

Water Sub-metering to Promote Water Efficiency – A Survey of Existing Literature and Local Case Studies

Greenest City Scholar Program 2016

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Executive summary

This project explores the potential for using water sub-meters as a method for increasing water efficiency and reducing water wastage in public and private facilities within the City of Vancouver. Water sub-metering refers to the use of secondary meters (in addition to a master meter) to measure water consumption of an individually leased space, piece of equipment or unit.

Theoretically, by charging tenants for their actual water usage, water sub-metering encourages tenants to use less water, and to use water more efficiently. Numerous case studies in U.S. states such as New York, Massachusetts and California show that the installation of sub-meters effectively reduced water usage. In these states, the increase in water sub-meter use is driven by incentive programs, such as rebates, and local ordinances and/or state regulations requiring the installation of water sub-meters. Local Vancouver case studies, such as the water sub-metering programs on Granville Island and at the Olympic Village, clearly show that water sub-metering encouraged tenants to replace their water in efficient equipment to reduce their water use.

The biggest challenge in implementing the local programs was the installation cost of the sub-meters and the lack of public awareness of the ongoing administrative cost of the sub-metering program. Retrofitting sub-meters in existing buildings such as the public market on Granville Island was time consuming and costly due to many technical challenges such as inadequate space. Furthermore, end-users are not aware of how the sub-metering program works and why and what they are paying for, posing challenges in the billing process.

In conclusion, this project makes these recommendations:

1. Encourage or require the installation of water sub-meters in all multi-unit residential and commercial buildings
 - a. Introduce inspection requirements on water sub-meters
 - b. Keep the sub-metering system non-proprietary
 - c. Ensure tenants' access to information
 - d. Educate developers and end-users
2. Consider an incentive program for retrofits

Table of contents

Acknowledgement	i
Executive summary	ii
Table of contents	iii
List of Figures	v
List of Tables	vii
Background and Context.....	viii
1. Introduction	1
1.1 What is sub-metering?	1
1.2 Benefits of sub-metering.....	3
1.3 What should be submetered?.....	3
1.4 Measurement Considerations.....	7
2. Meter selection	7
2.1 Meter sizing.....	8
2.2 Installation requirements.....	12
2.3 Meter maintenance.....	13
2.4 Meter reading.....	14
3. Perceived benefits of sub-metering.....	15
4. Perceived concerns of sub-metering	15
5. Sub-metering regulations in other jurisdictions	16
6. Billing requirements.....	21
7. Incentive programs	21
8. Case studies of local properties with a water sub-metering program	23
8.1. Granville Island.....	23
8.1.a. Types of water submeters	27
8.1.b. Costs	31
8.1.c. Installation	32
8.1.d. Maintenance.....	32
8.1.e. Billing	32
8.1.f. Benefits.....	33

8.1.g. Challenges.....	34
8.2. Olympic village	35
8.2.a. Types of meters	37
8.2.b. Costs	38
8.2.c. Installation	38
8.2.d. Maintenance.....	39
8.2.e. Billing	39
8.2.f. Benefits.....	41
8.2.g. Challenges.....	41
8.3 Region of Waterloo	42
9. Recommendations	42
10. Appendix	45
10.1. Appendix 1.....	45
10.2. Appendix 2.....	48
10.3. Appendix 3.....	49
10.4. Appendix 4.....	50
10.5. Appendix 5.....	51
11. References	63

List of Figures

Figure 1. Water consumption level in the past 10 years and the target to reduce the level by 33% from the 2006 level (Source: Water Design Branch, City of Vancouver).....	ix
Figure 2 Building with a master meter that measures the total volume of water supplied to all units.	1
Figure 3 Building with water sub-meters to measure water supplied to each unit.....	2
Figure 4 A water sub-meter that measures the water usage of a tenant space at the public market on Granville Island	2
Figure 5. A water sub-meter near the ceiling, which measures the water usage of a produce store at the Public Market.	23
Figure 6. A coffee shop at the Public Market.	24
Figure 7. A butcher store at the Public Market	25
Figure 8. A fresh produce store at the Public Market	25
Figure 9. The cement plant on Granville Island.....	26
Figure 10. A bakery at one of the buildings outside the Public Market	26
Figure 11. A manual reading water meter that measures the water use of a bakery on Granville Island.....	27
Figure 12. A GWF M-bus system outside a building on Granville Island.....	29
Figure 13. The pulse counter at one corner of the market.	30
Figure 14. The label on the totalizer that specifies the different water sub-meters and their respective pulse per unit.	31
Figure 15. The Public Market consists of five buildings that used to be separate.	34
Figure 16. A water sub-meter, protected by a wooden case, installed in a bookkeeping space of a coffee shop.....	35
Figure 17. An in-suite monitor that shows the monthly cold water consumption of a unit at Olympic Village (photo courtesy: Andrew Ling).	37

Figure 18. A daily water consumption graph of a unit in the Olympic Village where there was a leak for ten days..... 40

List of Tables

Table 1. Recommendations on water sub-metering measurement thresholds from the U.S. Environmental Protection Agency Section 2.2 <i>Metering and Sub-metering</i> , ASHRAE Standard 189.1-2014 <i>Standard for the Design of High-Performance Green Buildings</i> and International Association of Plumbing and Mechanical Officials' <i>2012 Green Plumbing and Mechanical Code Supplement</i> Section 409.0 (EPA 2012, IAPMO 2015; ASHRAE 2014).	6
Table 2. Overview of different types of meters (City of New York 2013; Smith 2008; Qmeters 2016; MetronFarnier 2015; FCM 2003)	11
Table 3. AWWA recommendation on meter maintenance frequency.....	13
Table 4. Description of meter registering technologies (City of New York 2013).	14
Table 5. Perceived benefits of sub-metering.....	15
Table 6. Perceived concerns of sub-metering.	16
Table 7. Overview of sub-metering regulations in some of the U.S. states (NCSL 2016).....	20
Table 8. Buildings in the Olympic Village that are fitted with water sub-meters.	36
Table 9. Summary of costs to install a hot and cold water sub-meter in a unit.....	38

Background and Context

Water is the most essential substance in our daily life. We use water for drinking, cooking, bathing, and preventing diseases (WHO 2015). In Vancouver, there is a misperception that the city's water supply is abundant, due to the plentiful precipitation, and that storage is unlimited. However, due to climate change and increasing water demand from a rising population, Metro Vancouver is seeking to use water more efficiently. The Region experienced a drought in the summer of 2015. To ensure that there is sufficient water to last until the end of this summer, the City of Vancouver commenced its drought response plan two weeks earlier than last year (City of Vancouver 2016).

Climate change is expected to affect the water supply and demand in the City of Vancouver significantly. It is predicted that climate change will cause the average temperature in the City of Vancouver to increase by a range of 1.7°C to 4.0°C by the 2050s (Pacific Climate Impacts Consortium 2016). As a result of the rise in temperature, snowpack mass in winter and spring is projected to decrease by 61% to 65% by the 2050s (Pacific Climate Impacts Consortium 2016). Furthermore, "the amount of rain in summer is expected to decrease by 20%, and the maximum length of dry spells is also projected to increase, by about 20% from 23 days to 28 days, on average" (Pacific Climate Impacts Consortium 2016).

In addition to climate change, the projected 1 million population growth in Metro Vancouver by 2041 (Metro Vancouver 2014) will increase, dramatically, the demand for water. The limited reservoir storage capacity and the desire to avoid increasing spending on infrastructure expansion have made water conservation planning an imperative task for the City of Vancouver. Consequently, the Greenest City 2020 Action Plan, the City of Vancouver's strategy for achieving sustainability and becoming the greenest city in the world, presents a specific target of reducing per capita water consumption by 33% from the levels in 2006 by the year 2020 (Figure 1). Additionally, the *Green Operations, Healthy Ecosystems* plan also specifies the target of reducing corporate water consumption by 33% from the 2006 level by 2020.

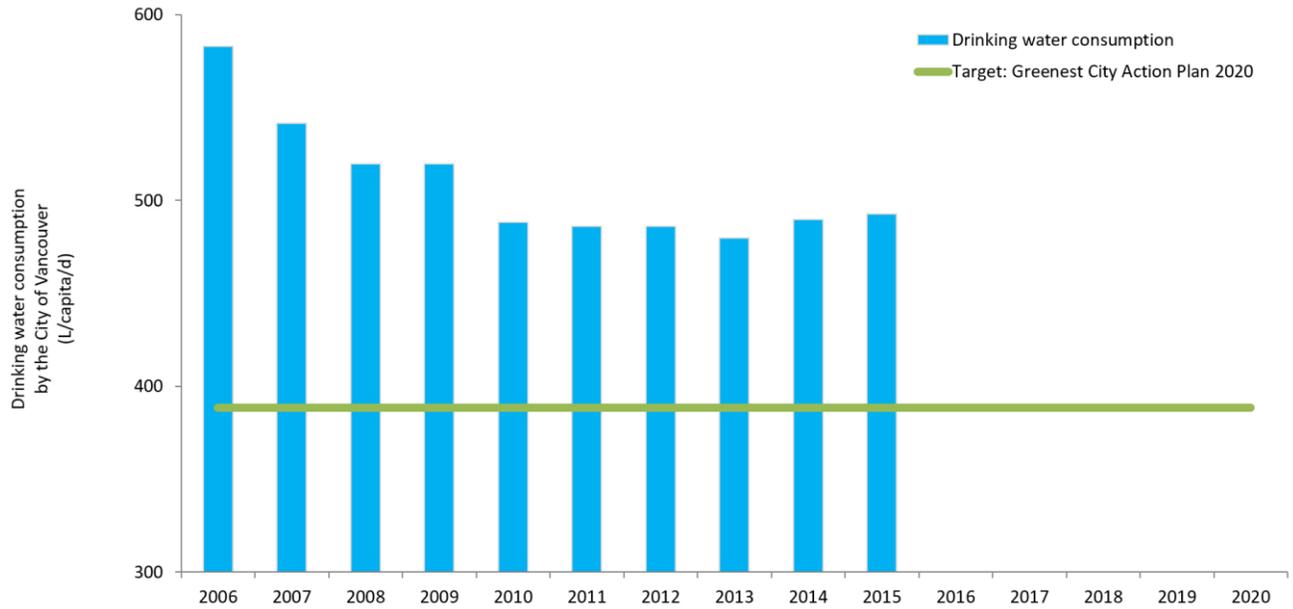


Figure 1. Water consumption level in the past 10 years and the target to reduce the level by 33% from the 2006 level (Source: Water Design Branch, City of Vancouver).

In 2015, per capita water consumption was approximately 27% more than the 2020 target (Figure 1). To help reduce per capita water consumption to the targeted level by 2020, this project explores the potential for water sub-metering as a policy tool for increasing water efficiency and reducing wastage in public and private facilities within the City of Vancouver¹. It examines examples of best practices in water sub-metering and discusses how they could be applied in buildings in the City of Vancouver to promote water use reduction and prevent water leakage.

Report 1 provides an overview of sub-metering, the effectiveness of sub-metering in increasing water efficiency, sub-metering requirements and regulations in other jurisdictions. Report 2 includes case studies of local properties with existing sub-metering practices. It also provides a cost-benefit analysis of sub-metering in the City of Vancouver. Finally, it concludes with policy recommendations with regards to water sub-metering in the City of Vancouver.

¹ See Greenest City Scholar project posting in Appendix 1

1. Introduction

1.1 What is sub-metering?

Water supplied to a property first goes through the primary meter (also known as the master meter), which measures and provides information on the total volume of water consumed by the entire property (figure 2). The limitation of a master meter is that it does not reveal how much and where water is consumed within the property. A sub-meter is “a water measuring device used at a subsection or end use of a water supply system for any of the following purposes: billing, water management, collecting and analyzing water usage data, detection of leaks, equipment failure, water waste and irregular or abnormal use for a specific application” (IAPMO 2015) (figure 3, figure 4). For instance, sub-meters can be installed for all units in a strata titled property, allowing property managers to identify the water usage of individual tenants who can then be charged based on their actual water usage. Moreover, sub-meters can also be installed to measure the water usage of water intensive fixtures such as boilers and irrigation systems within the property. Consequently, sub-metering allows property owners and/or managers to collect the water consumption data of each unit and/or fixture on their property, and hence identify water conservation possibilities.

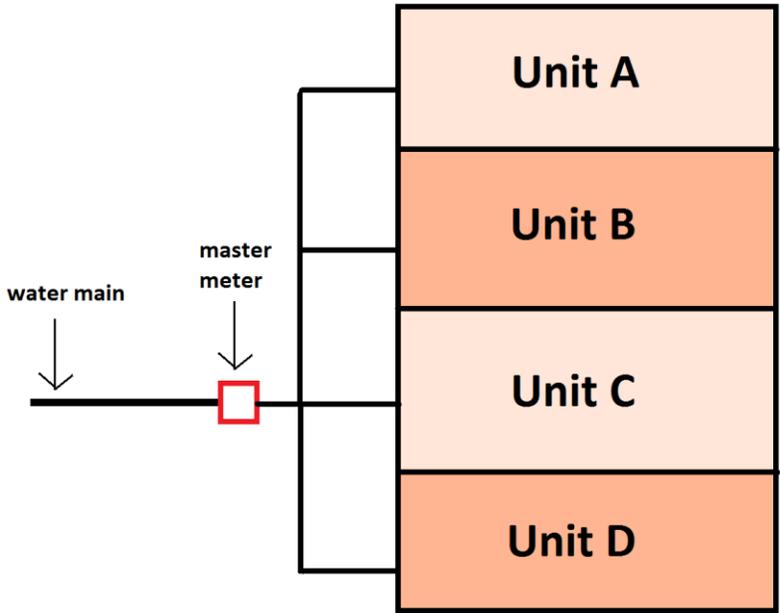


Figure 2 Building with a master meter that measures the total volume of water supplied to all units.

