Results

4.1. Domestic water supply

Domestic water supply in urban areas across Indonesia is provided by utility companies called *Perusahaan Daerah Air Minum* (or PDAMs). In Banda Aceh, PDAM Tirta Daroy operates the municipal water supply system. Fig. 5 displays the water distribution network in 2009. Table 3 describes the coverage of water supply by water user type in 2012, which was dominated by residential households followed by business, consistent with the land use pattern in the urban area. Table 4 presents the estimated percentages of residential households covered by the water supply service of PDAM Tirta Daroy over the period 2010–2012. Overall the residential service coverage improved in the considered period but fell short of their target levels.

4.2. Challenges for domestic water supply

Despite being classified by government as a healthy utility (BPPSPAM, 2014), PDAM Tirta Daroy like water utilities in most developing countries is subject to high percentages of non-revenue water (NRW). For example, in 2013, PDAM Tirta Daroy produced 21.39 million m^3 clean water and distributed 19.99 million m^3, among which 10.47 million m^3 was sold and 9.52 million m^3 (or about 47.6%) was non-revenue water (NRW) that was lost due to leakages and illegal connection (Badan Pusat Statistik, 2014b). Over the period 2010–2012, the percentage of NRW varied between 44.98% and 49.44%, which was high, given the nationally allowed maximum of 20% for NRW (Nasrizal Nasa ST 2014).

The high percentage of NRW has led consequently to other issues such as low cash balance, recurring financial loss, and low billing efficiency, reinforcing the occurrence of NRW. As shown by Table 5, PDAM Tirta Daroy was subject to financial loss every year over the period 2010–2012, despite the revenue from water sale higher than the production cost on the basis of per m^3.

Possible direct causes of NRW include:

- Poor maintenance and management of water distribution infrastructure such as pipelines contributing largely to water leakage
- Broken or improper water meters
- Inaccurate reading and recording of water meters by PDAM staff;
- Water theft;
- Low public awareness to pay water bills (or to pay water bills on time)

To solve the problem, substantial investment is needed but the cash balance of PDAM seems insufficient to recover the investment, as shown by Table 5.

In addition, the rejection of some residents to install water meters by PDAM in households has also contributed to NRW. For example, some households at the coastal area impacted by the 2004 tsunami were helped by NGOs to get connected to the water supply network by installing new pipes in their newly built accommodation. After the rehabilitation and reconstruction of the area, these households refused to grand access to allow installation of water meters by PDAM in their households.

4.3. Characteristics of survey respondents

Table 6 summarizes the demographical characteristics of the survey respondents, including gender composition, marital status, education level, occupation, household size, household income and expenditure, house materials, and house and land ownership. There are 3 main features worth noting. First, the education level of the survey respondents is relatively high, with most (or 40%) respondents at the high school level, followed by 36.7% for colleges/universities and 20.8% for technical/vocational schools. This may be due to the fact that the survey was targeted at residential households living in the city.

Second, respondent occupation, while diverse, is concentrated mainly in 3 types, including government (22.5%), private business (18.3%), and entrepreneur (19.2%). It is noticeable that farmers,

Table 5
Financial performance of PDAM Tirta Daroy over the period.2010–2012.

Financial performance measure	2010		2011		2012	
	Target	Achieved	Target	Achieved	Target	Achieved
Profit, IDR/m^3	185	618	293	831	330	774
Revenue, IDR/m^3	2,996	2,965	3,278	2,820	3,589	3,161
Cost, IDR/m^3	2,811	2,347	2,985	1,989	3,259	2,387
NRW, %	34.15	44.98	26.15	49.44	20.00	45.70
Profit, million IDR	−4,077	−3,864	1,727	−3,064	3,908	−5,019
Investment, million IDR	4,116	9,775	10,821	1,638	10,758	4,229
Cash balance, million IDR	2,343	1,099	3,814	2,964	9.317	3,380

Source: PDAM Tirta Daroy (2013).

Table 6
Summary statistics of households' demographic characteristics.

