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Role of Meters in Rural Development - A Case Study of Rural Water Systems in Belize

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Abstract

The government of Belize and other relevant stakeholders involved in rural water supply services have been actively promoting the implementation of meters in rural water systems to improve their financial sustainability and management. While it is generally understood that metering improves revenue collection based on consumption-based metric, few studies have investigated the extent that metering in rural water systems (RWS) impacts revenue generation, expenses and water conservation for rural water supply service providers such as village water boards in rural areas. This study aimed to investigate the impact of meters on RWSs' financial sustainability and water conservation in Belize.

This study finds that metered water systems generate higher revenues overall and per consumer connection compared to unmetered systems. The installation of meters is recognized as a viable strategy for village water boards aiming to enhance their revenue generation capabilities. In addition, metering was found to be positively associated with higher payment rates and reduced water consumption. However, our research reveals that metered systems incur significantly higher expenses compared to unmetered systems. Though not significant, metered systems had lower average net profit margin compared to unmetered systems. This can be attributed mainly to the higher expenses incurred by metered water systems. It is crucial for all stakeholders engaged in rural water supply services in Belize to explore effective measures that reduce the expenses of RWSs and enhance revenue collection. This is vital to guarantee their continued delivery of service and financial sustainability.

Key words: rural water systems, revenue, expenses, water usage

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1. Introduction

In Belize, approximately 53% of rural water systems (RWS) are metered. The Government of Belize (GOB) and local industry stakeholders have been actively promoting the implementation of metering in rural water systems to improve their financial sustainability, management and water conservation (MRTCDLLG, 2022). Historically, it has been common for water utilities to use flat rates or property taxes to bill water users. The introduction of meters presents a transformative opportunity to move to a consumption-based or usage-based pricing policy. These principles provide concrete incentives to promote water efficiency and promote responsible water use practices (Zetland & Weikard, 2011). Numerous studies have shown that metering positively contributes to improved management, revenue collection, payment rates, leak detection and reduced water demand in water supply systems (Drozdov, 2002; Harutyunyan, 2015; Ingram & Memon, 2020; MRTCDLLG, 2022).

However, there is an overall lack of research regarding the extent to which it improves revenue collection, impacts expenses, influences profitability, and affects water consumption patterns in RWSs. This problem extends to Belize, where only a few studies have investigated very basically the impacts of metering on RWSs' sustainability and water consumption patterns in Belize. Moreover, the availability and accessibility of reports and data on the subject is low. This study aims to investigate the impacts of metering on the financial sustainability and water consumption patterns of RWSs in Belize. Throughout this chapter, a background context will be introduced, followed by the research aim, objectives and questions and its significance.

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1.1 Background context

Water meter technology are devices and systems used to measure and monitor water use in residential, commercial, and industrial settings. Water meters operate by measuring the flow of water through them. Usually, they are made up of equipment that has a rotation mechanism or digital sensors. Their main purpose is to precisely measure and keep track of the water consumed by people or organizations for things like billing, resource management, leak detection, and encouraging water conservation ((Drozdov, 2002; Harutyunyan, 2015; Ingram & Memon, 2020; MRTCDLLG, 2022).

In Belize, there are three main operators in the water supply sector, namely: Belize Water Services Limited (BWSL), Village Water boards (VWB) and private suppliers. Urban areas and a few peri-urban areas are covered by BWSL. BWSL is a private entity, with a mixed ownership structure, with GOB as the majority shareholder, and provides water to approximately 70 percent of the Belizean population (Grau & Rihm, 2013; Scodelaro et al., 2022). Water supply provided by BWSL is completely metered (Scodelaro et al., 2022). The rural water sector is covered by VWBs and is governed by the Village Councils Act Chapter 88 of the Substantive Laws of Belize, Revised Edition 2011. This act establishes the structure of VWBs, who operate financially independent from village councils and are responsible for overseeing the day to day management and operation of the RWS in their village, or villages in the case where they provide service to multiple villages. RWS refers to the infrastructure and mechanisms put in place to provide safe drinking water to communities located in rural areas. They are characterized as piped networks that distribute water to households from a central reservoir. In Belize they are managed by VWBs. VWBs function as community-owned entities, where the villagers have a central role as the primary stakeholders in their water system (BSIF, 2017). In rural areas managed by VWBs, not

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all RWSs are metered. 57 of 107 RWSs in Belize use meters to regulate and monitor water consumption. In other rural areas, water services are provided by privately operated and unregulated water operations, catering to areas not covered by the VWBs or rural water systems (BSIF, 2017).

Belize as a country has made significant improvements in the past decades in improving water access, however rural water supply service providers face continuous challenges to maintain and operate their rural water supply systems. In Belize, the percentage of the population with access to safe water is 96 percent, however with huge disparities in rural areas (UNICEF, 2021). In Latin America and the Caribbean, the percentage with access to safely managed water services is 75 percent (WHO & UNICEF, 2021). When it comes to the percentage of the population using at least basic drinking water services, the percentage is 98 percent, with 98 percent for rural and 99 percent for urban respectively (World Bank, 2020). Despite significant improvements in water coverage, water delivery services in rural Belize face continued operational, maintenance, financial and institutional challenges (Grau & Rihm, 2013; BSIF, 2017; MRTCDLLG, 2022). Numerous rural water systems in Belize, including metered RWSs, are struggling financially, and in many cases generate revenues that are only sufficient to cover operation and management needs, and insufficient to undertake capital expenses required to expand or renovate their system (Grau & Rihm, 2013; BSIF, 2017; MRTCDLLG, 2022). For example, a 2022 report on struggling waterboards, shows approximately BZD $492,000 (US$246,000) would be required to assist them with the purchasing of meters to expand their water distribution networks (MRTCDLLG, 2022). With the exception of a few well performing RWSs, the majority of VWBs struggle to cover operation and maintenance expenses, and to undertake capital expenses to expand and improve their water distribution network and level of service (Grau & Rihm, 2013).

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Hence why it is compelling to investigate the extent of how meters impact RWSs' financial sustainability and water conservation given the positive benefits associated with the technology. Moreover, GOB and other development stakeholders such as the Belize Social Investment Fund (BSIF) actively promote the full adoption of meters by VWBs in an effort to strengthen their financial, managerial, operational and water conservation capacities, and to assist with cost recovery efforts. RWSs that are not metered are encouraged to adopt and embrace the technology.

Information on the impact of meters on the financial solvency and water conservation in RWSs of Belize is limited. Most of the studies point out where RWSs are struggling, such as in covering their operation and maintenance expenses, their lack of adequately trained personnel, low tariff payments and their inability to undertake capital expenses (Grau & Rihm, 2013; BSIF, 2017; MRTCDLLG, 2022). Information regarding the impact of the technology on RWSs' financial sustainability and water conservation in Belize is rudimentary, and consists of basic comparisons between similar sized water systems. Although these investigations are not statistically rigorous, they find positive benefits associated with metering such as the improved revenue generation, higher payment rates and water conservation (MRTCDLLG, 2022). However, there are challenges in generalizing the findings due to concerns regarding the statistical analysis's rigor and the sample size. The precise mechanisms through which meters alleviate or contribute to these sustainability issues within RWSs have not been thoroughly investigated. Consequently, existing studies on the effects of meters on RWSs' financial sustainability and water conservation in Belize lack the comprehensive information needed to extrapolate the benefits and impacts of metering across the RWS landscape in Belize.

Given the backdrop of GOB and other development stakeholders actively promoting the implementation of meters in the remaining RWSs that have not yet adopted the technology, the

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scant information available on the impacts of the technology in Belizean RWSs can act as a barrier, potentially hindering the adoption of the technology by the remaining unmetered RWSs. The absence of in-depth analysis on the impacts of meters can delay the technologies' adoption especially when communities have doubts on the benefits of the technology (Cairns, 2018; Tantoh, 2021).