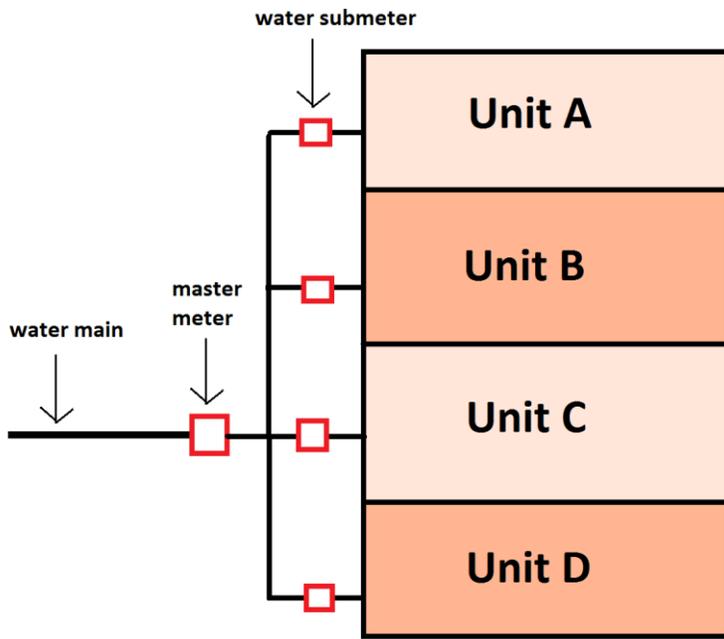


Figure 3 Building with water sub-meters to measure water supplied to each unit

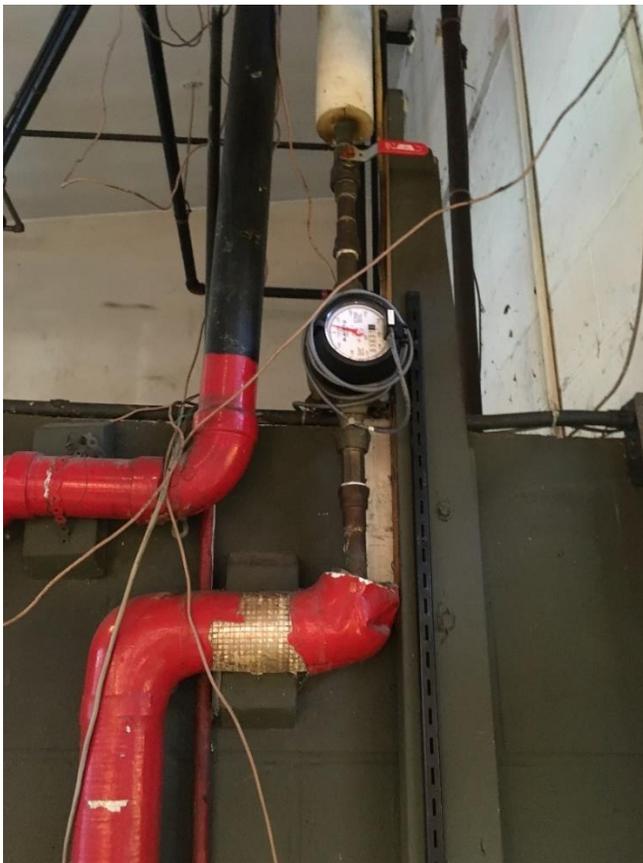


Figure 4 A water sub-meter that measures the water usage of a tenant space at the public market on Granville Island

1.2 Benefits of sub-metering

Sub-metering has been described as an essential element of effective water management (FCM 2003). Without sub-meters, tenants are typically charged a flat rate, meaning that they pay the same amount regardless of how much water they use. However, with sub-metering, information on the actual water consumption of individual tenants can be acquired. Thus tenants can be billed fairly for their actual water usage.

Water sub-metering has been documented to help reduce water use. A study conducted in the United States found that residential sub-metered properties led to water saving of 15.3% compared with similar rental properties that charge a flat rate for water. This study suggests that “water savings attributable to sub-metering and volumetric billing may reach 15% or more” (Mayer et al. 2004, 260). Moreover, according to Enerpro Systems Corp, a local case study of a building in North Vancouver shows that the installation of water sub-meters has led to 32% reduction in hot water use and 45% in cold water use.

Sub-metering provides the water usage data of individual units, allowing landlords/ tenants to identify and compare the water usage of these units throughout the year. By comparing regular water bills, landlords/ tenants can identify abnormal fluctuations in water usage that can signal the existence of water leakage. Landlords/ tenants can then find and fix the leaks promptly to prevent further wastage. It is estimated that leaks can account for more than six percent of a property’s total water usage (EPA 2012).

Furthermore, sub-metering data also allow landlords/ tenants to identify water conservation possibilities. For example, water sub-meters allowed Babcock and Wilcox Canada Ltd, a manufacturer of steam generation equipment in Waterloo, to discover that their washrooms accounted for the bulk of the company’s water usage. Accordingly, they replaced their inefficient flush-valve toilets, which they expect to allow them to reduce the company’s total water consumption by 5.8% annually (Region of Waterloo 2015). Lastly, sub-metering data allows property managers to identify high volume consumers, providing them with an opportunity to provide targeted education. They can also verify and measure water savings periodically.

1.3 What should be sub-metered?

Table 1 on the following page presents a comparative survey of the recommendations, from three different official and professional agencies, on the areas, equipment and processes that are suggested for sub-metering.

The United States Environmental Protection Agency (EPA) recommends that sub-meters should be installed within the property to measure specific water end uses. For instance, in addition to individual tenant spaces, EPA recommends the installation of sub-meters for water-intensive fixtures and systems, such as indoor and outdoor pools and ornamental water fixtures and HVAC systems (EPA 2012) (Table 1).

In addition to the EPA's recommendations, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has specified water usage measurement threshold levels for water sub-metering in the water efficiency section of the *ASHRAE Standard 189.1-2014 Standard for the Design of High-Performance Green Buildings*. This *Standard* serves as the alternate compliance option of the International Green Construction Code and specifies that sub-metering must be available for each of the building subsystems that exceed their respective threshold levels (ASHRAE 2014) (Table 1).

Similarly, the *2015 Green Plumbing and Mechanical Code Supplement* by the International Association of Plumbing and Mechanical Officials (IAPMO) outlines green buildings and water efficiency requirements applicable to plumbing, mechanical and energy systems. Regarded as an adjunct to any plumbing code in the US, this document conveys requirements on sub-meter locations and measurement threshold levels (IAPMO 2015) (Table 1).

Subsystems	EPA	ASHRAE	IAPMO
Individually leased space	Meter all leased spaces	Water consumption >3785 L/day (1000 gal/day)	<ol style="list-style-type: none"> 1. Meter all common areas 2. Meter each residential tenant space 3. Meter each non-residential space such as car wash space where a) water use > 3785 L/day (1000 gal/day) or b) the nominal size of the water supply pipe to the tenant space is greater than ½"
Total irrigated area with controllers	Meter all automatically controlled systems	Accumulative area >2323 m ² (25,000 ft ²)	Accumulative area with in-ground irrigation systems >232 m ² (2500 ft ²) or accumulative area using an automatic irrigation controller >140 m ² (1500 ft ²)
Roof spray systems	Meter roof spray systems for irrigating vegetated roofs or thermal conditioning	No guideline	Meter roof spray systems for irrigating vegetated roofs or thermal conditioning covering an area > 28 m ² (300 ft ²)
Cooling towers	Separately controlled cooling towers should have separate make-up and blowdown water meters	Water consumption >1893 L/min (500 gpm); makeup and blowdown water metered separately	Meter makeup water supply to cooling towers, evaporative condensers, and fluid coolers.
Heating, Ventilating, and Air Conditioning (HVAC) Systems	Water use >378,541 L/year (100,000 gallons/year) or conditioned space >4645 m ² (50,000 ft ²)	Evaporative coolers: Makeup water >3271 L/day (0.6 gpm)	Evaporative cooler: Air flow >850 m ³ /min (30,000 ft ³ /min); fluid coolers and chillers (open systems): meter makeup water supply; hydronic cooling systems (closed loop): meter makeup water supply of systems with 50 tons or greater of cooling capacity

Subsystems	EPA	ASHRAE	IAPMO
Steam and hot-water boilers	>500,000 British thermal units per hour (Btu/hr) (146 kW)	>500,000 Btu/hr (146 kW) input	Collectively > 1,000,000 Btu/hr (293 kW)
Any water-intensive process	Consumption > 378,541 litres/year (100,000 gallons/year) or >3,785 L/day (1,000 gal/day)	Consumption >3,785 L/day (1,000 gal/day)	Industrial processes: consumption >3,785 L/day (1,000 gal/day)
Single-Pass Cooling Systems	Meter all systems that do not use a chilled water system of closed-loop recirculation	Prohibited	Prohibited
Ornamental water features, pools and spas	Meter make-up water supply lines	No guideline	Meter water supplies of ornamental water features which use automatic refill valve; pools and spas: meter makeup water supply
Alternative water sources	Meter water use from sources such as gray water, rainwater or boiler condensate	No guideline	Meter onsite alternative water collection systems

Table 1. Recommendations on water sub-metering measurement thresholds from the U.S. Environmental Protection Agency Section 2.2 *Metering and Sub-metering*, ASHRAE Standard 189.1-2014 *Standard for the Design of High-Performance Green Buildings* and International Association of Plumbing and Mechanical Officials' *Green Plumbing and Mechanical Code Supplement* Section 409.1 (EPA 2012; ASHRAE 2014; IAPMO 2015).

1.4 Measurement Considerations

The expected accuracy standard can vary depending on the purpose of the measurement. In general, there are two types of measurement 1) informational measurement and 2) compliance measurement. Information measurement is mainly for reviewing overall water use patterns of property(ies) for management purposes and/or planning. Thus informational measurement does not require high accuracy standards. On the contrary, the second type of measurement - compliance measurement - which is used for billing purposes - requires much higher accuracy as the data are used for billing individual users. High accuracy is required to ensure that water users are charged equitably.

Several terms such as accuracy, calibration, resolution, repeatability, precision and error budget must be considered when determining measurement accuracy. An explanation of these concepts is beyond the scope of this project, but are introduced here for completeness. Every situation that involves measurements will involve all of these terms. For each water meter, the initial accuracy of the unit as a baseline will need to be calculated. After meter installation, the accuracy of the individual measurement should then be determined. It is important to document where, when, and how water meters are installed. When testing the accuracy of the meter, a minimal of five measurements are needed to allow meaningful statistical analysis. An error budget should be documented in every measurement record.

2. Meter selection

In order to provide accurate water use information, selecting, sizing, reading and maintaining sub-meters are four essential components (FCM 2003). There are various types of sub-meters designed for different applications. Table 2 provides a comparative summary of the mechanics, features, advantages and disadvantages of different types of sub-meters.

Some types of sub-meters are designed to measure low water flow while others are meant to measure high water flow. Depending on the use, size of the water line and water flow, an appropriate meter must be selected to obtain accurate water use measurements and minimize meter and pipe damage. Most sub-meters used in buildings for monitoring and cost allocating purposes are positive displacement or single jet sub-meters, whereas some other types are used for larger connections.

Positive displacement meters are suitable for residential and commercial buildings as they have high accuracy at low flows and can accurately measure peak flow. Some models of positive displacement meters can also service hot water as well. On the contrary, *turbine meters*, which are inaccurate at low flows, are not recommended for commercial, institutional and residential

buildings where water flow levels fluctuate constantly, often with minimal flow rates. These meters are, instead, best suited for continuous, high flow measurements. Moreover, **compound meters** are more suited for large commercial and institutional facilities as they can accurately measure both low and high flows with their multiple measuring chamber design (EPA 2012; Smith 2008).

Furthermore, some meters have additional capabilities. For instance, **single jet meters** are physically smaller than others and thus are more suitable for confined spaces. Among all the meter types, *single jet meters* are also able to measure hot water at a temperature of up to 140 degrees Celsius (Table 2).

Some jurisdictions have guidelines on approved water sub-meters. The Water Corporation in Western Australia provides a list of acceptable sub-meters² (Water Corporation 2014):

1. Actaries Model CT5 20 mm water meter
2. Esster Mode 20 mm V100 (aka PSM-LT)
3. RMC Model NMI 20 mm water meter [only if installed in the horizontal plane]

On the other hand, some jurisdictions do not have a requirement that sub-meters must be “approved”. The sub-metering legislation of New York City, for example, does not provide a list of “approved” sub-meters (NYC 2013). Similarly, the Region of Waterloo which has a sub-metering rebate program (Water Efficiency Technology Program) does not have guidelines on “approved” sub-meters to be eligible for the rebate.

2.1 Meter sizing

A properly sized meter is necessary to prevent damage to the meter and reduce water that is unaccounted for through inaccurate measurement. Sub-meters have different sizes and can be fitted onto different sizes of water lines. Large meters can be defined as those that can work on a water line of 1 ½” or greater³ (Table 2). These meters are often used in the Commercial, Industrial and Institutional (CII) sector. Small consumption meters are those that have a water line size of 1” or less. They are often used in the residential sector where water use is comparatively lower than the CII sector.

It is critical to consider several factors when selecting the appropriate size of the meters (EPA 2012; FCM 2003):

1. Building size

² A detailed report on water sub-meter hardware specifications by the Australian government can be found at <http://www.defence.gov.au/estatemangement/Governance/Policy/Environment/EnergyEfficiency/Docs/NSP/WaterSubMeterAndLoggerSpecificationV1.pdf> (Last accessed on 2/7/2016).

³ This sizing refers to the pipe diameter.

2. Function of building
3. Occupancy of building
4. Equipment/ fixtures on site

These factors can determine the minimal and maximum flow rates and thus a properly sized meter. The larger the flow meter size, the higher its velocity capacity, and the greater the flow rate it can measure. However, undersized water meters can cause excessive pressure loss, reduced flow, noise, and pipe damage. Oversized meters are not economical and cannot accurately measure minimal flow rates (EPA 2012).

	Positive displacement (“disc” meters)	Single jet meters	Multi-jet meters	Turbine meters	Electromagnetic meters
Overview	The chamber contains a piston or disk. The number of rotations of the piston or disc is converted to the volumetric register.	The chamber contains an impeller. The flow of water pushes the tips of the impeller.	Water is forced through a series of ducts open in the distributor. The ducts generate a series of symmetrical jets that push the turbine.	Inferential meters designed with a known cross sectional area. A rotor is installed inside the meter chamber. Passing the rotor blades, water impacts angular velocity to the blades and thus to the rotors. The angular velocity is proportional to the total volumetric rate.	Uses the Faraday principle. Flowing water produces electric current that is proportional to the flow velocity.
Application	Small residential and commercial building	Suitable for limited space	Popular in utilities that have suspended matter or grit in their water	Best suited for continuous, high flow measurement	Effective in measuring the flow rate of acidic or corrosive materials such as abrasives and slurries; can also measure flow rate of combustible or explosive liquids
Pros	Precisely measure pulsing flow. Low cost. smaller versions can operate for more than 10 years with only minor deterioration of accuracy; Some versions can service hot water	Physically smaller than positive displacement meters. Some versions can service hot water up to 140 degrees Celsius. Accurately measure low flow rate (under 7.57 L/min or 2 gpm)	It can measure water flow as low as 0.47 L/min or 1/8 gpm.	Accurately measure high and sustained flow rates	Have no moving parts (operate on Faraday’s Principle) thus reduces the risk of break-downs and the frequency of repairs

	Positive displacement (“disc” meters)	Single jet meters	Multi-jet meters	Turbine meters	Electromagnetic meters
Cons	Clean fluid is required. Any larger particles can be trapped and block the flow	More expensive than positive displacement or multi-jet meters	Not as accurate as positive displacement meters over the long term	Suspended particles or grit in fluid can affect the rotation of the turbine, distorting measurement. Susceptible to start/stop error and errors caused by unsteady flow	Only effective on conductive fluids
Meter sizes ⁴	5/8” through 2”	5/8” through 6”	5/8” through 2”	2” or larger	5/8” to 8”
Installation	Can be installed on inclined and even vertical pipe	Can be installed horizontally or vertically. No upstream or downstream straight pipe requirement.	Must be installed in a level horizontal plane	Requires straight run of pipe before and after the meter ⁵	Can be installed on horizontal, vertical, or slightly ascending pipe

Table 2. Overview of different types of meters (City of New York 2013; Smith 2008; Qmeters 2016; MetronFarnier 2015; FCM 2003)

⁴ Meter sizes are described in terms of the nominal National Pipe Thread diameter pipe to which the meter is connected.