Household Demographic Characteristics	Percentage of Respondents
Gender composition:	
-Male	55%
-Female	45%
Marital status:	
-Single	20.8%
-Married	70.8%
-Widow/Widower	8.3%
Education Level:	
-Primary school or no formal education	2.5%
-High School	40%
-Technical/Vocational School	20.8%
-College/University	36.7%
Occupation:	
-Unemployed	12.5%
-Student	7.5%
-Government employee	22.5%
-Private business and services employee	18.3%
-Employee of State-Owned Enterprise	4.2%
-Self-employed	6.7%
-Entrepreneur employee	19.2%
-Farmer/Fisherman	1.7%
-Labour workers	4.2%
-Others	3.3%
Number of household members	
-2	6.0%
-3	15.9%
-4	13.8%
-5	14.9%
-6	23.6%
-7	15.0%
-Beyond 7	10.8%
Household income	
-No income	0.0%
-Below IDR 500,000	0.0%
-IDR 500,001-1,000,000	0.8%
-IDR 1,000,001-2,000,000	6.7%
-IDR 2,000,001-3,000,000	14.2%
-IDR 3,000,001-4,000,000	15.8%
-IDR 4,000,001-5,000,000	18.3%
-IDR 5,000,001-10,000,000	25.8%
-Over IDR 10,000,000	18.3%
Household expenditure	
-Below IDR 500,000	0.8%
-IDR 500,001-1,000,000	5.0%
-IDR 1,000,001-2,000,000	16.7%
-IDR 2,000,001-3,000,000	20.0%
-IDR 3,000,001-4,000,000	16.7%
-IDR 4,000,001-5,000,000	20.8%
-IDR 5,000,001-10,000,000	15.8%
-Over IDR 10,000,000	4.2%
House construction material	
-Concrete	95.8%
-Wood	3.3%
-Other materials	0.8%
House and land ownership	
-Own	81.7%
-Rent	15.0%
-Others	3.3%

fishermen, and labour workers are rare, which may be due to the city location and citizens surveyed.

Third, household monthly income is distributed among 9 categories. The majority of the respondents is approximately equally distributed among different groups of income beyond IDR 2,000,000, except the group of IDR 5,000,001–10,000,000 that accounts for the highest percentage of respondents. The group with income below IDR 2,000,000, which is considered relatively low, is rare.

4.4. Household water use

Among the 120 respondents, 116 are customers of PDAM and the remaining 4 depend on wells. For the 116 PDAM customers, 4 of them do not receive water from PDAM due to disconnection. Fig. 6 presents the number of years of subscription to tap water supply of the 116 PDAM customers, which ranges from 1 to 36 years. However, most respondents seem relatively new in subscribing to tap water supply, with the subscription time no longer than 6 years. In other words, most respondents have no experience with the water supply impact of the 2004 tsunami.

Despite available tap water supply by PDAM, local households seem have adopted different practices for accessing alternative water sources rather than tap water alone to meet their diverse needs. Indeed, tap water delivered by PDAM is not the only source for domestic water use in Indonesia, due mainly to water quality concern. Table 7 presents the composition of drinking water supply by different sources in Banda Aceh over the period 2011–2013. As the Table 7 shows, there are in general 4 types of sources of drinking water, including packaged/bottled water and refilled water in addition to the traditional sources of tap water and wells. Packaged/bottled water is the water that is usually from natural spring and that is sold in stores in different size of packaging ranging from small (240–330 ml), medium (500–600 ml), and large (1500 ml) to a gallon size (19 l). Refilled water refers to water from refilling sites where tap water is further treated, processed, and sold to domestic water users.

Over the period 2011–2013, refilled water dominated all other sources, accounting for 78.3%–88.6% of household drinking water supply in Banda Aceh. Packaged or bottled water was also an important source of drinking water, which had the second highest percentage at 5.6%–11.1% among sources and which was followed by tap water from PDAM with a share of 4.2%–8.7%. The percentage of wells was small, which may be attributable to saltwater intrusion and limited availability of fresh groundwater in the city.

Considering the available alternative sources of water, our survey on household water use differentiates between drinking and non-drinking purposes. Fig. 7 shows the distribution of respondents among sources of drinking water, providing insights into the water use behaviour of residential households in Banda Aceh. The majority (or 67.5%) of respondents relies only on refilled water from kiosks as their drinking water, which is followed by using only bottled water for drinking by 17.5% of the respondents. Other respondents obtain their drinking water from either tap water only (8.3%) or both tap water and refilled water from kiosks (6.7%). Those respondents who depend on both tap water and refilled water use tap water for drinking only when refilled water is unavailable. In other words, these respondents in general tend to use refilled water from kiosk as the main source for drinking.