While it is generally well known by GOB and VWBs that metering improves revenue generation and water conservation. The extent of how much it impacts these factors is not well understood, moreover its impacts on VWBs' expenses and profitability is almost non-existent.

1.2 Research Aim

This study aims to investigate the impact of meters on RWSs' financial sustainability and water conservation.

1.3 Research objectives

- To investigate the impact of metering on revenue generation in RWSs of Belize.
- To investigate the relationship between metering and expenses incurred by rural water systems in Belize.
- To investigate whether metering impacts the profitability of RWSs in Belize.
- To investigate the impact of metering on water consumption patterns in rural water systems of Belize.

1.4 Research questions

1. Is there a significant difference in total annual revenue, average monthly income, total annual expenses, daily water usage and payment rate in metered and unmetered RWSs in Belize?

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2. What is the relationship between number of consumer connections in metered systems and total annual revenue among RWSs in Belize?
3. What is the relationship between the number of consumer connections in metered systems and average monthly income among RWSs in Belize?
4. What is the relationship between the number of consumer connections in metered systems and total annual expenses among RWSs in Belize?
5. What is the relationship between the number of consumer connections in metered systems and daily water usage in RWSs in Belize?

1.5 Significance

This study will contribute to the body of knowledge on rural water infrastructure development by evaluating the impacts of metering on RWSs' financial sustainability and water conservation in developing countries. Furthermore, this will help address the current shortage of research in this area, especially in Belize, and provide real-world value to organizations such as GOB and VWBs operating in rural water supply.

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2. Literature Review

2.1 Introduction to Water Metering Technology

Water meter technology comprises devices and systems employed for quantifying and overseeing water usage in various contexts, such as residential, commercial, and industrial settings. The primary objective of these tools is to accurately gauge and record the amount of water utilized by individuals or entities, facilitating tasks like billing, resource management, leak identification, and promoting water conservation ((Drozdov, 2002; Harutyunyan, 2015; Ingram & Memon, 2020; MRTCDLLG, 2022). Usually, they are made up of equipment that has a rotation mechanism or digital sensors. The device or sensor will record the amount of water that passes through as it flows through the meter. The data generated by the meter facilitates the identification of water performance metrics, encouraging behavioral and operational adjustments from both users and water utilities. In addition, measurement is essential to establish a fair payment system that correlates water costs with consumption, which is widely considered the most equitable approach (Harutyunyan, 2015). This helps to prevent inequalities and promotes equitable distribution of water resources, thus limiting the possibility for some individuals or households to consume more than their fair share.

2.2 Evolution of Water Metering Technology

In the last decade, technological developments in electricity metering have had a major impact on how advanced meters have become. In the water sector as well, this increased complexity and functionality of energy metering has also started to be reflected (UNESCO & UNESCO i-WSSM, 2019). This has changed water metering technology, from basic accumulation meters to advanced smart meters that can communicate real time information on water usage to

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managers and users. In Belize, the water meters that are used in urban and rural water supply are accumulation meters.

2.3 Implications of Metering on Tariff Structure and Supply and Demand

In the past, water utilities frequently employed flat rates or property taxes for billing water users. Nonetheless, the introduction of meters offers a significant chance to shift towards a pricing policy based on consumption or usage. This fresh approach offers tangible incentives to encourage water efficiency and responsible water use practices (Zetland & Weikard, 2011). From a supply point of view, water metering improves the transparency of water supply operations and facilitates better monitoring of the quality of water supply services. On the demand side, it provides users with the necessary incentives to make informed decisions on their daily water consumption, promoting responsible water use (Drozdov, 2002).

2.4 Metering benefits to Revenue Collection, Leakage detection, Payment Rates and Management

In Tanzania, rural water system managers indicate that the introduction of meters has improved revenue collection, improved monitoring capabilities, reduced non-revenue water, and increased economic efficiency (Ingram & Memon, 2020). These benefits derived from metering have played an important role in strengthening rural water supply systems in Tanzania. However, Ingram & Memon caution that despite the benefits of metering to strengthen RWSs' management and operation in Tanzania, water metering technology is not a one-size-fits-all solution (2020).

The adoption of meters allows water companies to be able to detect leakages early, ensure accurate level of water consumption, provide their customers with tools to monitor and reduce water usage, therefore reducing overall water demand and improving their ability to carry out preventive maintenance (UNESCO & UNESCO i-WSSM, 2019). Harutyunyan found that in

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Armenia, a country wide government mandated meter implementation in water supply systems enabled improved leakage detection (2015). Communities were able to detect and rectify leakages in a timely fashion, reduce water losses and minimize the necessity of expensive repairs by tracking consumption patterns and detecting unusual use (Harutyunyan, 2015).

Another benefit derived from the introduction of meters is an improvement in tariff payment rates. For example, Harutyunyan found a significant increase in tariff payment rates in Armenian water systems after meters were introduced, and attributed to enhanced water service delivery, compliance, and enforcement as result (2015). Harutyunyan elucidates further that as collection rates improved, water utilities were able to enhance their water services, resulting in a gradual extension of the average water supply duration. Consequently, this extended supply duration typically led to an overall consumer satisfaction with the system. An analysis conducted by the Belize Social Investment Fund (BSIF) on 15 waterboards in Belize highlighted the significance of payment rates. In 2015, three waterboards reported net losses, and if all bills for that year had been collected, only one village would have still experienced a net loss (BSIF, 2017). This underscores the importance of maintaining high payment rates to ensure adequate revenue collection and alleviate financial challenges of which metering has been positively associated with.

Finally, metering has been found to positively influence maintenance perception. For rural communities in Bolivia, metering has been seen as a way of monitoring the whole system and detecting any problems, by development professionals and local people alike (Cairns, 2018).

2.5 Metering and Water Suppliers' Expenses

There is a general lack of studies regarding the expenses incurred by water suppliers on the adoption of meters. Generally, studies show that the burden of installing a meter for a consumer is eased when it is subsidized by the government or covered by the utility company, given that they

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can recover their costs through adequate tariff adjustments over a reasonable period of time (Harutyunyan, 2015). How the installation of meters impact water suppliers' expenses is not well documented, although it is reasonable to presume that their material and equipment expenses will increase in the short term when meters are acquired to be installed for customers. For example, the cost of one meter, based on GOB estimates is approximately BZD $400 (US $200) (MRTCDLLG, 2022). MRTCDLLG report that struggling VWBs, would need approximately BZD $492,000 (US$246,000) in funds for the purchasing of meters to expand their service to new customers (MRTCDLLG, 2022). Additional expenses are expected to be incurred for maintenance and replacements of the meters, and staff to record and process water usage data for customers to prepare billing statements.

2.6 Metering and Water Supplier Sustainability

In developing countries, it is rare to find water supply service operations that have operating revenues significantly below operation and maintenance costs and yet manage to maintain their infrastructure and provide reliable services (McPhail et al., 2012). Financial sustainability in these cases heavily relies on the predictability and stability of revenues. Customers represent the most predictable and stable revenue source, provided they have access to quality infrastructure. Government budgets and external "donor" programs cannot be considered reliable sources of financing (McPhail et al., 2012). Cost recovery pertains to the ability of water supply service providers to generate revenues from customers, covering both operations, management and capital costs. Metering therefore is a tool with benefits that include improved revenue collection, improved monitoring capabilities, reduced non-revenue water, and increased economic efficiency (Ingram & Memon, 2020). In their 2017 study, Borja-Vega et al. found a moderate correlation between charging consumption-based tariffs, the level of monthly income, the presence of total

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monthly revenues exceeding operating costs, and the availability of adequate funds for operations, management, and institutional capacity building with RWSs' organization and financial sustainability. Regardless of whether a water supply system is a metered or unmetered system (volume-based or flat-rate pricing), pricing may not guarantee complete cost recovery. Even high-income private utilities often experience only a small profit margin for water supply (REAL-Water, 2023). Furthermore, there are pressures to maintain water at an affordable price as access to water is regarded as a basic human right (McPhail et al., 2012).