⁵ Turbine meters are susceptible to flow disturbances, therefore a straight run of pipe can help control swirl, jetting and pulsations.

2.2 Installation requirements

Different types of meters have different installation requirements for accurate measurement. For instance, positive displacement meters can be installed on inclined and even vertical pipes while the multi-jet meters must be installed on a horizontal plane (City of New York 2013). The best practice to ensure optimal meter operation is to follow the manufacturer's instructions on installation⁶. In general, regardless of the type of sub-meter, all meters should meet the following requirements (AWWA 2012; FEMA 2003):

- Be located in an accessible and protected location to allow for repair and reading.
- Be protected from freezing and other potential damage
- Possess an inlet-shut off valve for meter maintenance
- Provide an appropriate bypass assembly with valves to avoid water supply stoppage during meter servicing for critical water lines
- Have installed a strainer upstream of turbine, propeller and compound meters to prevent large debris from damaging the meter
- Provide for adequate straight length piping on upstream and downstream sides of the meter, as required by the manufacturer

When retrofitting sub-meters to existing buildings, there are several factors that may affect the velocity of the water flow and thus the accuracy of the meter:

- Orientation of the meter (e.g. inclination of the meter)
- Entry nozzle length
- Aging pipe with scale built-up
- Obstructed meter strainers
- Length of a straight pipe on the either side of the meter

For instance, when a single jet meter is placed in an inclined position, the impeller can make contact in areas that are not designed for such contact. Thus, the impeller will rotate slower at a given flowrate due to increased friction, causing the measured volume to be lower than the actual volume passed through the meter. This effect is most noticeable at low flowrate where the energy transferred from the water to the impeller is small and any modification to the force can affect the velocity rotation of the impeller.

Furthermore, the presence of an obstructed strainer or change in direction of the pipe near the entry point of the meter changes the velocity of the water flow, thus affecting measurement accuracy. The entry nozzle length can minimize the effect by regularizing the water velocity before it reaches the metering chamber. The nozzle that leads to the metering chamber often

⁶ An example of a manufacturer's installation recommendations can be found at https://www.nextcenturymeters.com/img/marketing/Installation_Instructions-M201_Series_Water_Meters.pdf (last accessed on 2/7/2016).

has a convergent shape, causing the flow to accelerate and regularise before it reaches the metering chamber. Thus a longer entry nozzle is more effective than a shorter one in minimizing the irregularities in water flow caused by, for example, obstructed meter strainers or bended pipes.

In addition to the manufacturers' instructions on installation, some jurisdictions have specific requirement on where and how sub-meters should be installed. For instance, Water Corporate, an enterprise owned by the Western Australia government and regulated by its Ministry of Water, has set out guidelines on water sub-meter installation. To facilitate meter reading, maintenance and/or replacement, sub-meter installation must comply with the following specifications:

1. Sub-meter must be 150mm above ground
2. Sub-meters must have a 300mm horizontal clearance all round
3. Sub-meters must have a 120cm vertical clearance
4. The "tails" must be 80mm long on either side of the meter
5. The fittings must be made of copper/brass or stainless steel
6. The meter viewing glass/window must not be damaged or difficult to read

2.3 Meter maintenance

In addition to proper installation, sub-meters also require regular maintenance to ensure accuracy. American Water Work Association (AWWA) recommends meters to be tested and calibrated for accuracy with the following frequency (AWWA 2012) (Table 3):

Meter sizes	Maintenance
5/8 inch to 1 inch	Every 10 years
1 inch to 4 inches	Every 5 years
4 inches or greater	Every year

Table 3. AWWA recommendation on meter maintenance frequency

2.4 Meter reading

There are different ways that water meters can be read. In addition to the traditional way of reading the meters directly by viewing the odometer display on site, several data transmitting technologies can provide accurate water usage measurement remotely. Automated meter reading (AMR) technologies, including absolute encoders, pulse and 4-20 mA, provide an efficient way of data collection, allowing property managers and owners to track water usages easily and implement a water management plan effectively (Table 4).

Meter registers	How it works
Traditional method	Physically read the odometer display on the meter
Absolute encoders	A specialized computer or AMR box is connected to the meter register. The device transmits a low voltage signal into the register and the register returns with the actual read. Some AMR systems can read real-time water use data.
Pulse	A pulse represents a specific volume of water, for example one pulse per gallon or one pulse for every ten gallon for larger meters (2" or larger). The pulses are sent to the remote device which acts as the totalizer ⁷ .
4-20 mA	Mostly used in the heating ventilating and air conditioning (HVAC) industry but less commonly used in the meter industry. But this can be an option for electromagnetic meters.

Table 4. Description of meter registering technologies (City of New York 2013).

Most automated systems are capable of:

- 1) Electronically storing and transmitting water use data hourly, daily, monthly or annually⁸.
- 2) Online consumption reporting, which allows property owners and/or tenants to track their water use throughout the billing cycle and identify abnormal use that may signify leakage and/or meter malfunctions.
- 3) Sending alerts to property managers and tenants when leaks or other operational anomalies such as lose wiring are detected.

⁷ A device that calculates the number of pulses received and the total corresponding volume.

⁸ Such interval metering can provide specific water use information and enable time-of-use pricing. Water rate can vary based on time of use and/or volume use. Some automated systems can send real-time water use data to a software which can generate a water bill based on a structured pricing system.

3. Perceived benefits of sub-metering

The following table outlines the perceived benefits of water sub-metering from the perspectives of utilities, property owners and tenants (Table 5).

Stakeholders	Perceived benefits
Utilities	<ul style="list-style-type: none"> • Sub-metering can induce water conserving behavior. Utilities can avoid developing new water supply infrastructure and reduce their operational costs
Tenants	<ul style="list-style-type: none"> • More control over total housing costs. Prior to water sub-metering, tenants are charged a fixed water rate (which is included in the monthly rent payments) regardless of how much they consume. With sub-metering, lower-water-consuming tenants are likely to pay less as they now pay for their actual water consumption • Be able to identify water use daily, weekly, monthly, which can recognise water conserving possibilities and leaks. This can reduce the cost paid for unused water
Property owners/ managers	<ul style="list-style-type: none"> • Be able to identify leaks • Sub-metering can potentially increase property value as tenants may prefer to be made aware of their water consumption and have control over their water bill

Table 5. Perceived benefits of sub-metering (Mayer et al. 2004).

4. Perceived concerns of sub-metering

Despite the aforementioned benefits of having submeters, there are barriers to sub-metering. Barriers to sub-metering are caused by concerns from different stakeholders including utility companies, property owners, and tenants (Table 6).

Stakeholders	Perceived concerns
Utilities	<ul style="list-style-type: none"> • If the utility is responsible for sub-metering, billing units separately can increase utilities operational costs as utilities may have to hire a third-party for the reporting and billing procedures. • If the utility is responsible for sub-metering, the operational cost will increase as utility companies may be responsible for maintaining individual sub-meters and held liable for meter malfunction and leaks

Stakeholders	Perceived concerns
Tenants	<ul style="list-style-type: none"> • Paying water bills separately (in addition to their monthly rent) may affect their monthly budget • Concerns over the accuracy of meter reading • Liability issue: tenants may be held liable for meter malfunction, leaks
Property owners/managers	<ul style="list-style-type: none"> • Installation and maintenance costs • Might have to pay monthly service fee to third party for specialized meter reading and allocation • Regulatory issue: a sub-meter is a plumbing modification. Local laws likely require permits, inspections and fees • Liability issue: owners may be held liable for meter malfunction, leaks • Fear of vacancy rate as tenants may not welcome another monthly bill (water) in addition to their monthly rent • Issue with uncollected water bills

Table 6. Perceived concerns of sub-metering (Mayer et al. 2004).

5. Sub-metering regulations in other jurisdictions

Currently the City of Vancouver has a building bylaw that requires sub-meter installation specifically for hot water. In Section 10.2.1.3, it states that “building shall be designed with sub-metering for a) hot water generated by a central hot water generation system...”

Numerous jurisdictions have implemented water sub-metering regulations or local by-laws. Twenty-two states in the United States such as Georgia, Texas and California and cities in Australia such as Tasmania and Queensland (Appendix 2) have imposed regulations and/or local ordinances on water sub-metering. This section provides a sample of regulations highlighting different aspects of sub-metering.

Jurisdiction	Regulations
Georgia	<p>The 2010 Water Stewardship Act requires that new multi-unit residential buildings and certain retail and light industrial buildings (construction permit granted after July 1, 2012) must have water sub-meters. The Act encourages but does not require the installation of sub-meters in (1) existing multi-unit buildings (2) for office components of newly constructed multi-unit buildings. Tenants must be charged based on their measured usage. Property owners can seek reimbursement from tenants for common area water usage. They can also charge tenants a reasonable fee for establishing, servicing and billing tenants' water service. Property owners are free of any liability that results from billing or meter-reading errors by an unaffiliated third party (General Assembly of Georgia 2010)</p>
DeKalb County, GA	<p>Local ordinance (enacted in 2008) specifies that sub-meters are required for any water supplied to a multi-unit building or single family residence built after June 1, 2008. Owners/ landlords can use the sub-meters to bill tenants for their actual water use. Sub meters are owned by and managed by property owners, whereas master meters are owned by utility. The county bills the property owners/landlord for water services based on the master meter bill and owners/landlords can bill their tenants based on sub-meter readings (DeKalb County 2008)</p>
Texas	<p>Texas Water Code 13.501-13.506 requires that buildings with five or more residential units built after January 1, 2003 must have a water sub-meter for each unit. Owners are required to maintain adequate sub-metering records, which are made available to tenants. They must ensure the sub-meters meet certain standards for accuracy, testing and record keeping. With regards to billing, owners are required to disclose their billing practices in the rental agreement. These include [1] tenants' right to receive information from the owner to verify their bills [2] clear description of the allocation method used to calculate the bills [3] the average monthly water bill for all dwelling units in previous years [4] the date bills are due [5] the number of days it will take to repair the leaks in the dwelling after tenants have reported it. Tenants are charged (1) the cost per gallon plus applicable taxes and surcharges charged by water company (2) a late fee up to 5% of the bill (3) a service charge for up to 9% of the costs related to sub-metering (e.g. cost of installation, reporting and billing) allocated to each sub-metered unit (Public Utility Commission of Texas 2015)</p>

Jurisdiction	Regulations
Massachusetts	<p>Massachusetts allows landlords to install water sub-meters at their own expense. The new law also required that landlords must meet all of the following requirements before they can bill tenants based on their sub-meter readings:</p> <ol style="list-style-type: none"> 1. Sub-meters are installed by a licensed plumber and certified by the Board of Health 2. Low flow fixtures such as water –conserving faucets, showerheads and toilets are installed in the unit by a licensed plumber 3. A written rental agreement is present which clearly states the billing arrangements of water 4. The previous tenant was not forced out. Since this law only applies to tenancies starting on or after March 16, 2005, landlords cannot force out existing tenants in order to bring in new tenants who would be required to pay for water 5. Landlord must obtain a certification from the local Board of Health or inspectional services that they have satisfied the above requirements. <p>Landlords must pay for the cost for installing sub-meters and all water conserving fixtures. The cost cannot be transferred to tenants. Landlord is responsible for reading the sub-meters for billing tenants for their water use. They may contract a third party water company for the services –reading, preparing, sending, collecting bills. Landlords are also responsible for paying the cost of testing the sub-meter. Tenants can request licensed personnel to test the meter if they feel that the sub-meter is not accurate. If the meter is found inaccurate, the landlord must pay for the cost of testing and repay the tenants the amount overcharged. If the sub-meter reading is found to be accurate, however, the tenants will have to bear the costs of the test. The law also states that landlords are not allowed to shut off the water even if tenants are late in payment. The state policy has recognized that water service is essential to the health of everyone. Moreover, water used in common areas such as shared laundry facilities, outdoor faucets and water used in common heating systems cannot be charged to tenants. These common areas must be separately sub-metered.</p>

Jurisdiction	Regulations
California	<p>If enacted, California's SB 750 requires the state's water companies to install water sub-meters for each unit of a newly constructed multi-unit building. The bill will require multi-unit landlords to bill tenants for the volume of water they use (low-income housing, student dormitories, long-term health care facilities, time-share properties, and residential care facilities are exempted). The bill will require the landlord to be responsible for repairing malfunctioning water systems in an individual unit. The water bills will be calculated by multiplying the water volume determined by the sub-meter for the billing period by the water company's rate for volumetric usage. The calculated bills can only include charges for (a) volumetric use, (b) a portion of the water company's fixed charges, (c) a fee for the landlord's billing costs capped at \$4.00, and (d) a late fee, if applicable.</p>
Los Angeles	<p>The local ordinance of the City of Los Angeles requires water sub-meters or separate water meters be installed within each individual dwelling unit and within common areas (such as the recreation and laundry room) of multi-family dwellings not exceeding three stories and containing 50 units or less. For buildings that exceed 50,000 square feet (4,645 square meters), sub-meters must be installed:</p> <ol style="list-style-type: none"> 1) for individual leased space with projected water consumption greater than 100 gallons per day (379 litres per day) 2) where potable water is supplied to a) makeup water for cooling towers where water usage is greater than 500 gallon per minute (1892 litres per minute) b) makeup water for evaporative coolers greater than 6 gallons per minute (22 litres per minute) c) steam and hot water boilers with energy input greater than 500,000 Btu per hour (147 kW). Sub-meters must also be installed for each building that uses more than 100 gallons of water per day (379 litres per day) on a parcel consisting of multiple buildings (City of Los Angeles 2015).
San Diego	<p>They city enacted an ordinance in 2010. Sub-meters are required on all new multi-family residential and mixed used developments with three or more units and in any existing buildings where interior water plumbing is being replaced. In addition, the City of San Diego also provides a rebate program on water sub-metering.</p>

Jurisdiction	Regulations
New York City	Local Law 56 (606.7) specifies that water sub-meters are required on water lines serving a commercial cooking facility, commercial laundry facility or commercial gym or spa. These sub-meters are to measure the amount of water supplied through such lines to the water-using equipment within such facilities. Makeup water lines serving 3 evaporative cooling towers or a swimming pool shall be equipped with at least one water sub-meter. All sub-meters are equipped with an electronic encoder with absolute or pulse based output. Section 608.16.2 requires that at least one water sub-meter must be installed on makeup water lines to boilers serving buildings greater than six stories ⁹

Table 7. Overview of sub-metering regulations in some of the U.S. states (NCSL 2016).