Respondents also provided cost information for drinking water of different sources. Water from kiosks costs IDR 3000–6000/gallon[1] while packaged/bottled water from supermarkets costs IDR 20,000-IDR 23,000/gallon. Respondents get water from kiosks mostly by delivery service. It is worth noting that comparing the average monthly expenditure of IDR 177,827 that respondents spend on drinking water to their household average monthly water bill of IDR 80,725 from PDAM, those respondents apparently pay 2.2 times (or 220%) more than their water bill for drinking water.

For non-drinking use, tap water from PDAM Tirta Daroy seems the main source (see Fig. 8). Specifically, about 74.2% of the respondents rely only on tap water. Alternative sources such as truck delivery, kiosks and wells are also used in combination with tap water supply but account for a small percentage. A small portion (or 6.7%) of the respondents relies only on wells for non-drinking water use, attributable to the fact that groundwater across the city except the southern part is mostly salty or brackish. There is one respondent using water only from truck delivery, resulting from interrupted water supply by PDAM after installation of new networks in his neighbourhood.

[1] Gallon here is in the meaning of bottle size (19 l) instead of volume unit (1 US gallon = 3.78541 l, 1 UK gallon = 4.5461 l)

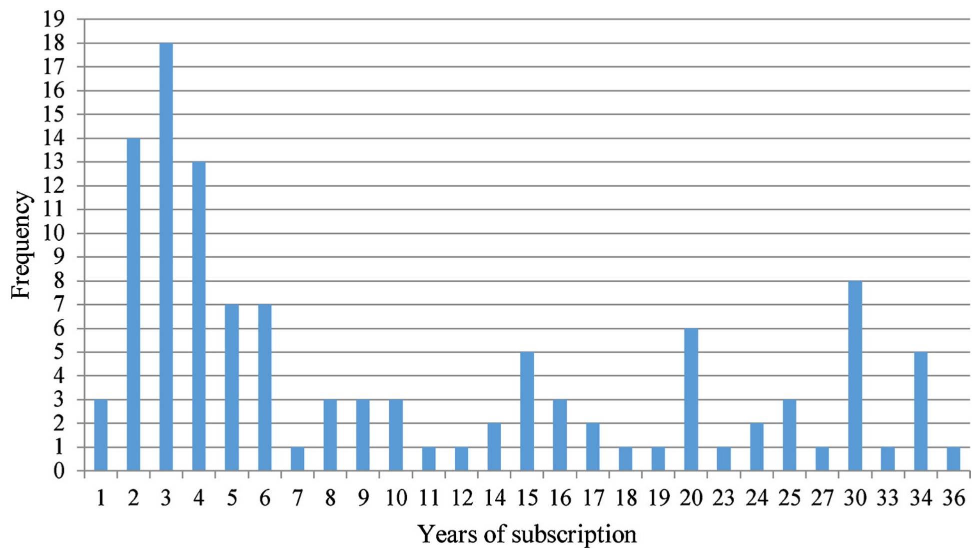

Fig. 6. Years of household subscription to PDAM.

Table 7
Percentages of household drinking water sources in Banda Aceh in.2011–2013.

Drinking Water Sources	2011	2012	2013
Packaged/bottled water, %	11.1	5.6	7.1
Refilled water [a], %	78.3	88.6	85.6
Tap water, %	8.7	4.2	5.9
Protected wells (using pump), %	0.9	0.1	0.2
Protected wells (manual withdrawal), %	1.1	1.4	1.3

a. Raw water is still coming from PDAM.
Source: Badan Pusat Statistik (2014a).

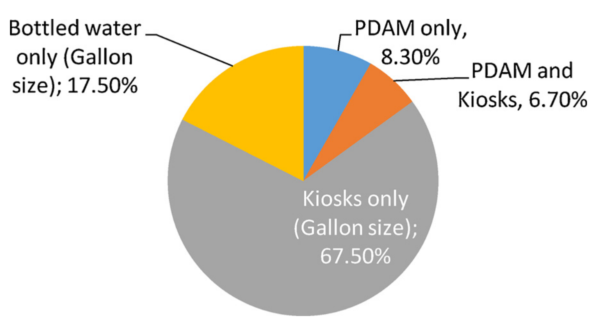

Fig. 7. Distribution of respondents among sources of drinking water.