2.7 Metering and Water Conservation

Metering allows for accurate measurement of water consumption, encouraging individuals to be more mindful of their water usage. In theory, a user has no incentive to use water efficiently if it is not metered (Harris et al., 2002). The goals of metering go beyond this as well, ensuring that environmental landscapes are preserved, that water projects and programs have sufficient funds to continue, and to ensure that ''economic incentives" change individual behavior related to water use (Ueda & Moffatt, 2012). Overall, metering water systems in rural communities helps promote water conservation, ensure fairness, recover costs, achieve financial sustainability, detect leaks, enable data-driven decision-making, and encourage behavioral change towards responsible water use.

The argument that metering will promote more conservation of water may not bode completely community members. Some may argue that due to customary or traditional practices, laws and past experiences with droughts, that they already practice conservation of resources such as by reducing deforestation and watershed protection (Cairns, 2018). While Cairns' study does not take a direct look at the impact of water meters in terms of conservation practices; in his study

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some community members explain that traditional water conservation practices had already been developed before metering was introduced (2018).

2.8 Potential Drawbacks of Metering to Consumers

While metering water systems in rural communities can provide a number of advantages, there are also potential drawbacks to consider. It may be expensive to install meters and establish a metering system up front. For rural water management committees with limited financial means, this expense can be challenging. Adoption may be hampered by the cost of acquiring and maintaining the meters, installing the infrastructure as well as the requisite data collection and management.

In some cases, implementing metering systems can lead to increased costs for consumers. This can be particularly burdensome for low-income households or communities where residents may already struggle to afford basic necessities (Harutyunyan, 2015). This may lead them to pursue alternative water sources such as rivers. Cairns explains that while consumers may perceive metering as a factor for improved management of rural water systems, there exists a perceived trade off with its implementation which is higher tariff rates (2018). For example, Cairns found that in Sapecho, Bolivia, each household has a monthly "right" to 8000 cubic liters of water, once this quota is consumed additional cost are levied to the consumer which may be unfair to them as the quota may not be sufficient and may be expensive for larger families and hotter areas like Sapecho (2018). Additionally, compared to surrounding areas, where no metering is in place, Sapecho's water costs are comparatively high and this results in financially burdensome situations for some residents. Notably Cairns, argues that the nuances of this hardship were overlooked monitoring and evaluation techniques at the policy level.

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Furthermore, communities may resist metering because they view it as an attempt to make profit. Some consider the implementation of water meters as an attempt to make money which goes against the principles of community development (Tantoh, 2021). Considering that in rural communities' income is generally lower than urban areas, the implementation of meters can be met with increased skepticism if it presented as a money-making venture rather than a service improvement mechanism

2.9 Accuracy of Water Meters

There are issues related to the accuracy of meters. As time goes by, a significant number of water meters are likely to lose their reliability in accurately recording the increasing volume of water flowing through them (Harutyunyan, 2015). Therefore, it is important that routine checks be done to ensure their accuracy or if the consumer detects unusual operations of the meter they can report it to the authorities. Consequently, with inaccurate meters if it is over reading, it can result in increased bills for consumers and increased profit for water companies, and if it is under reading results in a rise in non-revenue water for companies.

2.10 Rural Water Supply and Metering in Belize

Rural water boards are the dominant operator and provider of water supply services in rural areas. Currently, there are 107 rural water systems serving a rural population of approximately 105,689 people. Approximately 53% or 57 of the RWSs in Belize use meters to regulate and monitor water consumption. These VWBs ensure the availability of water for approximately 28,146 households (MRTCDLLG, 2022).

VWBs are governed by the Ministry of Rural Transformation, Community Development, Labor and Local Government (MRTCDLLG; herein referred to as "the Ministry") in Belize (Grau & Rihm, 2013; BSIF, 2017). The Ministry is designated by the Village Councils Act 2003 to be

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responsible for village councils and, in practice, its role includes financial oversight and to a limited extent capacity building support for the VWBs (BSIF, 2017).

2.11 Challenges in Rural Water Supply Management and Operation in Belize

One of the key challenges faced by the Government of Belize (GOB) for improving the situation in water service delivery is that the country's population is fragmented across a large number of communities, with over one-third of the population living in about 190 villages and communities with less than 4000 inhabitants (Grau & Rihm, 2013). In rural communities, water is supplied by rural water systems (RWS), hand pumps, water catchments, hand dug wells, or privately-owned small-scale water systems. Majority of the population in rural areas obtain water from RWSs, which are piped networks that distribute water to households from a central reservoir. Most rural communities have their own water systems and village water boards (VWB), who are responsible for the system's operation, maintenance and sustainability. However, there exists a few communities with shared water systems and waterboards. VWBs function as community-owned entities, where the villagers have a central role as the primary stakeholders (BSIF, 2017). The small size and number of RWSs pose a challenge to adequately staff them with the technical and financial capacity to ensure their long-term sustainability (Grau & Rihm, 2013). In numerous developing countries where rural water systems are community-managed, it is not uncommon to encounter deteriorated water and sanitation facilities that fail to meet the community's needs in terms of adequate service level and quality (Borja-Vega et al., 2017). In certain instances, these systems have reached the end of their intended operational lifespan. The early breakdown of most systems results from a combination of factors, including inadequate maintenance, scarcity of replacement materials, low tariff payment and collection, insufficient funding for sustaining full

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operational capacity, and limited administrative and technical skills among both service providers and users (Borja-Vega et al., 2017).

VWBs in Belize generally have low collection rates. While collection rates differ among water systems, the overall collection efficiency is commonly perceived as subpar, and a significant majority of VWBs lack the financial means to undertake the essential capital investments needed for expanding rural water systems (Grau & Rihm, 2013; BSIF, 2017; MRTCDLLG, 2022). Furthermore, the lack of adequate personnel with the necessary technical skills in VWBs has been found to negatively contribute to the poor performance of RWSs. VWBs often have members who do not actively participate in the functions of the board (BSIF, 2017). The absence of sufficient expertise and commitment by waterboards is a challenge for adequate management of RWSs. Moreover, financial performance has been found to vary significantly across waterboards and between the country's districts (BSIF, 2017). Additionally, tariff structures in RWSs can help explain some inefficacies. Tariff rates vary widely among water systems, unmetered systems charging a flat rate, and metered systems changing a variable rate based on consumption (generally, they offer a set rate for a certain volume, once that volume is surpassed then additional charges are made per gallon consumed).

2.12 Key Points

The introduction of water metering technology can have a significant economic impact to water supply managers. Although there is an initial cost to install meters, the benefits associated with it such as improved revenue collection, monitoring and reduced non-revenue water withdrawals can lead to long-term cost savings for water supply providers. Integrating metering technologies to ensure better performance and long-term sustainability is an important step in the modernization of water systems. Metered systems have been found to exhibit significant

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improvements in management performance compared to unmetered counterparts. While, unmetered water systems present several challenges, including the limited ability to track water usage accurately and lower revenue generation. Nevertheless, it is important to acknowledge the hurdles associated with metering technology. The upfront investment to install the system, operations and maintenance costs, the need for appropriate behavior change for the technology to be adopted and the accuracy of meters over time pose challenges. Nonetheless, the adoption of metering technology, despite these complexities, is a compelling tool for water supply managers to achieve effective and improved water management practices.