⁹ More information on the New York City sub-metering regulations can be found at <http://www.nyc.gov/html/gbee/downloads/pdf/l156-2010.pdf> (last accessed on 22/7/2016)

6. Billing requirements

In many jurisdictions where sub-metering policies are in place, utilities bill the property owners a mass water bill based on the master meter reading. It is the owners' responsibility to read the sub-meters and bill individual units based on the sub-meter readings. Property owners can hire a third-party to read the sub-meters and allocate the cost to tenants. Also, some states such as Georgia allow property owners to seek reimbursement from tenants for common area water usage while some states such as Massachusetts do not permit it.

The sub-metering regulations in Massachusetts provide thorough guidelines as to when tenants can be billed for their water bills and the rights and responsibilities of the landlords and tenants respectively. The landlord can only charge their tenants for their water bill if they have fulfilled the stated requirements and received approval by the local Board of Health or inspection services (see Table 7).

7. Incentive programs

Region of Waterloo (Canada)

The Water Efficient Technology (WET) program of the Region of Waterloo has a rebate program on water sub-metering in existing condominiums that lack individual water sub-meters for each unit. The proposed program offers a rebate of 50% of the supply cost of each sub-meter.

Santa Clara (United States)

The Santa Clara Valley Water District, which supplies water and flood protection for Santa Clara County, has a sub-meter rebate program that offers mobile home parks and condominium complexes up to \$150 rebate per installed sub-meter to encourage the installation of residential sub-meters (Santa Clara Valley Water District 2016). To qualify for the rebate program, property owners must select sub-meters that comply with the Uniform Plumbing Code¹⁰. The sub-meter must also be certified by the Santa Clara County Department of Weights & Measures¹¹.

¹⁰ The American National Standard on the installation and inspection of plumbing systems developed by the International Association of Plumbing and Mechanical Officials (IAPMO). More information can be found at <https://archive.org/stream/2012UPC/2012%20UPC#page/n463/mode/2up/search/submeter> (last accessed on 22/7/2016).

¹¹ More information can be found at <https://www.sccgov.org/sites/weights/Pages/Weights-and-Measures.aspx> (last accessed on 22/7/2016).

Tasmania (Australia)

For all multi-unit properties and strata schemes, property owners can install sub-meters at their own discretion. If they decide to install sub-meters, TasWater, the state water and sewage services of Tasmania, will supply the sub-meters at no cost to be installed at owner's expense. The sub-meters will be maintained and owned by TasWater. Once the sub-meters are installed, the property owners will be billed a fixed charge based on the sub-meter reading (TasWater 2015).

Additional information is provided in Appendix 2.

8. Case studies of local properties with a water sub-metering program

8.1. Granville Island

Granville Island, one of the most recognized waterfront developments in North America, houses more than 275 businesses and generates approximately \$130 million worth of economic activity annually (CMHC 2016). Since 1972, Granville Island has been administered and managed by the Canada Mortgage and Housing Corporation (CMHC). Granville Island is a chosen case study for this project as it is a vibrant and diverse commercial area. It consists of buildings and facilities such as the Public Market, boat repair shops, a cement plant, breweries, Emily Carr University and a theatre, each with differing levels of water consumption. In the past few years, CMHC has been installing water sub-meters for individually leased spaces at the Public Market in an effort to promote water efficiency on Granville Island (figure 5).



Figure 5. A water sub-meter near the ceiling, which measures the water usage of a produce store at the Public Market.

Sub-meters have been installed for approximately 75% of tenants in the Public Market. The water sub-meters are supplied by Quadlogic Meters Canada Inc. (QMC), which then hires a third party contractor to install the meters. Besides supplying the meters, QMC also provides data reading and reporting services. The data are sent to CMHC, the landlord of Granville Island, who charges individual tenants accordingly¹². CMHC is responsible for costs including the sub-meters, installation, maintenance and administration.

The Public Market is an ideal place to install water sub-meters. There are many individual tenants running a variety of businesses inside the market. These businesses include seafood stores, coffee shops, craft stores and flower shops, which often have different average water consumption levels (Figure 6-8). Prior to sub-metering, owners of these businesses were charged a fixed water rate based on the size of their leased spaces. The flat water rate was a rough estimate, resulting in some stores actually using significantly more water than they pay for while some pay too much for what they actually use. To charge each tenant equitably, CMHC has installed water sub-meters to accurately measure the water usage of individual tenants.



Figure 6. A coffee shop at the Public Market.

¹² CMHC pays the City of Vancouver for the total amount of water supplied via one water main to Granville Island with a master meter owned by the City of Vancouver.



Figure 7. A butcher store at the Public Market



Figure 8. A fresh produce store at the Public Market

Due to the number of tenants and the variety of businesses, the Public Market was prioritized for sub-metering. Water sub-meters were not widely installed in other buildings on Granville Island due to a variety of reasons. For instance, the cement plant is leased only to one tenant and there is already an existing manual meter that measures the amount of water supplied to the plant. CHMC arranges for a staff member to manually read that meter regularly and send a bill to the cement plant (figure 9).



Figure 9. The cement plant on Granville Island.

Similar to the cement plant, the other buildings that only house a single business rely on traditional manual read meters. The difference between these meters and those at the public market is that they have to be read manually. For instance, a bakery which occupies a separate building outside the Public Market has a traditional manual meter that measures its total water use (figure 10, figure 11). A CMHC worker regularly performs a manual reading of the meter.



Figure 10. A bakery at one of the buildings outside the Public Market



Figure 11. A manual reading water meter that measures the water use of a bakery on Granville Island.

The theatre is a building on Granville Island that does not have a water sub-meter due to its high tenancy turnover rate. CMHC decided that it is not cost effective to install water sub-meters within the building as the space is rented to different performance groups for short periods of time. For other buildings that have multiple tenants but are leased to a single head lessee, a sub-meter is installed to measure the total amount of water supplied to the building (figure 12). The meter determines the water bill paid by the head lessee to the CMHC. The head lessee can install sub-meter(s) within their building at their own discretion and charge the sub-tenants accordingly.

8.1.a. Types of water sub-meters

Besides the manual-read sub-meters, two other types of water sub-meters are used on Granville Island– GWF M-Bus enabled meters and Badger RTR water meters. These two types of sub-meters are supplied by QMC.

The GWF M-Bus sub-meters on Granville Island utilize a wireless meter reading communication system that provides absolute meter reading data. The specific models of the GWF sub-meters are:

- UNICOCoder Single-jet consumption meter with M-Bus interface
- MTKcoder Multi-jet domestic water meter

There are two versions of the UNICOCoder Single-jet model – one for servicing warm water up to 90 degrees Celsius; the other services cold water up to 30 degrees Celsius. MTKcoder Multi-jet domestic water meters can only service cold water up to 30 degrees Celsius. Both types of meters can be installed horizontally or vertically¹³. The sizes of these meters range from ¾” to 6”.

These GWF water sub-meters are used outdoors and installed in the water pits on Granville Island to measure water supplied to individual buildings. These individual buildings are often leased by CMHC to a head lessee, and these building may accommodate numerous businesses. The water supplied to the building is billed to the head lessee. The head lessee can install water sub-meters in the building at his/her own discretion in order to charge his/her tenants for their water use.

The M-bus system produces real-time data. Approximately 20 -25 GWF meters were installed over the past two years. The data transmission device is located on the ground next to the building (figure 12). A radio signal is sent every 5 to 10 minutes to a central antenna via antennae located throughout the island. In figure 12, an antenna is located about 50 feet from the transmission device of a water pit.

¹³ More information on the specifications of the meters can be found at <http://qmeters.com/wp-content/uploads/2016/01/Unicocoder-Residential-hot-water-meter.pdf>; <http://qmeters.com/wp-content/uploads/2016/01/Unicocoder-residential-M-Bus-Meter.pdf>; <http://qmeters.com/wp-content/uploads/2016/01/MTKcoder-commercial-M-Bus-Meter.pdf> (accessed on 21/07/2016)



Figure 12. A GWF M-bus system outside a building on Granville Island

In addition to the GWF M-bus water meters, the Badger meter is another type of sub-meter installed on Granville Island. Ranging from $\frac{3}{4}$ inch to 1.5 inches, Badger meters are primarily used at the Public Market. Approximately 35 Badger meters were installed in the Public Market in the past four years.

Unlike the GWF M-bus meter, the Badger¹⁴ meter uses pulse output and is part of a wired system that connects the meter to a pulse counter¹⁵ (Figure 13). A pulse represents 0.01 m^3 (10 litres) of water (figure 14). The meter sends a pulse to the pulse counter for every 0.01 m^3 of water consumed. Thus, compare to the GWF M-bus wireless system that sends real time data every 5 to 10 minutes, pulse output is delayed as the requisite amount of water must be consumed before the information is sent.

However, despite the potential delay of pulse output data, pulse output is considered to be more reliable than the M-Bus (wireless system) as the wired system can ensure that the signal

¹⁴ More information about Badger water meters can be found at <http://qmeters.com/meters/water/> (accessed on 21/07/2016).

¹⁵ A device that sums the number of pulses and the corresponding total volume.

is transmitted and received. For wireless transmission, a signal is received only when there is a clear line of sight to the antenna. For instance, if a truck is parked in front of the data transmitter (figure12), the signal can be delayed. Similarly, when used indoors, the wireless transmission can be affected by concrete structures within the premises. Furthermore, the pulse output can easily integrate with the data reporting software. Hence, a hardwired system is preferred by Granville Island over the wireless system whenever possible.

Hardwired (Badger) and wireless (GWF M-bus) systems are both used on Granville Island. The water sub-meters at the outdoor water pits are wireless models because the costs to install wires to connect the meters that are located sparsely throughout Granville Island to a central data logger are prohibitive.

On the other hand, the sub-meters inside the Public Market are located close to one another and thus the hardwired system, which is the more reliable data transmission system, is used. The hardwired system also prevents any interference caused to the wireless transmission from concrete structures inside the market. The hardwired system is costlier to install than a wireless system and the installation is more time-consuming as wires are required to connect the data logger and the meters.



Figure 13. The pulse counter at one corner of the market.

81005896		Unit/Pulse
Meter #		(W) 0.01m ³
M1 -	520 Seafood City	(W) 0.01m ³
M2 -	515 Sunlight Farms	(W) 0.01m ³
M3 -	505 Granville Island Florist	(W) 0.01m ³
M4 -	400 JJ Bean	(W) 0.01m ³
M5 -	410 Candy Kitchen	(W) 0.01m ³
M6 -	405 Lee's Donuts	(HW) 10L
M7 -	435 The Grainery	(CW) 10L
M8 -	435 The Grainery	(W) 0.01m ³
M9 -	425 The Milkman	(W) 0.01m ³
M10 -	420 Stuard's Bakery	(W) 0.01m ³
M11 -	415 Dussa's Ham&Cheese	(W) 0.01m ³
M12 -	East Water Main	(W) 0.01m ³
M13 -		
M14 -		
M15 -		
M16 -		
M17 -		
M18 -		
M19 -		
M20 -		
M21 -		
M22 -		
M23 -		
M24 -		

Figure 14. The label on the totalizer that specifies the different water sub-meters and their respective pulse per unit.

8.1.b. Costs

The supply cost of sub-meters ranges from \$400 to \$2000 per meter, depending on the size of the water line (e.g. 1" to 3"). A GWF 1" is approximately \$500.

The cost of installation ranges from \$500 to \$1000 depending on the physical challenges involved in fitting a water sub-meter to an existing system. Retrofitting water sub-meters is generally more expensive than installing sub-meters in new buildings. For example, CMHC's crew typically requires four hours to install one meter. Workers have to search for an optimal location to fit a water sub-meter to minimize any inconvenience that the sub-meter might cause to the tenants. The installation cost is largely dependent on the accessibility of the meter location and the presence of physical challenges.

The cost of maintaining the water sub-meters is minimal compare to other costs. According to the manufacturers' product description, the types of sub-meters used on Granville Island can last for approximately 10 years with minimal physical wear or drop in accuracy. Maintenance may be needed if the sub-meters or wires are physically damaged.

The administrative cost of water sub-metering program ranges from \$3 to \$9 per meter per month. QMC provides a range of services including the creation of customized reports and direct billing to tenants. The administrative cost varies, depending on the number of sub-meters on site and the level of services required. For instance, if a client wants to access the data online through its MeterConex software without engaging QMC's reporting service, the cost will be at the lower end of the spectrum.

8.1.c. Installation

The water sub-meters on Granville Island are installed based on the specifications recommended by the meter manufacturers. Some meters can be installed horizontally while some can be installed either horizontally or vertically. Apart from the manufacturer's recommendations, there is no protocol on how sub-meters should be installed.

CMHC arranges for technicians to install the sub-meters at the Public Markets at night to avoid interfering with the tenants' businesses during daytime. Retrofitting sub-meters on existing water pipes at the Public Market - an old structure with complex utilities - can present many challenges. More details of installation challenges are discussed in the *Challenges* section below.

8.1.d. Maintenance

QMC monitors the data remotely to ensure proper functioning of the sub-meters. The software sends alerts to its personnel when unusually low or high water profiles are detected. Such occurrences can be caused by the loss of meter communication due to 1) physical damage to sub-meters 2) loosening of wires or 3) leaks. In cases where an issue is detected, CMHC will send technicians to inspect the meters. However, CMHC does not inspect the meter regularly unless an issue is detected. The meters are tested and recalibrated when they are installed. There is no guideline from Measurement Canada on the re-certification of water sub-meter accuracy after installation. This is a different practice from that for electrical meters, which have to be retested every six to 10 years. According to the manufacturer's recommendation, inspection is recommended every five to ten years. However, there is no existing legislative requirement.

8.1.e. Billing

The water usage fees of Granville Island are paid by CMHC to the City of Vancouver based on the City's master meter. CMHC recovers the water cost by charging their tenants based on the data on the water sub-meters, which QMC collects and makes available to CMHC on the software MeterConnex¹⁶. The finance department of CMHC has access to the online information (individual tenants on Granville Island do not have login access to their water use data online yet). Based on the tenant's water use in the past two years, CMHC estimates each tenant's water use and send a monthly water bill to tenants. The water bill is included in a master bill to tenants that includes their rent, electricity and gas charges. The sub-metering data is used for water reconciliation that happens at the end of each year. Based on the sub-metering data, the conciliation process informs tenants whether they have been overpaying or underpaying for their water use, resulting in refunds or additional charges.

Should the tenant request for a detailed breakdown of their water charges, CMHC can provide a usage report. The report includes the total consumption, cost of water, any applicable taxes and a consumption graph which indicates peak water use and the fluctuations in water use. A sample water report can be found in Appendix 3.

In a situation where a tenant disputes their water bills, CMHC discusses with the tenant the possible factors that might have led to their unusually high water usage, such as their water use behaviors, or the addition of water-intensive equipment. If necessary, CMHC also sends crews to inspect the sub-meter to ensure proper functioning and accuracy. In the event of sub-meter malfunction, CMHC implements reconciliation policies by using the tenant's water usage for the preceding two months to make a new estimate of his or her water usage for the current month, which may result in refunds or additional fees to the tenants.