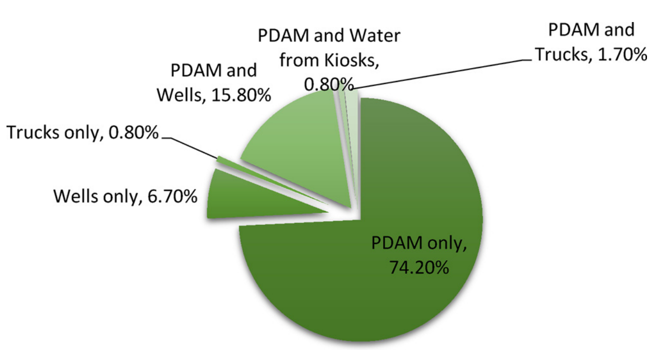

Fig. 8. Distribution of respondents among water sources for non-drinking use.

4.5. Perceived issues on domestic water supply

In the survey, respondents were asked to evaluate the water supply service of PDAM as perceived in 6 dimensions, including quality, pressure, pricing, meter reliability, meter reading, and service quality. Table 8 summarizes the result. The majority (or 63.2%) of the consumers of PDAM consider the quality of supplied tap water being good. Nonetheless, during the survey, some respondents pointed out that turbidity happens during rainfall periods. Low water pressure stands out as one of the problems faced by most (or 87.6%) of the respondents, and the majority (or 84.1%) use water pumps. The current water rate is considered reasonable by 91.3% of the respondents. About 93% of the respondents judge water meters installed in their houses reliable, and most (or 76.5%) regard meter reading by PDAM staff reliable. As to the quality of water supply service, most (or 64.3%) respondents are neutral, with 15.7% satisfied and the remaining 12.2% dissatisfied.

Table 8
Local perception of the water supply service by PDAM.

Indicators	Level	Percentages of relevant respondents, %
Water quality	Very good	5.3
	Good	63.2
	Neutral	25.4
	Bad	5.3
	Unknown	0.9
Water pressure	Normal	12.4
	Low but not using pump	3.5
	Low and using pump	84.1
Water bill	Unacceptably high	0.9
	High	1.7
	Reasonable	91.3
	Low	4.3
	No opinion	1.7
Water meter	Reliable	93.0
	Unreliable	4.3
	Don't know	2.6
Meter reading	Reliable	76.5
	unreliable	20.9
	No opinion	2.6
Water service	Very satisfied	4.3
	Satisfied	15.7
	Neutral	64.3
	Dissatisfied	12.2
	Very dissatisfied	3.5

As part of the survey, how the service of water supply compares to the situation before the 2004 tsunami was also examined. There are 45 respondents subscribed to the water service of PDAM both before and after the tsunami who are able to compare the service as perceived. Nineteen (or 42.2%) respondents perceive the current service the same

Table 9
Distribution of respondents by WTP bid and subjective certainty level.

WTP bids [a], %	Number of respondents by certainty level [b]				
	Def. Yes, (%)	Prob. Yes, (%)	Not Sure, (%)	Prob. No, (%)	Def. No, (%)
80	111 (100)	0 (0)	0 (0)	0 (0)	0 (0)
100	110 (99)	1 (1)	0 (0)	0 (0)	0 (0)
120	89 (80)	21 (19)	1 (1)	0 (0)	0 (0)
140	62 (56)	32 (29)	12 (11)	4 (4)	0 (0)
160	45 (41)	27 (24)	21 (19)	13 (12)	4 (4)
180	31 (28)	30 (27)	13 (12)	23 (21)	14 (13)
200	19 (17)	20 (18)	23 (21)	15 (14)	34 (31)
220	8 (7)	21 (19)	14 (13)	24 (22)	44 (40)
240	4 (4)	10 (9)	15 (14)	17 (15)	65 (59)
260	3 (3)	4 (4)	10 (9)	16 (14)	78 (70)
280	3 (3)	3 (3)	5 (5)	11 (10)	89 (80)
300	1 (1)	4 (4)	2 (2)	8 (7)	96 (86)
320	0 (0)	3 (3)	2 (2)	6 (5)	100 (90)
340	0 (0)	0 (0)	3 (3)	4 (4)	104 (94)
360	0 (0)	0 (0)	0 (0)	4 (4)	107 (96)
380	0 (0)	0 (0)	0 (0)	0 (0)	111 (100)

a. WTP bids are expressed in percentages of household average monthly water bill.
b. The numbers in parenthesis represent the percentages of respondents.

as before the tsunami, 19 (or 42.2%) considering it being worse, 6 (or 13.3%) better, and 1 (or 2.2%) neutral. Based on the limited responses, it seems that there is no significant perceived improvement in water supply as compared to before the tsunami although significant efforts and aid have been provided to help restore the system.