3. Data and Methodology

To answer our research questions, we obtained data from two main sources which are the 2022 Water Board Profile (WBP) and the 2022 and 2021 Annual Financial Summaries (AFS) created by the Ministry of Rural Transformation and individual VWBs respectively. Additionally, we obtain data on the poverty rates for RWSs based on the multidimensional poverty index at the district levels from the Statistical Institute of Belize. This study employs a multiple linear regression analysis to examine the effect of metering on VWBs' revenue generation, expenses and water conservation. A t-test analysis was also used to investigate if there was any significant difference in means for various variables relevant to VWBs' financial sustainability, operations and management. Data was collected from 98 RWSs through the 2022 WBP, and 55 and 57 RWSs from the AFS for 2021 and 2022 respectively. However, not all RWSs were included in the analyses due to missing data for certain variables used in the study.

The WBP provides comprehensive information on the financial, operational and administrative performance of the waterboards supervised by the ministry. The WBP is created by the ministry using data supplied to them from VWBs across the country. Data is organized by the

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year. Useful data obtained from this data source to answer this study's research question include: the meter status of the RWSs whether they are metered or unmetered, the number of consumer connections per RWS, the percentage of consumers paying monthly per VWB, and the RWSs' reservoir water capacity in gallons.

The AFS presents financial data for each individual VWB on a monthly and annual basis. It contains data on their monthly and annual income, and expenses that are divided into different categories. VWB revenue is dominantly from tariff payments. Although they do earn extra income for new consumer connections, it is not their main source of income. Income generated from new consumer connections is included in the analysis as part of VWBs' average monthly income and total annual revenue. The quality of the data is ensured through various checks conducted by ministry officials, where at the end of the fiscal year, the water boards submit their data to the ministry for review, verification and analysis. Useful data obtained from AFS to answer this study's research question include: Average monthly income, total annual revenue, total annual expenses, and total annual expenditure for various categories of expenses. Additionally, the net profit margin for each RWS was calculated per year using their total annual revenue and expenses data. For some RWSs, net profit margin was calculated for only one year, and two years for others where the data was available for the year 2021, and 2022.

Additionally, data pertaining to the poverty levels associated with each community hosting an RWS at the district level was acquired from the Statistical Institute of Belize. Data on the poverty rates is measured through the Multidimensional Poverty Index. The Multidimensional Poverty Index (MPI) is a measure that provides a broader understanding of poverty beyond just income levels (SIB, 2021). When assessing poverty in this index, multiple dimensions such as health, education and living standards are considered in order to simultaneously capture the various

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deprivations faced by individuals. In our analysis, we utilize the Multidimensional Poverty Index (MPI) per community hosting an RWS at the district level.

Due to insufficient data available for the Corozal districts from the WBP and AFS, water boards in the Corozal district were excluded from certain analysis specifically for our regression analysis on impact of meters on average monthly income, total annual revenue, and total annual expenses, and for the t-test analysis for variables which includes: total annual revenue, total annual expenses, net profit margin, and the different categories of expenses presented in Table 2.

3.1 Empirical Strategy

A multiple linear regression analysis was used to estimate the effect of metered status, number of consumer connections, percentage of consumers paying monthly, and the multidimensional poverty index on the total annual revenue, average monthly income, total annual expenses and daily water usage of rural water systems across Belize. We also conducted a difference in means t-test between metered and unmetered systems. The analysis was based on data available for the year 2021 and 2022. All data was processed using statistical software STATA. Additionally, a data cleaning and validation process was carried out. The currency utilized in our report is the Belize dollar.

For our regression analyses, our outcome variables of interest are total annual revenue, average monthly income, total annual expenses and daily water usage. Total annual revenue represents the sum total income that a VWB generated for the year; income which is dominantly from tariff payment, but also includes income from connection fees and other small services offered by the VWB. Average monthly income is the average revenue generated by a VWB on a monthly basis primarily from tariff payment but also includes income from connection fees and other small services offered by the VWB. Total annual expenses represent the sum total that a

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VWB spent for its operation and maintenance and other capital expenditures for the year across several categories of expenses. Daily water usage is an average value of the volume of water that is consumed daily per RWS by the population they serve. Data for total annual revenue, average monthly income, and total annual expenses was drawn from the rural water boards' AFS for 2021 and 2022, and daily water usage was drawn from the 2022 water board profiles.

The following gives a description of the explanatory variables used in the regression analysis which includes, 'Metered' which is a categorical variable indicating whether an RWS is metered, number of consumer connections, percentage of consumers paying monthly, multidimensional poverty index and an interaction term between Metered and the number of consumer connections.

Since this study focuses on the impact of metering on RWSs' revenues, expenses and water consumption patterns, the treatment variables were Metered and the interaction term between Metered and number of consumer connections. We use 'Metered' as an explanatory dummy variable, where if an RWS is metered = 1 and unmetered = 0. RWSs across Belize have different levels of metering. Some are fully metered, meaning that they have a metered installed for every consumer connection that they collect tariffs from, or are partially metered, meaning they do not have metered installed at every consumer connection that they collect tariffs from but are in the process of completing it. For simplification purposes, this study categorizes RWSs as metered as long as it has been utilizing meter technology, regardless if they are fully or partially metered, as long as there is evidence to show that they are using the technology to track user's consumption and or charge a consumption-based tariff. RWSs are categorized as unmetered when they do not use the technology at all and charge a flat rate.

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Number of consumer connections represent a sum value of the number of consumer connections, whether it be a household or enterprise, per RWS, that is charged a tariff for water consumption regardless if the RWS is metered or not. In developing our regression models, it was found that the number of consumer connections had a high positive correlation with daily water usage with a correlation coefficient of 0.8433. Importantly, the analysis used the number of consumer connections rather than daily water usage as an explanatory variable based on the rationale that more connections equals more water used, and more daily water usage does not necessarily mean more consumer connections. Therefore, the number of consumer connections was used as an explanatory variable and daily water usage as outcome variable to see if there was any effect on the use of meters in water conservation, being that metered connections use less water due to greater consciousness of water usage by consumers in metered systems.

We control for other explanatory variables that may help explain our outcome including poverty via the multidimensional poverty index which is an index value for the poverty rate for a given RWS based on which district they are located (each district in Belize has a different index value). Multidimensional poverty index is a measure of poverty that takes a holistic account of deprivations an individual may face beyond income levels. The values for this variable range from 0 to 1. A household is considered multidimensionally poor if their deprivation score is greater than 0.25 (SIB, 2021). The other explanatory variable we control for is percentage consumers paying monthly which is a measure for each RWS of the percentage of users paying their monthly water bills versus those that do not.

This study uses four models for the regression analysis. The following is a description for each model.

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Below shows the equation for model 1

$$\text{Totalannualrevenue}_i = \beta_o + \beta_1\text{Metered}_i + \beta_2\text{Numberofconsumerconnections}_i + \beta_3\text{Multidimensionalpovertyindex}_i + \beta_4\text{Percentageconsumerspayingmonthly}_i + \beta_5\text{Metered*Numberofconsumerconnections}_i + \varepsilon_i \quad (1)$$

Where $\text{Totalannualrevenue}_i$ is the outcome variable, which represents an average value of the total annual revenue that VWBs generated for the year dominantly from tariff payment, but not excluding income from connection fees and other small services offered by the VWBs. $\beta_1\text{Metered}_i$ is a binary variable where the water system is metered = 1, and unmetered = 0. $\beta_2\text{Numberofconsumerconnections}_i$ represent the number of consumer connections, whether it be a household or enterprise, per RWS, that are charged a tariff for their water consumption regardless if they are metered or not. $\beta_3\text{Multidimensionalpovertyindex}_i$ is a measure of the average poverty rate for a given RWS based on which district they are located, based on a range from 0 to 1, with increased values indicating higher poverty. $\beta_4\text{Percentageconsumerspayingmonthly}_i$ is a measure for each RWS of the average percentage of users paying their monthly water bills. $\beta_5\text{Metered*Numberofconsumerconnections}_i$ is an interaction term to estimate the effect of the relationship between the number of consumer connections in a metered system on total annual revenue. ε_i is the random error term.