8.1.f. Benefits

Water sub-metering at the Public Market has encouraged tenants to replace their water-intensive equipment with water efficient versions. According to CMHC, tenants upgraded their equipment (for example, by replacing water-cooled refrigerators with air-cooled ones) immediately after being notified of the water sub-metering program. With water sub-metering, detailed water use reports can be made available, allowing tenants to understand their water use behavior and identify water conservation possibilities. For instance, a customized report can notify a tenant that their peak water use period was during their closing time, suggesting that their employees use a significant amount of water for cleaning up before closing the store. Consequently, the tenant can identify ways to use less water for cleaning up, such as turning off the hose when it is not in use and using buckets to store water while cleaning.

¹⁶ More information about MeterConnex can be found at http://qmmeters.com/wp-content/uploads/2016/01/QMC_MeterConnex_SalesSheet.pdf (accessed on 21/07/2016).

Water sub-meters in the Public Market send real-time data remotely to a software, allowing technicians to identify abnormality in water use promptly. With the automated alert system, technicians can catch any leaks or fix any damage to the sub-meters before more water is wasted. Furthermore, since tenants pay for what they actually consume, they are inclined to use less water. Some tenants who are now paying less for their water than before are happy that they are being charged equitably. On the contrary, tenants who are paying more for their water after sub-metering have become unhappy. For instance, the owner of a seafood store suggested that his water bill has increased since the introduction of sub-metering. He is aware that the equipment in the store such as the refrigerators use the most water. Yet it was not cost-effective for him to upgrade his equipment yet.

8.1.g. Challenges

One of the challenges of installing water sub-meters at the Public Market was the complexity involved in figuring out the specific water line(s) that supply water to individual spaces. Since the Public Market consists of five old buildings that used to be separate, the utility system (including water lines) is fairly complicated and the layout of the system was not well documented (figure 15). Thus the CMHC faced challenges in figuring out the water line(s) that supplied water to each tenant space in order to install the sub-meters.

In addition to the complicated water system, there may not be adequate shut-off valves. Or worse, some valves may be broken. In some cases, the CMHC maintenance team had to turn off the entire water supply to install one sub-meter. Thus it can be time consuming and inefficient to install one sub-meter as CMHC would have to ensure that all tenants are notified about the water shut-down. It can have significant effects on products that are stored in equipment that requires water to function, such as water-cooled refrigerators.



Figure 15. The Public Market consists of five buildings that used to be separate.

Another challenge of retrofitting water sub-meters in the Public Market is to find a big enough space to fit the sub-meter. Depending on the locations of the water lines, sub-meters can be installed 20 feet above the ground or underneath the sink. In some cases, water lines can be coming up from the floor to a sink or hiding behind a wall, providing minimal space for workers to add a sub-meter to a water line.

Figure 16 shows a water sub-meter sticking out of a wall at a coffee store. The sub-meter is not measuring the water use of the coffee store but instead that of the store next door. The sub-meter is also located in a tight space where the coffee store conducts their bookkeeping. Due to the limited room, the sub-meter is easily damaged (e.g. by being knocked down or having its wire loosened) by the tenant's activities at the store. After several maintenance calls, CMHC installed a wooden box to protect the sub-meter (figure 16). Hence, retrofitting sub-meters can be a challenging task due to the lack of physical space to fit a meter.

Given all the physical and technical challenges, the cost of retrofitting sub-meters in an existing facility can be large. The major challenges to retrofitting are the costs and the technical complexities - where, how and when to fit a sub-meter on the old, complicated water systems on Granville Island.



Figure 16. A water sub-meter, protected by a wooden case, installed in a bookkeeping space of a coffee shop.

8.2. Olympic Village

Located in southeast False Creek, the Olympic Village was developed by the Millennium Development Group for the 2010 Winter Olympic Games. Designed as one of the greenest communities in the world, the Village housed athlete and Olympic officials during the Winter Olympic Games. After the Olympics, the Village was converted into residential housing with

approximately 1,100 residential units, parks, and many retail and services businesses. Aligned with Vancouver’s Greenest City targets, the Village is equipped with innovative energy efficiency systems, such as solar heating, green roofs, and also water sub-metering for individual residential units.

Enerpro, a private energy management company, provides full water sub-meter management services at Olympic Village. Enerpro supplies the water sub-meters, conducts full maintenance of the communication system, performs data collection, data storage and billing, and also collects the tenants’ water charges. The installation of the sub-meters was done by the developer during the construction of the village.

Currently, a number of buildings in the Olympic Village are fitted with water sub-meters (Table 8). In total, 1100 units are equipped with both hot and cold water sub-meters. As a building requirement, 2,200 water sub-meters were installed during the construction of the village.

PARCEL ID	ADDRESS	STRATA	BLDG. NAME
P2A	181 W 1st Ave	3818	Brook
P2B	151 W 1st Ave	S.U.C.C.E.S.S	Co-Op
P3A	1616 Columbia St.	3863	The Bridge
P3B-1	170 Athletes Way		
P3B-2	160 Athletes Way		
P3B-3	150 Athletes Way		
P3C	169 Walter Hardwick Ave.	Bentall Kennedy	
P4A	181 Athletes Way	3862	Canada House
P4B	151 Athletes Way		
P5A	123 W 1st Ave.	3830	Compass
P5B	122 Walter Hardwick Ave.	S.U.C.C.E.S.S	
P6A-1	138 Athletes Way	3849	Shoreline
P6A-2	128 Athletes Way		
P6A-3	118 Athletes Way		
P6B	1625 Manitoba St.		
P6C	111 Walter Hardwick Ave.	Bentall Kennedy	
P9A	1661 Ontario St.	3841	Sails
P9B	75 W 1st Ave.	Bentall Kennedy	
P9C	80 Walter Hardwick Ave.	S.U.C.C.E.S.S	
P10A	77 Walter Hardwick Ave.	3859	Kayak
P10B	12 Athletes Way		
P10C	1633 Ontario St.		

Table 8. Buildings in the Olympic Village that are fitted with water sub-meters.

8.2.a. Types of meters

Single jet and multi-jet water sub-meters are installed in the Olympic Village. Some specific models include¹⁷:

- Master Meter Multi-Jet Water Meters 5/8", 3/4", and 1"
- NextCentury Multi-Jet Cold/Hot Water Meter (model M201)
- CD SD Plus Super Dry Single-Jet Water Meter
- Zenner Single-jet Dry Dial Meter for cold and hot water

All these meters have versions that are suitable for use with either cold or hot water.

The meter reading system in Olympic Village uses a pulse output which sends meter read information daily. The data can be used for both diagnostic and billing purposes. The pulse output system is reliable and non-proprietary, meaning that the meter reading data is not exclusively owned by Enerpro. In the event that Enerpro no longer provides the service, any new service provider would be able to have access to the data with no additional costs.

Other than the water sub-meters in the building, another green feature at the Olympic Village is an in-suite monitor to show tenants their daily electricity, hot water and cold water usage (figure 17). This is made possible by the real-time water consumption data that the water sub-meters are able to send daily.



Figure 17. An in-suite monitor that shows the monthly cold water consumption of a unit at Olympic Village (photo courtesy: Andrew Ling).

¹⁷ For more information on the specifications of the water sub-meters, please see Appendix 5.

8.2.b. Costs

The cost of each water sub-meter supplied by Enerpro is approximately \$90. Installation of both hot and cold water sub-meters can cost approximately \$220 per unit/suite. The cost of installation is heavily dependent on the wiring requirements, and the timing of installation of wiring. Wiring is the process of connecting the sub-meters to the central data logger. Often, if the wiring can be completed alongside other cable installations such as television or phone line services, the cost of wiring can be reduced. The average cost of wiring is approximately \$100 per unit. After wiring, it costs around \$120 per unit to program the sub-metering system to ensure proper functioning (Table 9).

As the service provider, Enerpro charges tenants at Olympic Village an administrative fee of \$9.50 per unit per month for both the hot and cold water sub-meters. This administrative fee cover a full range of services, including maintenance, reporting, billing collection and mailing¹⁸. As the owner of the buildings in the Olympic Village, the City of Vancouver paid for all the installation costs. Tenants are responsible for the monthly administrative fees.

Item	Cost
Water sub-meter (cold)	\$90
Water sub-meter (hot)	\$90
Wiring	\$100
Programming	\$120
Estimated installation cost per unit	\$400

Table 9. Summary of costs to install a hot and cold water sub-meter in a unit

8.2.c. Installation

The water sub-meters at Olympic village are installed close to a shut off valve, on the downstream side of the valve. Because water sub-meters were installed during the construction of the building, there were fewer physical challenges to the installation of meters on the water line, as compared to the situation on Granville Island. Enerpro suggested that it took approximately five minutes to install a sub-meter in Olympic Village not including the wiring. The most time consuming and challenging part of the process was the wiring and programing of

¹⁸ The \$9.50 administrative fee is for the full complement of services. The administrative fee can be as low as \$0.50 per unit per month if the property manager only requests the sub-metering data.

the communication system. In cases where the wires could be installed at the same time as other telecommunication systems, the process would be less challenging and cheaper.

The sub-meters are installed based on the manufacturer's recommendations. Both the single-jet and multi-jet sub-meters used widely in the Olympic Village were installed either vertically or horizontally. Both types of meters are not required to be installed on a straight flow (absence of bending pipe on either the upstream or downstream side of the sub-meter).

8.2.d. Maintenance

Enerpro inspects the communications system in the buildings at Olympic Village once a month. The inspection of sub-meters is infrequent as the meters are designed to be reliable and durable for years. Enerpro inspects the sub-meters when any data abnormality, such as disproportionate hot water to cold water consumption ratio, is detected. Maintenance is also conducted when tenants report issues.

8.2.e. Billing

Tenants at the Olympic Village receive a monthly invoice from Enerpro. The invoice specifies the cost for heating, cold water and hot water for the month (Appendix 4). Other information shown on the invoice includes the meter serial number, meter reading, date and period of when the sub-meter is read, and the final utility cost.¹⁹ The invoice also shows how the water consumption of the unit is compared to the British Columbia average. The per unit cost of hot water is more expensive than cold water as it encompasses both the cost of water and the thermal energy used to heat the water.

A water consumption graph can be provided to tenants upon request. Figure 18 is a consumption report that Enerpro provided to a tenant in July 2016. The tenant was able to identify a faulty hot water valve in their laundry which leaked for 10 days, resulting in the sudden spike in water use seen at the end of May.

¹⁹ Enerpro does not state the water rate per unit on the invoice because it is not the utilities provider.

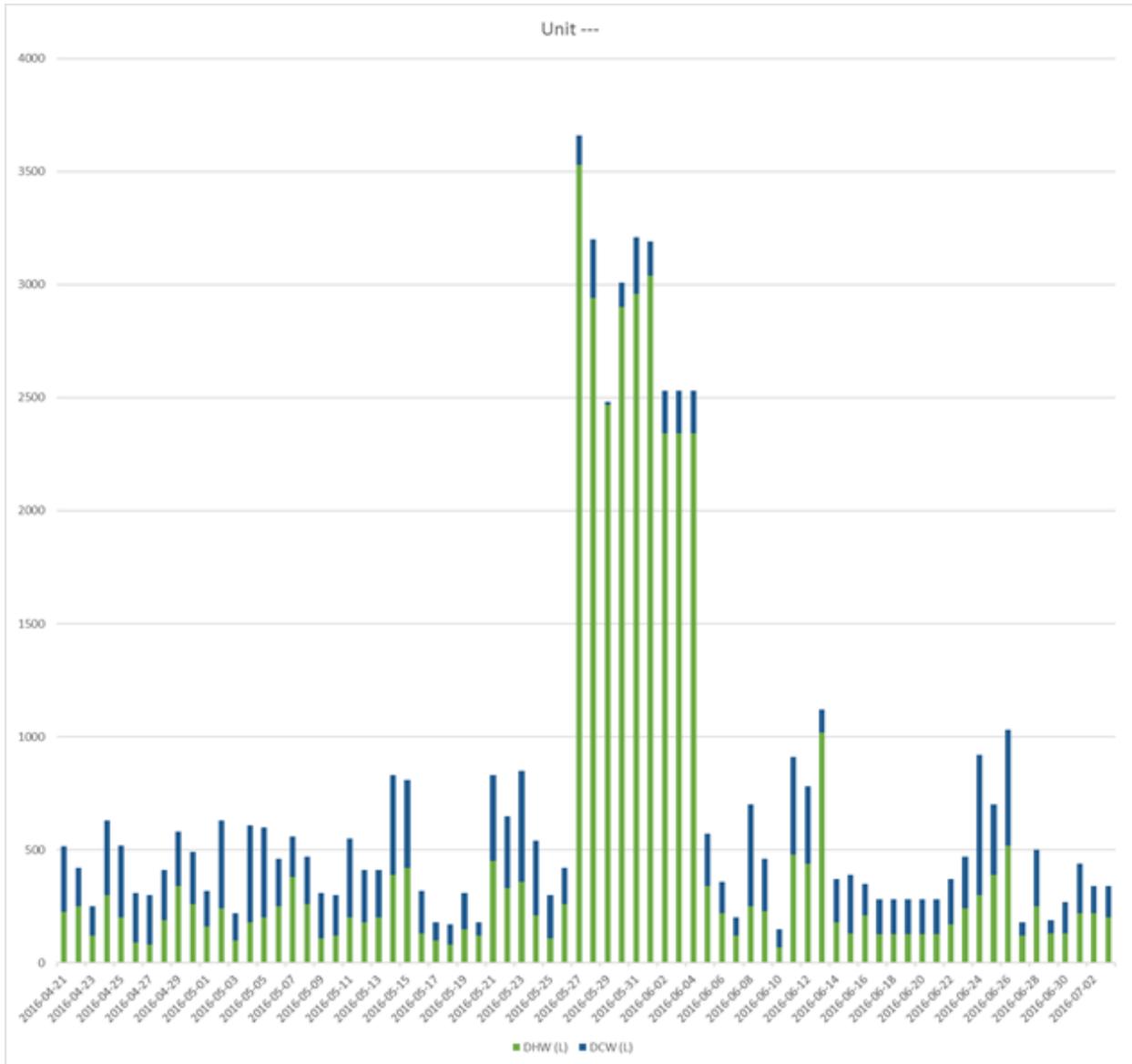


Figure 18. A daily water consumption graph of a unit in the Olympic Village where there was a leak for ten days.

In cases where tenants disagree with their water bill, Enerpro has a dispute resolution protocol. Enerpro will first check the meter to ensure that the meter reading is the same as that registered on the software. If tenants question the accuracy of the meter, tenants can sign an authorization form stating that they authorize a third party to test the meter. If the meter is tested to be accurate, the tenants have to pay the costs. If the meter is found to be inaccurate, Enerpro will pay for the fee and refund tenants the overcharged fees.