4.6. Household WTP for reliable water supply

Among the 120 survey respondents, 111 receive monthly bills from PDAM for tap water use in their households, and the remaining 9 either are not connected to the water distribution network or receive a fixed monthly charge for connection without getting water. Therefore, for the 111 respondents with water bill, their WTPs were elicited in terms of percentage change in household average monthly water bill, while the remaining 9 respondents were presented WTP bids in absolute value. Table 9 presents the resulting distribution of the 111 respondents among WTP bids and subjective certainty levels.

As demonstrated by Table 9, with a rising WTP bid, the number of respondents with certainty to pay the elicited amounts decreases. Specifically, for the WTP bids at 80% and 100% of household average monthly water bill, nearly all the respondents are willing to pay the charge for reliable water supply. However, when the WTP bid increases to 120% of the current monthly bill of households, the extent that the respondents are willing to pay become less certain, as indicated by 18% of the respondents changing their position from *definitely yes* to *probably yes*. When the WTP bid rises up to 380% of household average monthly water bill, all respondents are certain that they would be unwilling to pay the elicited amount for reliable water supply. It is interesting to note that, if both the certainty levels of *definitely yes* and *probably yes* can be aggregated and considered as "yes", Table 9 shows that more than half of the respondents become less willing to pay more than 200% of household current monthly water bill for reliable water supply, which seems comparable to the 220% more than the monthly water bill that most households currently pay for drinking water from sources other than tap water. The responses to WTP bids, as depicted by Table 9, shows the economic potential for raising water price to improve water supply service.

Fig. 9 summarizes and converts the WTP responses and subjective certainty levels of Table 9 into cumulative relative frequency distribution (CRFD) of household WTP. To derive the CRFD curve, we first quantify the subjective certainty levels by assigning numeric probability values in the following matter: *definitely yes* – 100%, *probably yes* – 75%, *not sure* – 50%, *probably no* – 25%, and *definitely no* – 0%, with the assigned values measuring the probability of household WTP being less than a specified WTP bid. We then calculate, for each WTP bid, the effective frequency count of respondents whose WTP values are no less than the specified WTP bid, which is equal to the summation of frequency counts weighted by the assigned probability values of the corresponding subjective certainty levels. Finally, we derive the relative frequency of WTP bid by dividing individual effective frequency counts by the total number of respondents, i.e., 111, who receive water bill each month from PDAM.

The Fig. 9 shows how the cumulative relative frequency rises with household WTP. Specifically, the curve shows that the relative frequency is nearly zero for households with their WTP less than 80–100% of their current average monthly water bill. In contrast, the relative frequency is 100% for households with their WTP less than 380% of their current average monthly water bill. Interestingly, the figure shows that the cumulative relative frequency rises quickly starting from the WTP level of 100% of the monthly water bill, and slows down once household WTP reaches 240%–260%. This dynamic features means that the household WTP of most respondents tends to be not far away from their current water bill. More precisely, the household WTP range of 100%–240% of water bill accounts for 80% of the respondents. It is worth noting that household WTP at cumulative relative frequency 0.5, or median household WTP, is in the range of 180% and 200%, approximately a bit greater than 190% of household average monthly water bill.

Fig. 10 depicts the probability distribution of WTP of survey respondents. Each individual's WTP is described by a probability density curve, which accounts for possible uncertainty or confidence of the individual towards their underlying WTP, as revealed by the certainty levels specified by respondents for given WTP bids. As demonstrated by Fig. 10, while most respondents show their mean WTP largely concentrated in the range of IDR 0–200,000, there is a small portion of respondents having widely distributed WTP, implying relatively high subjective uncertainty about their WTP.