Below shows model 2 - 4

$$\text{Averagemonthlyincome}_i = \beta_o + \beta_1\text{Metered}_i + \beta_2\text{Numberofconsumerconnections}_i + \beta_3\text{Multidimensionalpovertyindex}_i + \beta_4\text{Percentageconsumerspayingmonthly}_i + \beta_5\text{Metered*Numberofconsumerconnections}_i + \varepsilon_i \quad (2)$$

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$$\text{Totalannualexpenses}_i = \beta_o + \beta_1\text{Metered}_i + \beta_2\text{Numberofconsumerconnections}_i + \beta_3\text{Multidimensionalpovertyindex}_i + \beta_4\text{Percentageconsumerspayingmonthly}_i + \beta_5\text{Metered*Numberofconsumerconnections}_i + \varepsilon_i \quad (3)$$

$$\text{Dailywaterusage}_i = \beta_o + \beta_1\text{Metered}_i + \beta_2\text{Numberofconsumerconnections}_i + \beta_3\text{Multidimensionalpovertyindex}_i + \beta_4\text{Percentageconsumerspayingmonthly}_i + \beta_5\text{Metered*Numberofconsumerconnections}_i + \varepsilon_i \quad (4)$$

Model 2, 3 and 4 use the same explanatory variables as model 1, except that we change the outcome variables. In model 2, our outcome variable is average monthly income which is an average value of the mean monthly income generated by VWBs primarily from tariff payment, but not excluding income from connection fees and other small services offered by the VWBs. For model 3, the outcome variable is total annual expenses which is an average value of VWBs total annual expenses for the year. In model 4, our outcome variable is daily water usage which is an average value of the mean volume of water that is consumed daily per RWS by the population they serve. For each model we included the interaction term Metered*Numberofconsumerconnections to estimate the effect of metered connections on the outcome variables.

To address the concern of heteroscedasticity in our regression analysis, we use robust standard errors. These robust standard errors are better equipped to handle heteroscedasticity issues and offer a more precise estimation of the true standard error for a regression coefficient. We use the statistical analysis package STATA for our analysis.

Furthermore, this study uses t-tests to investigate if there are any significant differences in means between different variables of interest between metered and unmetered RWSs. Below is a breakdown of the variables.

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Capacity of tanks refers to the volume in gallons that each RWS' water reservoir can contain. Net profit margin, also known as net margin, quantifies the percentage of net income or profit generated in relation to revenue. It showcases the profitability of a company by illustrating the portion of each revenue dollar that results in profit. Net profit margin is usually represented as a percentage, although it can also be expressed in decimal form (Murphy, 2022). The formula used for this study to calculate net profit margin was [(total annual revenue – total annual expenses)/total annual revenue*100]. Other variables such as number of consumer connections, daily water usage, percentage consumers paying monthly, multidimensional poverty index, total annual revenue, average monthly income and total annual expenses have been previously described in the regression analysis models. The results of the t-test for these variables are reported in Table 1.

From the AFS, data was obtained on the sum expenses incurred by RWSs for various categories of expenses which include expenditure on energy, diesel and electricity, materials and equipment, transportation, labor for repairs, billing clerks, pumphouse operators, social security and donations. T-tests were done to investigate if there were any significant differences in the mean for the various categories of expenses between metered and unmetered RWSs. The results of these t-tests are presented in Table 2.

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4. Results

Table 1 presents the results from the t-tests to investigate if there were any significant differences in means between different variables of interest between metered and unmetered RWSs. This also includes variables used in the regression analysis, and others not included in the regression models but still considered as important indicators that can be used to analyze for difference in means. The names of the variables are shown in the column labeled indicators. Columns 1 and 2 report the average for metered and unmetered systems respectively. We report the difference of these means in column 3.

As shown in the table, for the capacity of the tanks, there was no significant difference between the water systems, although on average metered systems had bigger water reservoirs. For the number of consumer connections, there was no significant difference between the systems, however, unmetered systems had on average slightly more consumer connections. For daily water usage, our difference in means test show no significant difference, however, we find that on average unmetered systems consumed more water. Remarkably, we find that metered systems had on average a significantly higher percentage of consumers paying monthly. The average for the multidimensional poverty index shows that meter systems had significantly higher multidimensional poverty index levels compared to unmetered systems, or in other words metered RWSs are situated in areas with higher poverty levels. Metered systems had on average significantly higher mean values for total annual revenue, average monthly income, and total annual expenses compared to unmetered systems. Finally, when examining the average net profit margin for each system, no significant difference in net profit margin between the two systems was found, however, strikingly unmetered systems averaged higher net profit margin than metered systems.

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Table 1: Comparison of key indicators between metered and unmetered water systems

Indicator	Metered Water System	Unmetered Water System	Mean difference (Metered-Unmetered)
Capacity of Tanks	21884.62	18762.16	3122.453
Number of consumer connections	237.5263	299.8293	-62.30295
Daily Water Usage (gallons)	28591.5	37616.17	-9024.667
Percentage Consumers paying monthly	0.6375026	0.5562906	**0.0812119** *
Multidimensional Poverty Index	0.2042655	0.1839036	**0.0203619** **
Total annual revenue	66842.94	34584.33	**32258.61** **
Average Monthly Income	6117.127	3098.245	**3018.882** **
Total annual expenses	62297.71	32583.49	**29714.22** **
Net Profit Margin	1.679563	5.959709	-4.280146

***, **, * indicate statistical significance at the 1%, 5% and 10% level based on two- tailed tests. Source: Author, 2023. Data from 2022 MRTCDLLG Water Board Profiles and 2021-2022 Waterboard Annual Financial Summaries.

A subsequent test was done to investigate the mean differences for the different categories of expenses between the systems. Table 2 presents the results of the differences in categories of expenses between the two systems. Column 1 lists the different categories of expenses. Column 2 is the mean for metered systems, column 3 the mean for unmetered systems and column 4 the mean differences. The results show that metered systems had on average higher expenses for all categories of expenses compared to unmetered systems. In the category for energy, diesel and

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electricity expenses we observed no significant difference between the two systems; although on average, metered systems had higher expenditure.

Table 2: Mean differences between different categories of expenses for metered and unmetered systems

Type of Expense	Metered Water System	Unmetered Water System	Mean difference (Metered-Unmetered)
Energy, Diesel, Electricity	17439.13	13991.41	3447.724
Materials, Supplies, Equipment	14551.28	5693.12	**8858.162** **
Office Supplies	1432.813	751.5971	**681.2157** *
Transportation	2098.573	975.9724	**1122.6** **
Labor for Repair Services	13182.22	5886.536	7295.688
Billing Clerk	3696.596	2700.702	995.8944
Pump House operator	5871.471	2990.425	**2881.046***
Social Security	1115.782	245.9265	**869.8559** *
Donations	468.4707	167.6986	300.7721
Telephone	456.7747	137.5351	**319.2396** *

***, **, * indicate statistical significance at the 1%, 5% and 10% level based on two- tailed tests.
Source: Author, 2023. Data from 2021-2022 Waterboard Annual Financial Summaries.

For materials, supplies and equipment expenses, metered systems had a significantly higher expenditure with an average difference of $8858. In transportation, metered systems also had significantly higher expenses with an average difference of $1122. Metered systems had on

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average significantly higher office supplies, pumphouse operators, social security and telephone expenses. There was no significant difference in expenses with respect to labor for repair, billing clerk, and donations between the two systems, although metered systems on average exhibited higher spending on these categories as well.

Table 3 presents the estimation results for the multiple linear regression analyses for models 1,2,3 and 4. Model 1 shows the estimation effect of metering and number of consumer connections towards total annual revenue. The results reveal interesting insights into this relationship. Our results show that metered systems had on average a significantly higher total annual revenue by $50,035.09 compared to unmetered RWSs. Furthermore, our analysis demonstrates that a 1 unit increase in consumer connection, regardless if the RWS is metered or not, results in a $103.91 increase in total annual revenue. Moreover, this effect is more pronounced in metered systems, where a 1 unit increase in consumer connection is associated with a remarkable increase in total annual revenue by $237.89. These results show statistical significance at the 1% confidence level, supporting the robustness of the observed relationships, and highlighting the critical role of metering in driving revenue growth. Notably, the coefficients for percentage of consumers paying monthly and the Multidimensional Poverty Index yielded no significant effect in this analysis.