8.2.f. Benefits

Water sub-meters were installed during the construction of the buildings, thus the installation process was easier than in Granville Island where sub-meters were retrofitted. There were less technical challenges, and the sub-meters could be installed within a short period of time with low costs.

With in-suite monitors, tenants are able to know how much water they consume per day. They are able to identify if the increase in their daily consumption is caused by the increase in the number of guests in the unit, or the installation of new equipment, or leakage.

Furthermore, Enerpro provides a daily consumption graph to tenants upon request.²⁰ Thus tenants can identify their water use behavior and start possible water conservation strategies. Enerpro suggested that there is 50 to 70% water saving in the Olympic Village compared to comparable buildings without water sub-meters (Enerpro Systems Corp. 2010).

Water sub-metering can also reduce the building's operational costs. All sub-meters are connected to a central data system where meter readings are collected. The centralized system makes water cost allocation more equitable and efficient. Property managers can hire a third party like Enerpro who can provide full services including meter reading, maintenance, billing and data storage. Tenants are responsible to pay the administrative fee to the third party, which keeps the water sub-metering program running. Thus, from the building manager's perspective, the water sub-metering program reduces their operational costs.

8.2.g. Challenges

Unlike on Granville Island, the biggest challenge in the Olympic Village is not technical but rather education on the water sub-metering program among tenants. Due to the fact that residential water sub-metering is not prevalent throughout the City of Vancouver, some tenants are not used to paying for water on a metered basis. Prior to sub-metering, tenants would see a water "flat rate" or understand it was built into their rent. Some tenants at Olympic Village questioned why they had to pay for water, presenting challenges in the water bill collection process.

Another challenge is related to the administrative fee which is a flat fee of \$9.50 per unit regardless of how much water is consumed. Some tenants are conscious about their water use and use very little. Yet they have to pay the flat administrative fee which can constitute a large proportion of their water bill. For example, a water bill could include only a \$2.50 water fee

²⁰ Currently, tenants at Olympic Village do not have access to their water use data online. Enerpro is in the process of creating online login access to tenants, allowing them to track their water usage anytime.

with a \$9.50 administrative fee. Some tenants complain that the administrative fee is “excessive”. Furthermore, some tenants complain that there was never a signed agreement between Enerpro and them and therefore they should not be charged the administrative fee. Moreover, some tenants admit that they stopped looking at the in-suite monitor after a few months.

Educating the public about the value of sub-metering program and the meaning of the administrative fee (e.g. maintenance, billing, reporting etc) is essential in bringing success to the sub-metering program.

8.3 Region of Waterloo

The Water Efficiency Technology (W.E.T.) program of the Region of Waterloo has a sub-meter rebate program in place. Property owners are encouraged to retrofit sub-meters in their properties at their discretion. After the installation, they are eligible to request for a 50% rebate on the supply cost of every meter.

Apart from the rebate program, the Region of Waterloo does not have sub-metering bylaws or guidelines on meter selection, installation, and maintenance²¹. Thus far, the rebate program has received positive responses as more people are incentivized to install sub-meters amid rising water and sewage charges in the region.

9. Recommendations

Local water sub-metering programs have been successfully implemented on Granville Island and at Olympic Village. Through these case studies, a number of recommendations are presented to the City of Vancouver moving forward:

1. Encourage or require the installation of water sub-meters in all multiunit residential and commercial buildings

Case studies in other jurisdictions have shown that water sub-metering leads to water conservation. Existing buildings should be encouraged to retrofit water sub-meters where possible unless technical challenges prove the costs of doing so to be prohibitive. All newly-constructed multi-unit residential and commercial buildings should be required to install water sub-meters for individually leased spaces, common areas and

²¹ This is due to the fact that the Region of Waterloo is a large municipality that would require legislative coordination among three cities and four townships- the cities of Kitchener, Cambridge, and Waterloo, and the townships of Woolwich, Wellesley, North Dumfries and Wilmot.

other subsystems as recommended by the EPA, ASHRAE and IAPMO (Table 1). To reduce the cost of sub-meter installation, the wiring of the sub-meter and the communication system should be conducted with the installation of other telecommunication systems where possible.

Such a program could incorporate the following elements:

a. Introduce inspection requirements on water sub-meters

To ensure sub-meter accuracy, there should be regular inspections of the sub-meters to ensure that they comply at minimum with AWWA recommendations (Table 1) and manufacturers' requirements.

b. Keep the sub-metering system non-proprietary

The sub-metering system should remain non-proprietary, meaning the data should be exportable to any software. The non-proprietary nature of the system is essential as it does not tie the building to one single service provider for the provision of water sub-metering services. Thus, building management can easily switch service providers with minimal costs.

c. Ensure tenant access to water consumption data

The City of Vancouver should require service providers to provide login access to tenants so they can view their water consumption data online at their convenience. In addition, water consumptions statements should include a water consumption graph of each household so tenants can spot any irregularity in their water use easily. There may be a concern that allowing tenants to have login in access would increase administrative fee which falls on tenants.

d. Educate developers and end-users

Developers do not always recognize the potential value of water sub-metering to lower operational costs of the building. Promoting the program to developers and encouraging them to start utilizing the program is essential in making water sub-metering more prevalent in the city. Education is vital as it makes developers aware of the value and benefits of water sub-metering. In the event that an incentive program ended or were not in place, developers could still be inclined to install water sub-meters.

Education to tenants who are the end users is important because they pay for the administrative cost to keep the water sub-metering program running. Tenants should be made aware of what they are paying for and why. Education on the pricing system and the use of the administrative fee can minimize confusion among tenants. Tenants should also be made aware of their rights, such as the right to inspect the accuracy of the sub-meters. They should also know who to contact when there is a water bill dispute.

2. Consider an incentive program for retrofits

Given that costs to retrofit water sub-meters can be substantial, the City of Vancouver could consider rebate or subsidy programs to assist property owners/ managers to purchase and install water sub-meters.

10. Appendix

10.1. Appendix 1

Greenest City Scholar project (water sub-metering) posting:

Research project title

Water sub-metering to promote water efficiency

Supports the following Greenest City Goal or Green Operations Plan goal area:

Greenest City Action Plan

Goal 6: Clean Water

Target 2: Reduce per capita water consumption by 33% from 2006 levels.

Green Operations

Healthy Ecosystems

Target: Reduce corporate water consumption by 33% from 2006 levels

Outline scope of project and why it is of value to City and describe how and when the scholar's work will be actionable

Overview / Background

Sub-meters are commonly installed for energy utilities by landlords to encourage conservation efforts by their tenants. In the City of Vancouver, water sub-meters are not widely used by public or private buildings. Instead, buildings typically receive water through a "master" City meter, and tenants are usually charged a flat water and sewer rate. Consequently, tenants have little to no accountability for water use or incentive to reduce water wastage.

Extensive research based on North American case studies suggest that that water sub-metering offer significant water savings (e.g., Mayer, P. *et al.* (2004) "National Multiple Family Sub-metering and Allocation Billing Program Study"). For example, recognizing that "[l]eaks and equipment malfunctions waste a tremendous amount of water in ... buildings, and they can persist undetected for years," New York City Council passed Local Law 56 in 2010 to require water sub-meters on major water-using equipment in private and public buildings.

Building on the excellent work of the 2015 Greenest City Scholar to examine opportunities for reducing water wastage at parks sites, this project seeks to explore the potential for water sub-metering as a policy tool for increasing water efficiency and reducing wastage in public and private facilities within the jurisdiction of the City of Vancouver.

Scope of Work

The Scope of Work will be divided into two phases.

Phase 1

- Perform a literature review of water sub-meters and their effectiveness in:
 - o (1) promoting water conservation by residential and commercial tenants and
 - o (2) catching leaks within a building.
- Conduct a survey of buildings owners within the City of Vancouver to ascertain the prominence and uses of water sub-meters.
- Review the existing collection of data from water sub-meters at City of Vancouver facilities.
- Conduct targeted telephone interviews with North American jurisdictions with water sub-meter regulations (e.g., New York City) and sub-meter incentive programs (e.g., Waterloo) to learn “best practices.” In these jurisdictions, contact building owners to learn about their experience.

-

Phase 2

- As warranted by the literature review, explore the logistics, costs and benefits of:
 - o (1) installing water sub-meters for the City’s residential and commercial tenants rather than charging a flat water and sewer rate;
 - o (2) installing water sub-meters on major water uses within City facilities; and
 - o (3) prescribing and/or incenting water sub-meter use within privately held buildings for water conservation by tenants and/or leak detection.

Why this Work is of Value

The Greenest City Scholar’s research will inform the Water Design Branch on potential policy / program options to help achieve the Greenest City Action Plan and Green Operations [water conservation targets](#).

Deliverables

- Two reports, one interim presentation and one final presentation are expected.
- Phase 1 report: This report will address the Scope of Work described above for Phase 1. A 15 minute interim presentation will accompany this report.
- Phase 2 report: This will incorporate the Phase 1 report (revised as necessary), will address the Scope of Work described above for Phase 2 and provide recommendations

for potential policy / program options to help the City achieve its water conservation targets. The final version of this report will serve as the final report for the USI website.

- A 15 minute final presentation to City staff: Summarizing the final report, with additional time for extensive discussion including questions and answers.

Time Commitment

- This project will take 250 hours to complete.
- This project must be completed between May 2 and July 28, 2016. The scholar is to complete hours between 7:30 am and 4:00 pm, approximately 20 hours per week.
- An interim project update presentation and the Phase 1 report are expected on or before June 8, with the Phase 2 report submitted by July 14, 2016.
- The final report must be submitted and the final presentation held on or before July 28, 2016.

Skill set/background

- Excellent research, writing and verbal communications skills, including the ability to synthesize a range of data including information from field review and interviews.
- Basic background in building mechanical systems or a background with which to learn this quickly. Likely most suitable for an environmental scientist or engineer.
- Self-directed, collaborative and able to budget time and effort to address the scope of work within the timeline.
- Familiarity with conducting cost/benefit analyses.
- Demonstrated interest in water conservation is an asset.

10.2. Appendix 2

Water Sub-metering requirements in cities in Australia:

Tasmania

Housing Tasmania (Housing Department) oversees water sub-metering policies. Not all strata-titled units/ multiple dwellings are sub-metered. Strata-titled unit owners are encouraged to install sub-meters to each unit. The Residential Tenancy Act 1997 supports a user-pay charging system (charged for the measured volume of water used). Sub-meters shall be installed for strata title properties newly constructed for public rental. The cost of installation is apportioned to all unit holders in the strata title plan. Sub-meters installed in strata titled properties are wholly owned by Housing Tasmania. State-owned buildings will retrofit sub-meters provided that the cost is not excessive. Once the sub-meters are installed, they will not be taken out. In properties where water meters cannot be practicably installed (too technically problematic or too costly), the water authority will bill tenants at a proportion based on relative unit size (Taswater 2013).

Queensland

The City of Brisbane implemented by-laws (Queensland Plumbing and Wastewater Code Requirements) in 2008 requiring all new multi-unit developments and some non-residential premises to be sub-metered. The bylaw does not apply to the retrofitting of existing buildings, and applies only to newly constructed ones. The water services providers will own, read, and maintain the meters. They will also be responsible for charging the customers accordingly.²² (Brisbane City Council 2008).

²² More information on the requirements of the by-law can be found at <http://www.ahsca.com/qld/technical/City%20Hall%20Forum.pdf> (retrieved on 25/6/2016)

10.3. Appendix 3



Quadlogic Meters Canada Inc.
341-17 Fawcett Road
Coquitlam, BC V3K 6V2

Account Information

Name	[REDACTED]
Service Address	[REDACTED]
Account #	[REDACTED]
Current Amount Due by:	\$1,659.58
Amount Paid	\$

[DRAFT]

Please return this portion with cheque payable to: "Quadlogic Meters Canada Inc."

[REDACTED]
VANCOUVER, BC V1A 2B3
CANADA

Quadlogic Meters Canada Inc.
341 - 17 Fawcett Road
Coquitlam, BC V3K 6V2

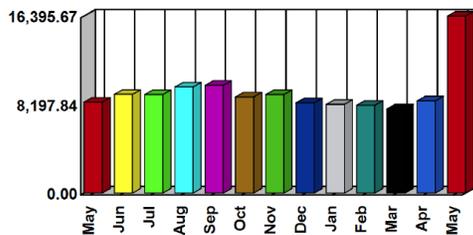
REGULAR BILL

Service Addr: 1166 Alberni Street, Vancouver, BC

Resident Name	Unit Number	Resident ID	Statement Date	Invoice Number	Security Code
[REDACTED]	2	10105	10/02/15	1040	10105C21B9PI

Meter Number	Start Read	End Read	Multiplier	Usage	UOM
QLC-81014346-3-13	1,390.34	1,502.94	35.3147	3,976.4318	kVARh
QLC-81014346-2	538,381.441	554,777.111	1	16,395.67	KWH

Electric Consumption Chart



Summary of Charges				
Description	Start Date	End Date	Days	Amount
Electricity Usage - 0.08021512 per kWh x 16,395.67 kWh = \$1,315.18	03/28/15	05/28/15	62	\$1,315.18
Water Usage - 0.04241233 per CuFt x 3,976.43184 CuFt = \$168.65	02/01/15	05/31/15	120	\$168.65
Admin Fee				\$9.50
PST - XXXXXXXX - 1315.18 x 0.07 = \$92.06				\$92.06
GST - XXXXXXXX - 1483.83 x 0.05 = \$74.19				\$74.19
CURRENT CHARGES				\$1,659.58
AMOUNT DUE				\$1,659.58

MESSAGES:

GO GREEN!
Did you know that you can choose paperless invoicing for your QMC Invoice?

Sign up for eBills, and view your past invoices at: www.qmeters.com

FOR BILLING QUESTIONS:

If there are any questions concerning your bill, please call our Customer Care Department at (604) 526-5155. Monday-Friday from 9:00 AM to 5:00 PM PST, excluding holidays. View your past invoices, and sign up for eBills at: <http://www.qmeters.com>.