4.7. Regression analysis of respondents mean WTP estimates

Table 10 presents the result of regression analysis of respondents mean WTP estimates. The specified regression function fits the estimated mean WTP of individual respondents well, as indicated by adjusted R^2 estimated at 0.7541. The result shows that household income in its natural log value highly significantly affects the mean WTP of respondents. More specifically, the higher the household income, the higher the mean WTP of the respondent. The effects of the numbers of adults and children in each household are also highly significant and positive, implying a bigger household with more adults and children tends to be willing to pay more for reliable water supply. It is interesting to note that households dependent on bottled water as the only source of drinking water are willing to pay more for reliable water supply than other households whose drinking water come from sources other than bottled water such as refilled water from kiosks, tap water, or wells.

The dummy variables for gender, marriage status, education, and position seem insignificant in influencing respondents WTP. Specifically, the male respondents who are married, have education up to the university level, and are government employees do not seem to have significantly different WTP than do other respondents. The perception of good water quality for tap water appears negatively affect respondents WTP but is not significant. Respondents who are satisfied with the current water supply do not have significantly different WTP

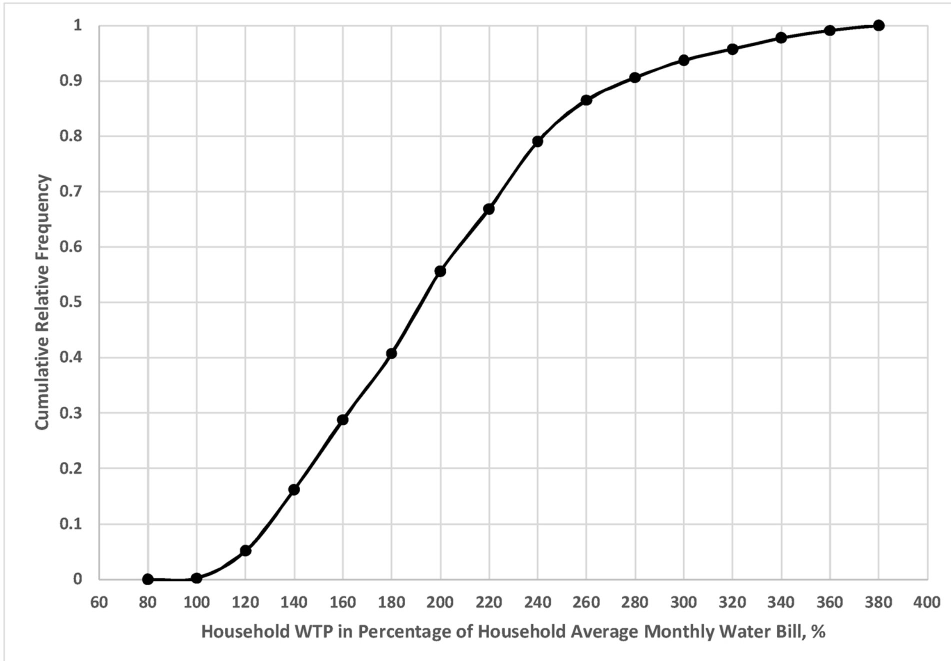

Fig. 9. Cumulative relative frequency distribution of household WTP in percentage of average monthly water bill for reliable water supply.

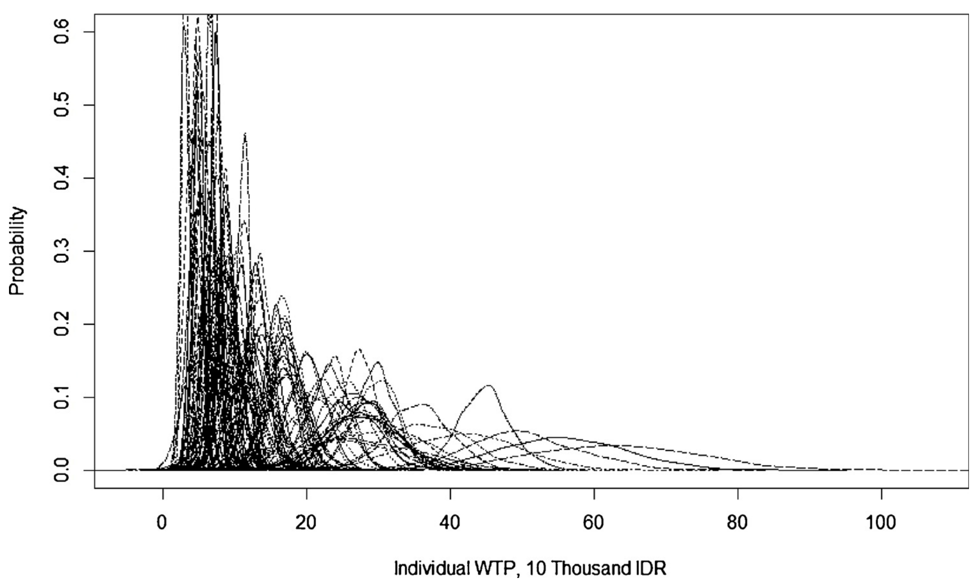

Fig. 10. Distributions of individual survey respondents WTP for reliable water supply.

from those of other respondents.