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Table 3: The Impact of Metering on Total annual revenue, Average Monthly Income, Total annual expenses and Daily Water Usage for Rural Water Systems in Belize.

	(1)	(2)	(3)	(4)
Dependent Variable	Total annual revenue	Average Monthly Income	Total annual expenses	Daily Water Usage
Metered	**50035.09*****	**5216.06*****	**45511.76*****	-499.44
	(11327.74)	(1028.88)	(9842.89)	(3628.28)
Number of Consumer connections	**103.91** ***	**9.46*****	**79.68*****	**55.17*****
	(13.3587)	(0.99)	(11.74)	(15.07)
Percentage consumers paying monthly	27907.11	1738.90	30631.51	9791.31
	(26728.8)	(2636.50)	(20529.91)	(7651.50)
Multidimensional Poverty Index	-40364.84	-43.64	-19527.22	**-60264.03****
	(67898.35)	(7289.16)	(53441.05)	(27483.39)
Metered X Number of Consumer connections	**237.89*****	**22.47*****	**275.63*****	**49.64*****
	(22.39)	(2.27)	(23.16)	(16.80)
Constant	20331.60	1682.83	14035.71	**39509.15*****
	(13207.16)	(1283.13)	(10872.87)	(7436.84)
R^2	0.84	0.83	0.89	0.76
Number of Observations	46	46	46	71

***, **, * indicates statistical significance at the 1%, 5% and 10% level.
Robust standard errors in parentheses.
Source: Author, 2023. Data from 2022 MRTCDLLG Water Board Profiles and 2021-2022 Waterboard Annual Financial Summaries, and SIB Multidimensional Poverty Index 2021.

In Model 2, our analysis reveals compelling findings regarding the effect of metering and number of consumer connections towards average monthly income in RWSs. Firstly, metered systems had a significantly higher average monthly income by $5216.06 compared to unmetered systems. A unit increase in consumer connection regardless of meter status results in an average

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monthly income increase of $9.46. However, the impact is even more substantial for metered systems, with a 1 unit increase in consumer connection resulting in a notable average monthly income rise of $22.47. These coefficients demonstrate statistical significance, highlighting the strength of the observed effects. The coefficients for the percentage of consumers paying monthly and the multidimensional poverty index did not exhibit statistically significant relationships with average monthly income in this model.

Model 3 sheds light on the relationship between metering and number consumer connections on RWSs' total annual expenses, offering valuable insights into the subject matter. Our analyses reveal that metered systems incurred on average significantly higher total annual expenses by $45, 511.76 compared to their unmetered counterparts. Furthermore, our findings show that a 1 unit increase in consumer connection regardless of meter status is associated with an increase in total annual expenses, by $79.68. Notably, for metered systems, this effect becomes even more pronounced, with a 1 unit increase in consumer connection associated with a substantial increase in total annual expenses of $275.63 which is significantly higher than the average. These findings exhibit statistical significance, indicating the robustness of the observed relationships. The coefficients for the percentage of consumers paying monthly and the Multidimensional Poverty Index did not yield statistically significant effects in this analysis.

In model 4 our analyses reveal interesting results regarding the relationship between meter status, number of consumer connections, and poverty with daily water usage. The coefficient for the Metered is -499.44. This indicates that, holding other variables constant, being metered is associated with a decrease in daily water usage by approximately 499 gallons. Although the p-value for the coefficient is not significant, it shows that metered systems on average use less water. For the number of consumer connections, we find that for each additional consumer connection,

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daily water usage increases by approximately 55.17 gallons regardless of the RWS' meter status. For metered systems, a 1 unit increase in consumer connection is associated with an increase in daily water usage by 49.64 gallons, which is significantly lower than the average per consumer connection for an RWS regardless of meter status. Both these results are significant. The coefficient Multidimensional Poverty Index is -60,264.03. This suggests that, holding other variables constant, a 1 unit increase in the multidimensional poverty index is associated with a decrease in daily water usage by approximately 60,264.03 gallons. This effect is statistically significant. We do not observe any significant relationship between the percentage of consumers paying monthly and daily water usage. The constant term is statistically significant.

The coefficients corresponding to the treatment variables "Metered" and the interaction between "Metered" and the number of consumer connections displayed statistical significance across all four regression models. This indicates that the presence of metered RWSs and the interaction between being metered and the number of consumer connections significantly influences the outcomes of total annual revenue, average monthly income, total annual expenses and daily water usage in the context of RWSs in Belize.

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5. Discussion

This study aimed to investigate the impact of meters on the financial sustainability and water conservation of RWSs in Belize. The research objectives aim to investigate the impacts of metering on revenue generation, expenses incurred by RWS, profitability, and consumption patterns in Belizean RWSs. Our research questions are:

1. Is there a significant difference in total annual revenue, average monthly income, total annual expenses, daily water usage and payment rate in metered and unmetered RWSs in Belize?
2. What is the relationship between number of consumer connections in metered systems and total annual revenue among RWSs in Belize?
3. What is the relationship between the number of consumer connections in metered systems and average monthly income among RWSs in Belize?
4. What is the relationship between the number of consumer connections in metered systems and total annual expenses among RWSs in Belize?
5. What is the relationship between the number of consumer connections in metered systems and daily water usage in RWSs in Belize?

From the t-test analysis, our study indicates that there are significant differences in total annual revenue, average monthly income, total annual expenses, daily water usage and payment rate between metered and unmetered RWSs. Our findings show that metered systems had significantly higher average total annual revenue, average monthly income, total annual expenses, payment rate (percentage of consumers paying monthly) and reduced daily water usage compared to unmetered RWSs. Expenditure for metered systems were on average higher across all categories of expenses incurred by RWSs. In regards to the profitability of the water systems, this study

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reveals no significant difference in net profit margin between the two systems, however our findings show that unmetered systems had slightly higher net profit margin.

From the regression analysis, this study finds that an RWS being metered was associated with a significant increase in total annual revenue by $50,035.09 and average monthly income by $5216.06. Furthermore, this study finds that a one unit increase in consumer connection for metered RWSs was associated with a remarkable increase in total annual revenue by $237.89 and average monthly income by $22.47 which is significantly higher than the average for a one unit increase in consumer connection regardless if the RWS was metered or not. Our analyses reveal that metered systems incurred on average significantly higher total annual expenses by $45, 511.76 compared to their unmetered counterparts. A one unit increase in consumer connection for a metered system was associated with a substantial increase in total annual expenses by $275.6 which is significantly higher than the average $79.68 for an RWS regardless of meter status. For daily water usage, this study reveals that an RWS being metered is associated with a decrease in daily water usage by approximately 499 gallons, while a one unit increase in metered consumer connection was associated with an increase in daily water usage by 49 gallons which is lower than the 55-gallon increase in daily water usage by an average consumer connection regardless of the RWS' meter status.

This study shows that metered water systems generate higher total annual revenue and average monthly income overall and per consumer connection compared to unmetered systems. The implications of these findings for management suggest that metering is an effective strategy for enhancing revenue generation. These results align with previous studies conducted in Tanzania and Armenia, which demonstrated that metering led to improved revenue generation, enhanced

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monitoring capabilities, reduced non-revenue water, and increased economic efficiency (Harutyunyan, 2015; Ingram & Memon, 2020).