10.4. Appendix 4



ENERPRO SYSTEMS CORP.
For 122 Walter Hardwick Ave
351 Bewicke Avenue, North Vancouver, BC V7M 3E9
Phone: (604) 982-9155 Toll Free: (877) 982-9155 Fax: (604) 982-9166 Email: billing@enerprosystems.com

Prepared For: # - 122 Walter Hardwick Ave. Vancouver, BC V5Y 0C9	Billing Date Jul 04, 2016	Account Number [REDACTED]	Invoice # [REDACTED]
	Pay By Jul 29, 2016	Please Pay \$42.93	Page 1

Balance payable from your previous bill	\$42.20
Thank you for your payment Jun. 06, 2016 (BPY37 06June2016)	42.20 CR
Balance from your previous bill	\$0.00

Metering Administration Charge: Jun 01 to Jun 30	\$9.50
GST at 5% (#89009 6480)	\$0.48
Total Metering Administration Charges:	\$9.98

Heating Charges: Jun 01-16 to Jun 30-16 (30 Days)

Consumption (kW.h):	Consumption Charge	\$0.32
Meter #: 65720572H	Total Heating Charges:	\$0.32
Jun. 30-16 22,360	The BC average consumption for heating in a unit of your size for this reporting period is 250 kW.h (Natural Resources Canada RETScreen International). Your consumption is 97% below the BC average.	
Jun. 01-16 22,353		
30 days 7		

Hot Water Charges: Jun 01-16 to Jun 30-16 (30 Days)

Consumption (US Gal):	Consumption Charge	\$22.53
Meter #: 6025501HW	Total Hot Water Charges:	\$22.53
Jun. 30-16 85,279	Average water consumption in BC is 490 litres per person per day (http://livingwatersmart.ca/didyouknow.html). Hot water is about 40% of the total water consumption (DeOreo and Mayer (2000)). Your hot water consumption is equal to what 0.9 people use based on the BC average.	
Jun. 01-16 83,862		
30 days 1,417		
(5,364 litres)		

Cold Water Charges: Jun 01-16 to Jun 30-16 (30 Days)

Consumption (US Gal):	Consumption Charge	\$10.10
Meter #: 6025502CW	Total Cold Water Charges:	\$10.10
Jun. 30-16 82,683	Average water consumption in BC is 490 litres per person per day (http://livingwatersmart.ca/didyouknow.html). Cold water is about 60% of the total water consumption (DeOreo and Mayer (2000)). Your cold water consumption is equal to what 0.6 people use based on the BC average.	
Jun. 01-16 81,219		
30 days 1,464		
(5,542 litres)		

Total New Metering Administration and Energy Charges: \$42.93

Please Note:

- 1) Heating and hot water in Southeast False Creek is provided by the Neighbourhood Energy Utility ("NEU").
- 2) Energy rates are set by NEU (<http://vancouver.ca/sustainability/neuRates.htm>).
- 3) Water rates are set by the City of Vancouver ("CoV") (<http://vancouver.ca/fs/treasury/utility/meterRates.htm>).
- 4) Invoiced amounts are a proportion of the NEU and CoV invoices based on the metered consumption in your unit.

Return this portion with your payment
Please Make Cheques Payable To
Enerpro Systems Corp
351 Bewicke Avenue
North Vancouver, BC, V7M 3E9

Billing Date
Jul 04, 2016

Account Number
[REDACTED]

Pay By
Jul 29, 2016

Please Pay
\$42.93

INVOICE TO:
[REDACTED]
- 122 Walter Hardwick Ave.
Vancouver, BC V5Y 0C9

Invoice #
[REDACTED]

Amount Paid

- Payment Options:
- 1) Cheque
 - 2) Financial Institutions (in person or online)
 - 3) Pre-authorized Payments

10.5. Appendix 5

The below information is kindly provided by Enerpro. Inclusion in this booklet does not mean that the meter is approved or endorsed by the City of Vancouver.

Multi-Jet Cold/Hot Water Meter Model M201



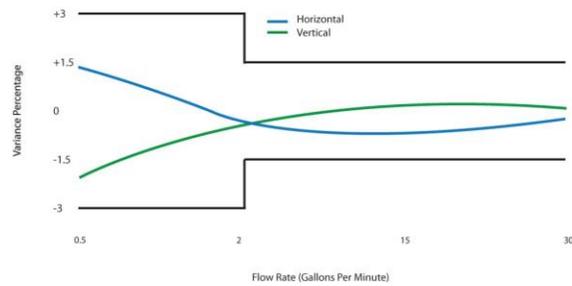
Features include:

- Meets AWWA C708 accuracy standards in a horizontal or vertical position.
- NSF/ANSI 372 Certified and Marked.
- Sealed register for tamper resistance.
- Meter body made of the highest grade polymer with a weight of just 18 oz.
- Pulse output
- Pre-wired connector and mounting plate to enable plug and play set-up.

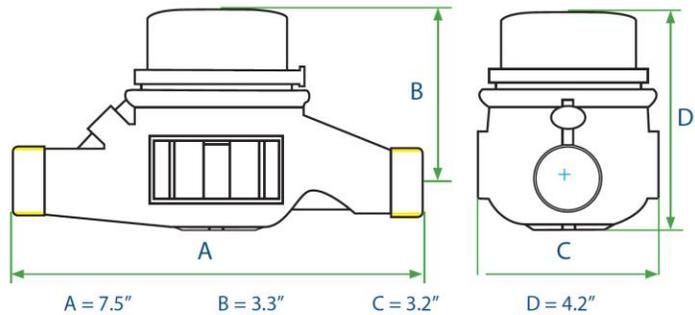
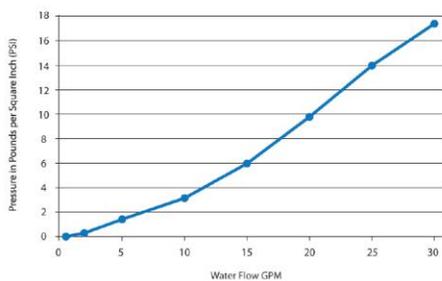
Specifications:

Max Flow Rate	30 gpm
Normal flow range (+/- 1.5%)	2-25 gpm
Min Flow Rate (+/- 3%)	0.50 gpm
Max working pressure	150 psi
Max working temp	194° F
Nominal pipe size	3/4"
Main Case Material	Glass Reinforced Nylon Polymer
Weight	18 oz.
Pulse Value	1/10gal

NCSS M201 Accuracy Curve for Cold/Hot Water



Next Century M201 Pressure Loss



For specific installation instructions, please refer to the NextCentury Installation Instructions for the M201 Series Water Meters.

www.nextcenturymeters.com | sales@nextcenturymeters.com

ver 3.12.15



Multi-Jet Water Meters

5/8", 3/4" and 1"

Our Multi-Jets quietly perform to a high standard. Yours.



Millions of our 5/8", 3/4", and 1" meters are in operation today. Using superior measurement technology, these meters represent the perfect balance between accuracy, cost, and longevity. With sensitivity to measure water flowing as low as 1/8 gallon per minute and accuracy unaffected by common particulates and build-up that would freeze other types, you can count on a Multi-Jet.

Our meters are designed with the future in mind as well. Choose from the many optional devices and you can create a modular reading system that has no equal. Remote Read? We can handle that. Wireless? We make it almost too easy. These meters are ready to work for you.

FEATURES & BENEFITS

- Meets All AWWA Standards; NSF Certified
- Tamper Detection and Prevention
- Patented Frost Protection (option)
- High-Quality, Long-Life Parts
- Durable Basket Strainer Protects from Damage



TECHNICAL SPECIFICATIONS:

AWWA/NSF Standards	Meets or exceeds all sections of AWWA Standard C-708, most recent revision; Certified by NSF to NSF/ANSI Standard 61.	Register	Standard direct read, DIALOG® Reading System and Electrical Output Registers are available. A six wheel odometer is standard.
Design/Operation	Velocity-type meter. Water, evenly distributed by multiple jet nozzles, flows past an impeller in the measuring chamber, creating an impeller velocity directly proportional to water flow rate. The meter's register integrates velocity into totalized flow.	Register Sealing	Direct read and DIALOG registers are permanently sealed, with a tempered glass lens, stainless steel base and wrap-around gasket to prevent intrusion of dirt or moisture.
Main Case	Choice of waterworks bronze case of 81% copper composition or EnviroBrass® II, 87% copper, low lead bronze. All main cases incorporate externally threaded ends and wrench pads to aid installation. Bronze register retaining rings are standard.	Register Units	Registration available in U.S. gallons, cubic feet or cubic metres.
Measuring Chamber	The measuring chamber housing and measurement element are constructed of a durable synthetic polymer and can easily be removed from the main case without removal of the meter from the line. The chamber housing is constructed in two parts to allow access to the impeller. Measurement surfaces are not wear surfaces, providing sustained accuracy despite the presence of entrained solids in the water. A long-life, sapphire serves as a wear surface, with balanced water flows minimizing bearing wear.	Test Circle	Large center sweep hand with ten clearly indicated gradations per minimum registration unit.
Magnetic Drive	A reliable, direct magnetic drive provides linkage between measurement element and register. No intermediate gearing is required; no gearing is exposed to water.	Low Flow/Leak Indicator	Center mounted indicator with high sensitivity resulting from direct one to one linkage to the measuring element.
		Strainer	A rugged, 360-degree polymer basket strainer protects the critical measuring element from damage.
		Frost Protection (option)	Patented, pressure-activated plug is expelled from the meter by expansion of freezing water. The frost plug can be replaced without meter removal or disassembly.
		Adjusting Port	Sealed after factory calibration. Port is accessible for utility recalibration, to compensate for inaccuracy in older meters without parts replacement.
		Tamper Detection	The Master Meter Multi-Jet adjusting port is sealed to prevent tampering and provides a visual indication of tampering attempts.

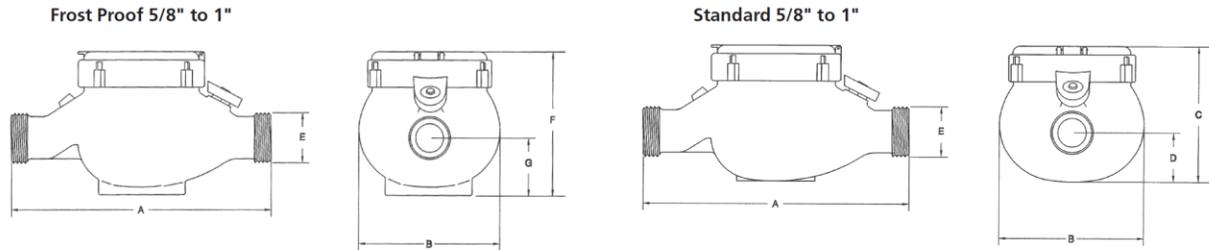
See reverse side for more specifications »

Multi-Jet Water Meters

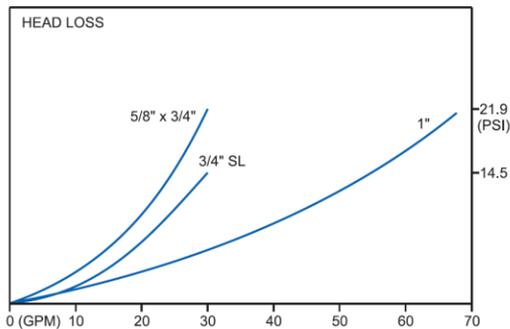
5/8", 3/4" and 1"

METER OPERATING CHARACTERISTIC/DIMENSION	5/8"	5/8" x 3/4"	3/4" SL	1"
Flow Rating (gpm)	20	20	30	50
Continuous Flow (gpm)	15	15	20	30
Normal Flow Range (gpm)	1-20	1-20	2-30	3-50
Low Flow (gpm)	1/4	1/4	1/2	3/4
Maximum Working Pressure (psi)	150	150	150	150
Maximum Working Temperature (°F)	122	122	122	122
Length (A below)	7-1/2"	7-1/2"	7-1/2"	10-3/4"
Width (B below)	3-3/4"	3-3/4"	3-3/4"	4-1/8"
Width, side-mounted DIALOG unit	4-1/2"	4-1/2"	4-1/2"	4-1/2"
Height, standard register with lid (C below)	4-1/8"	4-1/8"	4-1/8"	3-7/8"
Height with DIALOG register	4-7/8"	4-7/8"	4-7/8"	4-5/8"
Height, Frost Proof, standard register with lid 4-3/8" (F below)	4-3/8"	4-3/8"	4-3/8"	4-3/8"
Height, bottom to center line (D below)	1-3/16"	1-3/16"	1-3/16"	1-3/16"
Height, Frost Proof, bottom to center line (G below)	1-3/4"	1-3/4"	1-3/4"	1-3/4"
Meter Casing Spuds, Nominal Thread Size* (E below)	3/4"	1"	1"	1-1/4"
Weight (lbs)	3.6	3.7	3.6	5.25
Packed To Carton	6	6	6	4
Carton Weight (lbs)	23	23.6	23	22.4

*External Straight Threads



Head Loss Curves



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©2006 Master Meter, Inc. All rights reserved. DIALOG and Master Meter are registered trademarks of Master Meter, Inc. Master Meter reserves the right to make modifications to the products described herein at any time and without notice. U.S. Patent No. 6,819,292, Patent No. 6,954,178. Others pending. EnviroBrass® is a registered trademark of ASARCO.

MMDS_MJ-58341 Rev11/01/06

Residential Use

CD SD PLUS MID WATER METER



Single Jet Super Dry Dial Magnetic Drive Water Meter

CD SD PLUS is the latest range of Super Dry single jet water meters by Maddalena. CD SD PLUS meters utilize a magnetically driven dry dial design.

They comply with the strict requirements of the Directive 2004/22/EC on measuring instruments and European Standard EN 14154. CD SD PLUS meters combine high performance at low flow rates and maximum resistance to high flow rates and pressure. CD SD PLUS meters are designed for remote communication: a pulse emitter and an M-Bus or radio module may be retrofitted maintaining the mechanical and metrological features and without affecting readability.

CD SD PLUS meters are guaranteed by Maddalena: manufacturer of high quality measuring instruments for a century.

CD SD PLUS MID WATER METER

CD SD PLUS is a Super Dry single jet water meter. CD SD PLUS utilizes a magnetically driven dry dial design and is suitable for use with either cold (T50) or hot (T30/T90) water. The impeller is the only part in contact with the water, thus ensuring readability with scaling water or with water containing small debris or sand particles.

CD SD PLUS water meters comply with Directive 2004/22/EC (Annex MI-001) and have undergone conformity assessment procedure B + D. The maximum measuring range Q3/Q1 (R) certified is 100 for horizontal position and 50 for vertical position.

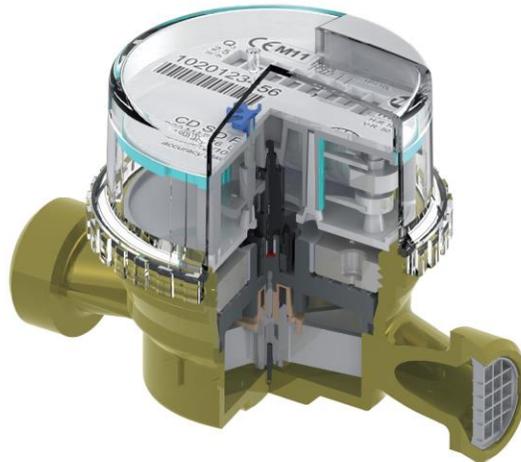
CD SD PLUS come also pre-equipped to retrofit a pulse emitter. The pulse emitter may be fitted maintaining the meter's standard features and without affecting readability.

CD SD PLUS water meters are certified for use with potable water in accordance with Italian and international regulations.