5. Discussion

5.1. Status of domestic water supply and utility performance

In nearly ten years after the 2004 tsunami disaster, water supply in Banda Aceh seems have recovered and being improving, at least in terms of the coverage of water supply service. Indeed, over the recent past years with available data, the service coverage provided by PDAM increased from 74.2% in 2010 to 85.0% in 2012, a significant achievement for post-disaster reconstruction and restoration in the water sector although slower than expected. To achieve the SDG goal for water supply, local water utility and government, however, still need to further extend the service coverage and expedite the process.

Despite the progress, the performance of water supply system is of concern. Domestic water supply in Banda Aceh like in other developing countries is subject to high percentages of NRW, sizable financial loss, and poor performance. The high percentage of NRW directly has led to the financial loss of PDAM over the past years, despite the revenue from water sale higher than the production cost on a per m^3 basis. As such, low cash balance and investment in infrastructure has resulted, further worsening the situation of NRW, threatening the financial sustainability of water supply, and challenging the improvement of water service to achieve water SDG. Reducing the share of NRW represents an important task for the local water utility that requires multiple strategies and measures to holistically and jointly address the diverse causes such as administrative losses, leakages, and illegal connections.

Table 10
Regression results of individual respondents mean WTP for reliable water supply.

Independent variable	Estimated coefficient	Standard error
Constant	−1.6686***	0.4300
Log_Income	0.5152***	0.0791
Num_Adults	0.1993***	0.0233
Num_Children	0.0830***	0.0334
D_Male	0.0772	0.0665
D_Married	0.0856	0.0797
D_Univerity	0.0323	0.0807
D_Government	−0.0052	0.0796
D_Bottled	0.2152**	0.0885
D_WQGood	−0.0964	0.0726
D_WSSatisfied	0.0565	0.0845
Adjusted R^2	0.7541	

*** Significantly different from 0 at the level of 0.01, ** significantly different from 0 at the level of 0.05, and * significantly different from 0 at the level of 0.1.

5.2. Household water use behaviour, public perceived quality of water services, and opportunity for improvement

In Banda Aceh, household water use behaviour differs between drinking and non-drinking purposes. The finding that most households rely on refilled water from kiosks at an additional cost instead of tap water as the main source of drinking water reflects either poor quality of tap water or insufficient household information and/or awareness of tap water quality. Monitoring tap water quality and information disclosure through education campaigns by PDAM via a third independent party may help build public trust, thereby creating an enabling environment for water supply improvement and sustainability. This is relevant and important, considering that residential households represent the major segment of water users in the city.

Regarding the quality of water service provision as perceived by residential households, one major issue raised is low water pressure such that most households use water pumps. Occasional turbidity in water supply after rainfall was also reported by some respondents. From the technical and operational perspective, water supply could be improved by better design and setting of pumping stations and water pressure and by timely monitoring of source water quality and due response for water intake and appropriate treatment. Noticeably and interestingly, most respondents are neutral about the quality of water supply service despite their coping behavior in accessing drinking water. This finding further highlights the importance of education and information disclosure that may be an instrument for encouraging public participation in supporting management and improvement of domestic water supply. It is worth noting that there seems a lack of perceived improvement of water supply for post-tsunami reconstruction based on limited responses.

Opportunity exists for improving water supply to better meet local needs. This is at least partially reflected by the diverse sources characterizing drinking water supply and by the behavior of households in accessing drinking water. On one hand, tap water is provided by PDAM at financial loss; on the other hand, local households adopt different practices incurring additional private costs for getting quality drinking water. The contrasting situation not only suggests the gap between water supply and demand for further improvement but also identifies direction and opportunity for closing the gap in the future. The way that local households access drinking water implies positive WTP and stakeholder support for water supply improvement, constituting a good foundation for management reform to mitigate the financial loss of supplying water and to increase service coverage.