In contrast, our study reveals, as indicated by both the t-test and regression analysis, that metered systems exhibit higher total annual expenses in general and per consumer connection. average expenses. When the means of the different categories of expenses were examined, metered systems had on average higher expenditure across all categories. These findings are noteworthy considering that metering is generally perceived as a revenue generation tool with the potential to enhance the financial solvency of rural water systems. The association between metering and increased expenses is not readily apparent. Upon further examination of the categories of expenses between metered and unmetered systems, we find that metered systems incurred significantly higher expenses across several categories. These include materials, supplies, equipment, office supplies, transportation, pump house operator salaries, social security costs, and telephone expenses. These disparities shed light on the specific areas where metered systems are allocating greater resources, which can be further categorized as increased operation and maintenance costs.

The reasons behind the higher expenditures observed in metered systems warrant further examination. To address this inquiry, we consider several financial, infrastructural, and managerial distinctions between the two systems. Metered rural water systems typically involve the installation of water meters at individual households or consumption points, with billing based on actual usage. Conversely, unmetered systems lack such meters and instead rely on estimates or fixed charges for billing purposes. The increase in costs for metered systems may be attributed to various factors. Firstly, the implementation of a metered system in a rural water system necessitates the purchase and installation of water meters at each consumer location, contributing to higher expenses compared to an unmetered system where individual meter installations are

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unnecessary. This initial investment can substantially elevate costs relative to an unmetered system.

Furthermore, metered systems require regular maintenance, calibrations, and periodic replacement of water meters, further augmenting overall expenses. The costs associated with meter maintenance, calibration, and replacement contribute to the higher expenditures of metered systems. In contrast, an unmetered system may have fewer maintenance requirements in this regard. Moreover, operational costs such as meter reading, data administration, and billing can be more expensive for metered systems. These systems necessitate dedicated personnel or automatic systems for the collection, processing, and analysis of meter data, resulting in higher operational expenses. In contrast, an unmetered system typically relies on simpler billing methods based on fixed estimates (Zetland & Weikard, 2011).

Metered systems can also incur additional administrative costs due to disputes between consumers and the managing authority regarding water usage readings or billing discrepancies. The resolution of these disputes involves extra administrative resources and expenses for management, which may be comparatively lower or nonexistent in an unmetered system. Leakages in the system can contribute to higher expenses, as they require additional efforts and resources to address (Ingram & Memon, 2020). These problems can lead to reduced revenue and increased non-revenue water, amplifying overall costs.

Additionally, faulty equipment, materials, supplies, and inadequately trained personnel can result in higher expenses, particularly if these items require regular replacement or if installation errors necessitate repeated troubleshooting (Borja-Vega et al., 2017). The long-term sustainability of water facilities is significantly influenced by factors such as the availability and affordability of spare parts and water quality (Kwena & Moronge, 2015). Aging infrastructure can also lead to

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greater operational and maintenance costs, which may impact expenses for both metered and unmetered systems, depending on the age of the infrastructure. Newer systems are associated with fewer breakdowns, compared to systems a decade older than them (Borja-Vega et al., 2017). The influence of age on expenses falls beyond the scope of this study. Overall, the relative expenses for metered and unmetered rural water systems can vary based on various factors, including the cost of water meters and installation, maintenance and operational costs, issues of leakage, customer disputes, and the age of the system.

In order to further examine the relationship between revenue and expenses, we analyzed the net profit margin of both systems. Net profit margin serves as a percentage measure of the profit remaining after subtracting expenses from revenue. Our t-test did not reveal any significant difference between the two systems. However, the average net profit margin revealed an intriguing pattern: unmetered systems exhibited higher average net profit margins.

The lower net profit margin observed in metered systems can be attributed to the higher expenses they incur. For many metered RWSs, their operational and maintenance costs exceed the total annual revenue they collect thus reducing their net profit margin. The range of net profit margin values for metered systems ranged from -142% to 38.01%, while for unmetered systems, it varied from -57.25% to 40.38%. In their study, Borja-Vega et al. (2017) discovered a moderate correlation between RWS' organization and financial sustainability with factors such as the implementation of charging volume-based tariffs, monthly income levels, monthly revenues exceeding operating costs, availability of adequate funds for operations and management, and the capacity for institutionalization. Therefore, while metered systems charge a consumption-base tariff, and generate greater revenue it does not directly translate to them being more profitable. Having expenses lower than their cost is of utmost importance if they want to be financially

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solvent. Other factors such as their institutional capacity and access to external funds other than those generated from tariffs and other sources of income by the RWS can also impact their profitability (Webster et al., 1999; Cleaver & Toner, 2006; Borja-Vega et al., 2017.

Though the water systems in our study operate on a non-profit basis, the lower net profit margin in metered systems raises concern regarding the financial sustainability of these water systems. While it is only briefly explored in this study with the available data, further research is recommended to understand how these values evolve over time and the factors influencing such changes. These factors may include external support from government or donors, savings practices, occurrences of natural disasters, and the effectiveness of management strategies. Examining the net profit margin of RWSs provides valuable insights into their financial and underscores the importance of addressing the higher expenses incurred by metered systems. By gaining a deeper understanding of the dynamics influencing net profit margins, water system authorities can make more informed decisions to enhance the financial viability and sustainability of these systems.

This study finds that metered systems had lower daily water consumption compared to unmetered systems, as evidenced by our t-test and regression analysis. These findings align with an independent study sponsored by the Belize Social Investment Fund (BSIF), which reported that metered systems had an average water consumption of approximately 24 US gallons per consumer, while unmetered systems consumed 26.4 US gallons per consumer (BSIF, 2017). The conscious water usage behavior observed in metered systems can help account for this lower volume. Similar results were found by Harutyunyan in Armenian cities, where the introduction of water meters initially led to a reduction in water demand due to consumers' awareness of being metered and the concern of higher bills (2015). However, over time, as consumers received bills reflecting reduced

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water charges and in the absence of tariff changes, the water conservation effect gradually diminished. Interestingly, in the long run, an increase in tariff rates within metered systems resulted in a decrease in water demand, even with improved water supply services (Harutyunyan, 2015). Harutyunyan's findings emphasize that the impact of meters alone on water demand is limited and should be complemented by additional conservation measures (2015).

Haris et al. argue that in the absence of metering, users lack the incentive to use water efficiently (2002). Without financial incentives tied to water usage, there is less motivation for consumers to conserve water. The absence of a direct relationship between usage and cost can result in excessive water use and a lack of incentive to adopt water-saving behaviors. This argument could help explain why unmetered systems demonstrated higher daily water usage. Without the feedback and accountability provided by meters, individuals in unmetered systems may not perceive a need to conserve water.

While the impact of meters on reduced water usage is evident from this study. Our regression analysis shows that poverty has an even greater impact on daily water usage. A one unit increase in the multidimensional poverty index was associated with a significant decrease in daily water usage by approximately 60, 264 gallons. This result indicates that RWSs in poorer areas use less water. Borja-Vega et al. found that consumers with lower water usage tended to be poorer or experience economic limitations (2017). It is reasonable to presume that RWSs situated in poorer areas use less water because their customers simply cannot afford to use a lot of water.

This study highlights the effectiveness of metering in reducing water consumption and promoting water conservation. Metered systems, where individuals have access to information on their water usage, exhibit lower daily water consumption compared to unmetered systems. However, it is essential to recognize that meters alone may not be sufficient to drive long-term

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water conservation efforts. Additional measures and policies should be implemented to complement metering and further encourage sustainable water usage practices within communities. Although this study's research questions did not directly seek to investigate the impact of poverty on water consumption, this study shows that it has a significant impact on reduced water consumption.

The implementation of water meters brings forth numerous advantages for managers, particularly in terms of enhanced revenue collection (Ingram & Memon, 2020). A notable aspect of improved revenue collection is in having higher payment rates. Our study revealed that metered systems had significantly higher payment rates compared to unmetered counterparts. This finding aligns with the research conducted by Harutyunyan in Armenian water systems, where the installation of meters led to water supply managers experiencing improved payment rates, which is likely attributed to enhanced water service delivery, compliance, and enforcement brought upon by the installation of the technology (2015).