5.3. Household positive WTP for reliable water supply and impact factors

Residential households appear to be willing to pay for improved, reliable water supply service. Our analysis shows a positive WTP in the range of 100%–380% of household average monthly water bill across survey respondents. The finding that more than half of the respondents are less willing to pay more than 200% of household average monthly water bill seems comparable to and consistent with the fact that most households currently pay 220% more than their monthly water bill for drinking water from sources other than tap water. Given the mean household monthly water bill of IDR 80,725 for considered survey respondents, the median household WTP of approximately 190% of water bill implies IDR 153,378 per month per household potential available for improved, reliable water supply.

One of the advantages for the MBDC approach to WTP estimation lies in its explicit consideration of possible subjective uncertainty towards different levels of WTP and incorporation of the uncertainty in model estimation. Our analysis shows the individual distribution of household WTP of each respondent. While household WTP estimates are widely distributed, most respondents have a concentrated WTP distribution in the range of IDR 0–200,000, implying reliable mean WTP estimates for policy analysis on water supply.

Many factors affect the WTP of residential households for reliable water supply. In our study, significant determinants identified include household income, family size, and adopted source of drinking water. As expected, the higher the household income, the higher the mean WTP of the respondent. The higher WTP by households with a bigger family seems make sense as bigger households would benefit more from better reliable water supply when they in status quo likely spend more in getting clean drinking water from alternative sources than otherwise would be. For households relying only on more expensive bottled water rather than other alternatives as their drinking water source, it is not surprising to find higher WTP from them. As bottled water is the most expensive source of drinking water with perceived good quality, households would likely be willing to pay more for reliable water supply if they usually choose the more reliable but expensive source of drinking water among others. Other demographic factors such as gender, marriage status, education, and occupation plus perception and attitude do not seem to significantly affect household WTP.

6. Conclusion

The water supply system of Banda Aceh, Indonesia, was severely damaged by the Indian Ocean Tsunami of 2004. Based on primary and secondary information collected from both water utility and residential households, we find that after nearly 10 years since the disaster, water supply in the city seems have recovered and been improving at least in terms of expanding service coverage. Despite the improvement, the quality of water supply service is of concern. This is reflected particularly by the high percentage of NRW, financial loss, and poor performance currently suffered by the local water utility that have formed a negative cycle. From the user's perspective, low water pressure stands out as a major issue as perceived by residential households for water supply. The way that residential households access alternative water sources differentially between drinking and non-drinking purposes, however, implies also public concern and distrust over the quality of tap water.

The most important finding of the study perhaps is that the majority (or 80%) of survey respondents are willing to pay 100%–240% of their household monthly water bill for reliable water service, with the median at approximately 190% of the water bill. While survey respondents exhibit some uncertainty on their household WTP, most of the respondents appear to have a concentrated WTP distribution, with its mean depending on household income, family size, and drinking water source. The findings may serve as the foundation and rationale for management reform to improve water supply service and performance in the city.

To improve domestic water supply in Banda Aceh requires a holistic, systematic approach. The above assessment based on both utility performance and user perception highlights the need and importance of improving the quality of domestic water supply service in addition to service coverage in the future. Such improvement may include measures to reduce the share of NRW and/or to improve the financial performance of utility. The positive WTP of residential households identified by our survey implies a strong potential for raising money through water pricing reform to improve water supply service. Management and governance measures, such as monitoring, system optimization, and information disclosure and education campaigns for awareness raising and participatory decision-making, are equally important and should be an integral component for improving domestic water supply in Banda Aceh, Indonesia.

Appendix I

Table A1
Example of WTP Question Formulated as MBDC.

WTP bid [a]	Implied WTP amount [b]	Uncertainty level of respondents toward WTP bid				
		Definitely Yes	Probably Yes	Not Sure	Probably No	Definitely No
Bid 1						
Bid 2						
Bid 3						
Bid 4						
….						

a. The bids are in the order of increasing magnitude.
b. This column is needed only if WTP bids do not explicitly show the monetary amount of household WTP. For example, in our survey, for respondents who subscribed to water utility and received monthly water bills, the WTP bids were expressed in percentages of household average monthly water bills and, thus, the corresponding implied monetary amounts of WTPs were calculated for which respondent preferences were elicited.

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