As revealed in our study, metered systems incurred higher expenses. Having low payment rates can further exacerbate their financial strain. An analysis conducted by the Belize Social Investment Fund (BSIF) on 15 waterboards in Belize highlighted the significance of having high payment rates. In 2015, three waterboards reported net losses, and if all tariffs for that year had been collected, only one village would have still experienced a loss (BSIF, 2017). This underscores the importance of maintaining high payment rates to ensure adequate revenue collection and alleviate financial challenges. These findings underscore the critical role of water meters in improving payment rates and revenue collection for VWBs.

Our findings provide valuable insights into the financial landscape of rural water systems in Belize. Metered systems exhibited noteworthy advantages over unmetered systems, especially

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concerning revenue generation. The revenue generated by metered systems was notably higher, a result of consumption-based and accurate measurement of water usage. The lower water consumption observed in metered systems suggests that consumers are more mindful and conservative in their water usage habits. Interestingly, metered systems also demonstrated significantly higher payment rates. This outcome indicates that these systems may have achieved better service delivery, compliance, and enforcement mechanisms, fostering a culture of timely payments among consumers (Harutyunyan, 2015). Conversely, this study shows that metered systems also incurred notably higher expenses across all expense categories compared to unmetered systems. This disparity can be attributed to the higher operational and maintenance costs associated with metering. Other factors, such as the age of the system, could potentially contribute to the observed heightened expenditures. Furthermore, our analysis revealed that, on average, metered systems exhibited reduced net profit margins in comparison to their unmetered counterparts. Although these differences were not statistically significant, we ascribe this trend to the higher expenses incurred by metered systems. The greater financial burden associated with having higher operational and maintenance costs may impact the profitability of metered systems.

While our analysis does not examine the impact of external support on the financial sustainability of water systems. Studies have shown that external support has a meaningful impact on the financial sustainability of rural water systems, particularly an organization that is able to provide appropriate resources and support (Webster et al., 1999; Cleaver & Toner, 2006). For rural water systems in Belize, such an organization would most likely be the ministry of rural transformation and the government of Belize along with other international donor organizations, which do provide grants and training to assist struggling waterboards. The impact of such support lies beyond the scope of this study. While GOB and other development stakeholders continue to

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advocate for the full implementation of meters in RWS of Belize, caution must be taken with how they persuade VWBs to adopt the technology. In examining literature for this study, one of the points put forth by GOB to endorse the adoption of meters is the potential for cost reduction. This is primarily attributed to reduced electricity expenses, as consumers in metered RWSs tend to use less water; potentially leading to a reduction in VWBs' energy demand and costs (MRTCDLLG, 2022). While our t-test did not yield a statistically significant difference in electricity and energy expenses between the two systems, it is noteworthy that metered systems exhibited relatively higher expenditures on average within this category. This trend extended to higher expenditures across all categories of expenses. Furthermore, the results of the regression analyses in this study indicate that metered systems incur significantly higher total annual expenses both overall and on a per consumer connection basis. Therefore, caution must be exercised when discussing the potential of meters to reduce expenses, as our study demonstrates that this is not applicable to RWSs in Belize. Nonetheless, this study can substantiate support for other 'selling points' put forth by GOB, such as the role of meters in enhancing revenue generation, promoting water conservation, and improving payment rates (MRTCDLLG, 2022). The validity of these arguments is confirmed by the findings of this study. Moreover, GOB asserts that the enhanced revenue generation attributed to meters is projected to strengthen savings within VWBs, thereby fortifying VWBs' financial sustainability and ability to undertake capital expenditures (MRTCDLLG, 2022).

While this study supports the contention that meters contribute to improved revenue generation, the extent of their impact on savings lies beyond the scope of this investigation. It is reasonable to speculate that RWSs, with increased revenue, would potentially be able to save more. However, if their expenses remain equivalent or surpass the revenue increase, the likelihood of achieving substantial savings diminishes.

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Finally, our study did not directly aim to investigate the connection between RWSs and poverty. However, our t-test showed that metered systems had a higher multi-dimensional poverty index in comparison to unmetered systems. In simpler terms, the locations of metered systems were associated with elevated poverty rates. We attribute these results to the unique circumstances of the Toledo district, which is the southernmost administrative division in the country, which not only registers the highest poverty rates but also encompasses the district with the most RWSs using meter technology.

Our findings shed light on the unique characteristics and dynamics of rural water systems in Belize. Metered systems demonstrate advantages in terms of revenue generation, payment rates, and lower water consumption. However, these benefits come at the expense of higher operational costs and maintenance costs. Additionally, we find that poverty has a significant effect on reducing water usage. Metered systems were found to be situated in areas with higher poverty, which can be ascribed to a higher number of metered RWSs in the poorest district of Belize. Understanding these factors is essential for policymakers and water system managers, enabling them to make well-informed decisions regarding the implementation and management of metered RWSs in order to ensure their financial sustainability.

6. Conclusion

This study aimed to investigate the impact of meters on the financial sustainability and water conservation of RWSs in Belize. Our findings reveal that metered RWSs earn a significantly higher total annual revenue on average and per consumer connection compared to their unmetered counterparts. Our results show that if VWBs want to enhance their revenue generation capabilities, installing meters is a viable strategy. Additionally, this study finds that metered systems had

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significantly higher payment rates, and reduced daily water usage. However, this research reveals that metered systems incur significantly higher total annual expenses in general and per consumer connection compared to their unmetered counterparts. Moreover, metered systems had significantly higher average expenditure for several categories of expenses which includes material supplies, equipment, transportation, pump house operator salaries, social security costs, telephone and office supplies expenses. While this study does not find any significant difference in the net profit margin between the two systems, the average shows that unmetered systems had higher average net profit margin. This result is concerning. A lower net profit margin in metered water systems could be attributed to the higher expenses that they incur. Thus, it's crucial to recognize that metering alone does not guarantee profitability. Therefore, it's important for all stakeholders involved in rural water system management, including the ministry and VWBs, to consider implementing measures to reduce the expenses of the RWSs and enhance revenue collection. For water conservation, our regression analysis shows that metered systems are significantly associated with reduced daily water usage. Likewise, poverty was found to have a significant impact on reduced water usage.

This study provides valuable data driven information that GOB and other relevant stakeholders in the rural water supply sector can use to responsibly promote the implementation of meters in RWSs of Belize. Moreover, this study contributes to the body of knowledge on rural water infrastructure development regarding the impact of meters on RWSs' financial sustainability and water conservation. Furthermore, this study helps address the current shortage of research in this area, especially in Belize.

Limitations to study include sample size constraints due to paucity of data, and generalization of results. For example, data for the Corozal district was excluded from the analysis

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of this study due to the unavailability of data. The exclusion of this district and other waterboards whose data were not available for analysis could impact the generalization of the results of this study. The impact of tariff rates, gender, training, age of the water systems, savings, and external support on the revenue, expenses, and overall financial sustainability of rural water systems falls beyond the scope of our study. These factors can be influential to VWBs' financial sustainability, however due to time and data paucity were not included in this study. Additionally, we did not examine potential fixed effects for year and location in this study, which hold the potential to influence the observed results. This omission is attributed to limitations in the available data.

This study found that metered RWSs had significantly higher average multidimensional poverty index indices than unmetered systems. Future research is recommended to investigate factors that impact the acceptance of meters in RWSs and its relationship to poverty rates. This study analyzes data for 2021 and 2022. An extensive study over an extended period of time is recommended, as it could reveal valuable insights into the evolution of the operations and sustainability of rural water systems over time. Lastly, further research is recommended to investigate the impact of external support, such as that provided by government and donor organizations, on the sustainability of rural water systems in Belize.

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