Specifications

- Meters comply with Directive 2004/22/EC (Annex MI-001) **(1)**
- Hot forged brass body
- **Dual pivot** for balanced impeller rotation under any flow rate and installation conditions. Pivots are made of non-magnetic, AISI 316 stainless steel
- Inlet strainer with wide straining area
- **Protection against external magnetic fields**
- Internal adjusting device
- Internal components are made of anhygroscopic, anti-scaling and hard-wearing resistant plastic materials
- Protective cover available as an option
- Nominal pressure (PN): 16 bar
- Installation: horizontal or vertical
- **No upstream and downstream straight pipe requirements**
- Maximum water temperature: 50 °C or 90 °C
- **The serial number is marked on the dial both in numbers and in bar code format (2)**
- Water meters also come pre-equipped to retrofit a pulse emitter **(3)**
- Hydraulic tests are carried out at three flow rates (Q1, Q2, Q3) on 100% of the production. Our testing benches comply with ISO 4064/3 and ISO 4185 (EN 14154/3) Standards and are approved by a European notified body
- A non-return valve fitted into the coupling comes as an option



HYDRAULIC PERFORMANCE

SIZE	mm	15	20
	in	½	¾
Module B no.	TCM 142/10-4794		
Module D no.	0119-SJ-A010-08		
MID metrological class	R (Q3 / Q1) ≤ 100 H - ≤ 50 V		
Performance data in accordance with Directive 2004/22/EC			
Q ₃	m ³ /h	2.5	4.0
Q ₄	m ³ /h	3.13	5.0
R100			
Q ₁	l/h	25.0	40.0
Q ₂	l/h	40.0	64.0
R80			
Q ₁	l/h	31.25	50.0
Q ₂	l/h	50.0	80.0

R options available upon request

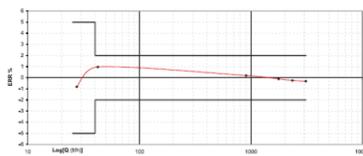
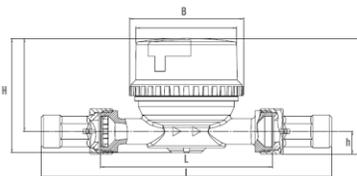
TECHNICAL SPECIFICATIONS

Maximum permissible error between Q ₁ and Q ₂ (excluded)	+/- 5%		
Maximum permissible error between Q ₂ (included) and Q ₄	+/- 2% with water temperature ≤ 30° C +/- 3% with water temperature > 30° C		
Temperature class	T50 and T30/90		
Flow profile sensitivity classes	U0 - D0 (no upstream and/or downstream straight lengths requirements)		
Starting flow rate	l/h	10	12
Pressure loss class (ΔP @ Q ₂)	bar	ΔP 63	ΔP 40
Nominal pressure	bar	16	16
Maximum reading	m ³	100,000	100,000
Minimum reading	l	0.05	0.05
Turbine revolutions per litre		41.33	29.76
Pulse pre-equipment (available as an option)	l/pulse	10	10
Weight	kg	0.45	0.50

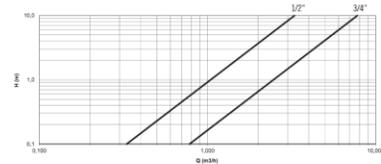
DIMENSIONS

L	mm	80-100-110-115-120	115-130
Length with couplings	mm	160-180-190-195-200	228
H	mm	73.2	73.2
h	mm	14.5	14.5
B	mm	72.8	72.8

Typical error curve



Headloss diagram



ACCESSORIES



SINGLE REED SWITCH PULSE EMITTER

Available separately or paired with a CD SD PLUS water meter.
Also compatible with CD SD 8 meters (EEC approved).



ARROW RADIO MODULE

Paired with a pulse emitter for the remote reading of a water meter.



COMPACT RADIO MODULE

Compact radio module with inductive sensor (CD SD EVO).



M-BUS MODULE FOR TWO METERS

Designed for the remote reading of meters via M-Bus.
Equipped with two pulse inputs.



NON-RETURN VALVE

Fitted into the coupling; designed to stop reverse flow
that may damage the water meter.



COUPLING KIT

It consists of two nuts, two tail pieces and two gaskets (couplings with
built-in non-return valve are available on DN 15 mm meters).



SEALS

Designed to secure the water meter to the pipe.

For more information on the accessories please refer to the relevant data sheet.

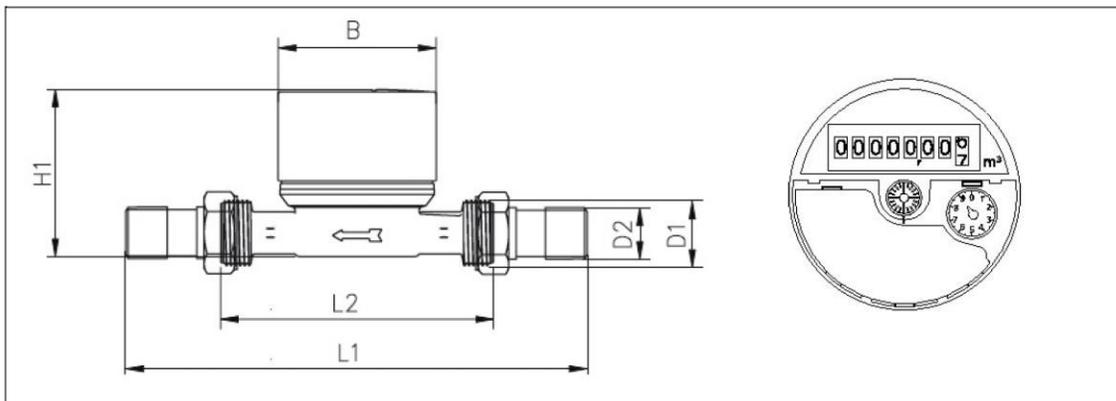
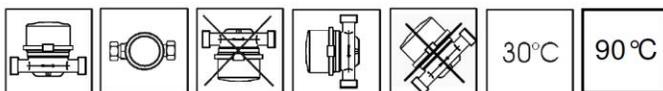


ISO 9001 - Cert. n° 0773/5



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For more information, please contact your sales representative:



Besondere Eigenschaften ETK-M/ETW-M

Aufputzzähler Einstrahl-Trockenläufer mit Optionszählwerk, bewährt durch millionenfachen Einsatz weltweit.

Für Durchflüsse bis $Q_3 = 2,5$ bieten wir unseren Einstrahlzähler an. Er hat einen sehr niedrigen Anlaufwert und ist horizontal und vertikal einbaubar.

Die kompakte Bauform des Volltrockenläufers ermöglicht es, den Zähler auch in schwierigen Einbaustellen zu verwenden. Sein 8-Rollenzählwerk garantiert richtige Ablesergebnisse.

Für Kaltwasser bis 30°C Wassertemperatur kommt unser ETK-M zum Einsatz. Alternativ ist für Temperaturen bis 90°C die Warmwasservariante ETW-M lieferbar.

Leistungsmerkmale im Überblick:

- Innovatives Zählwerk mit Modulooption zur Funktionserweiterung
- Ideal als Aufputzzähler für die wohnungsweise Verbrauchserfassung
- Variante für Kaltwasser bietet Sicherheit bis 50°C
- Variante für Warmwasser bietet Sicherheit bis 90°C
- Für waagerechten und senkrechten Einbau (horizontal und vertikal)
- MID konform

Special characteristics ETK-M/ETW-M

Surface-mounted single-jet dry dial meter with modular counter, proven through worldwide use of million times over

Our single-jet is suited to flow rates of up to $Q_3 = 2,5$. This meter has a very low starting value and can be installed horizontally and vertically.

The compact design of the dry meter allows it to be installed in confined or hard-to-reach places. Its 8-digits roller counter guarantees correct readout results.

Our ETK-M can be used for cold water up to 30°C. The hot water version ETW-M is an alternative for temperatures of up to 90°C.

Performance characteristics in overview:

- Innovative counter with modular options for extending functions
- Ideal as a surface-mounted meter for consumption metering per apartment
- The cold water model offers safety up to 50°C
- The warm water model offers safety up to 90°C
- For horizontal and vertical installation
- According to MID standard

Technische Daten / Technical data

ZENNER®

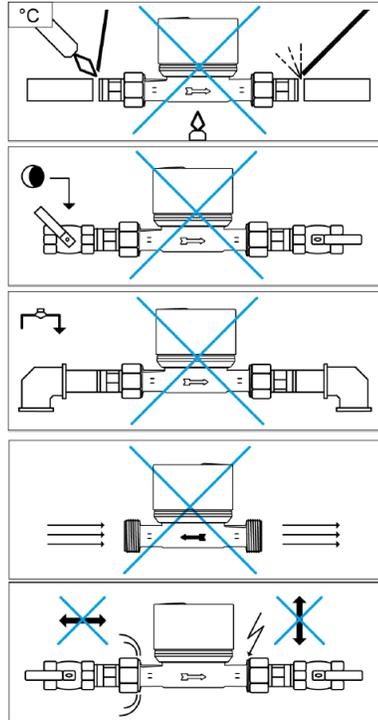
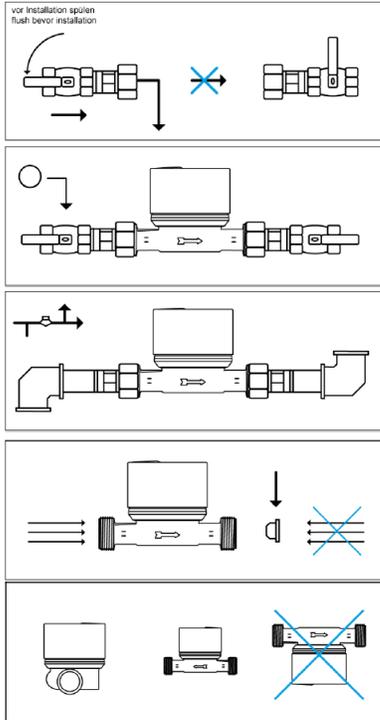
Einstrahl-Trockenläufer für Kalt- und Warmwasser / Single-jet dry dial meter for cold and hot water

Nenndurchfluss Nominal flow	Q ₃	m ³ /h	1,6				2,5
Anschlussweite Nominal diameter	DN	mm	15	15	15	20	20
		Inch Zoll	1/2	1/2	1/2	3/4	3/4
Überlastungsdurchfluss Maximum flow	Q ₄	m ³ /h	2				3,125
Mindestdurchfluss Minimum flow	Q ₁	l/h	20				31
Messbereich horizontal /Measuring range horizontal*	Q ₃ /Q ₁	Ratio	R 80 H				R 80 H
Messbereich vertical/Measuring range vertical*	Q ₃ /Q ₁	Ratio	R 25 V				R 25 V
Anlauf Starting flow	l/h	l/h	12				22
Anzeigebereich Display range	min	l	0,05				
	max	m ³	99.999				
Maximale Temperatur Maximal temperature	-	°C	30/90				
Betriebsdruck Operating pressure	PN	bar	10				
Druckverlust Pressure loss		bar	1				
Impulswertigkeiten Puls-rate available		l/Imp.	1 L				
Höhe Height	H1	mm	74				74
Breite Width	B	mm	64				
Baulänge Overall length	L2 without connectors	mm	80	110	115	130	130
	L1 With connectors	mm	160	190	195	228	228
Gewicht / Weight	-	kg	0,42	0,42	0,45	0,52	0,52

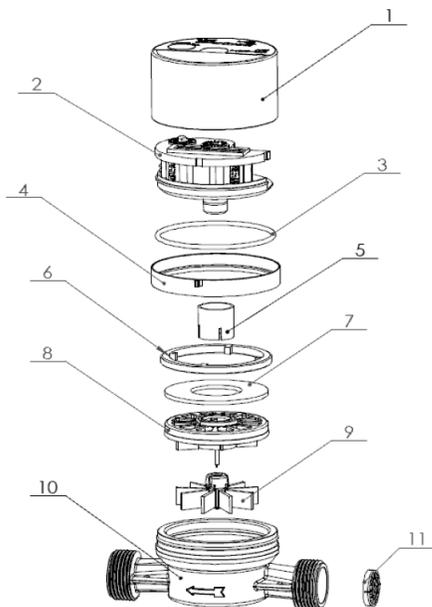
Standardausführung R50H / R25V
Standardversion R50H / R25V

Einstrahl-Trockenläufer für Kalt- und Warmwasser / Single-jet dry dial meter for cold and hot water

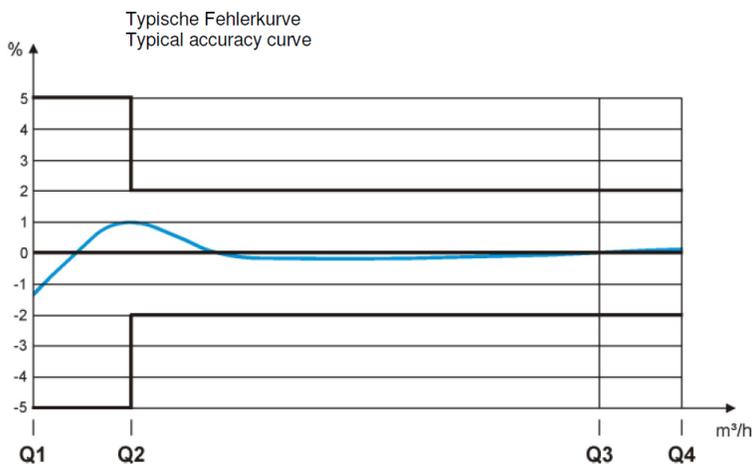
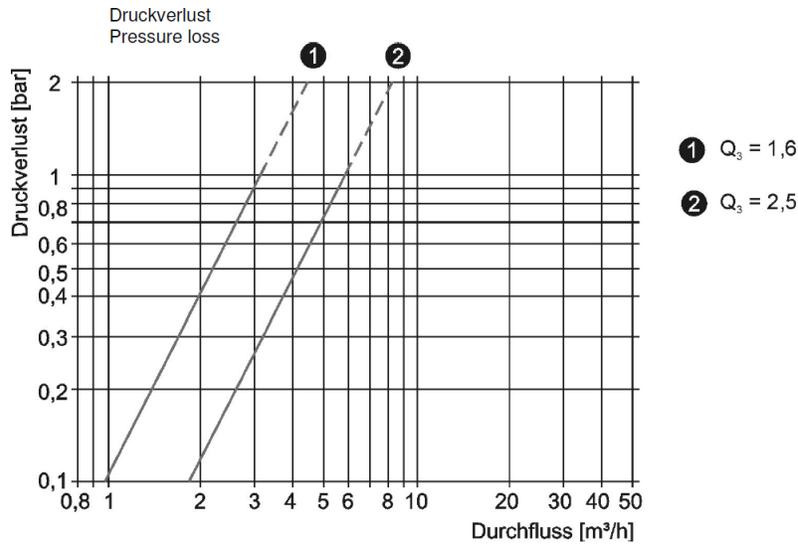
Installation von Einstrahl-Wasserzählern
Installation of single-jet water meters, recommendation



ETK-M/ Q3 1,6 – 2,5



- | | | |
|----|----------------|----------------------|
| 1 | Haube | hood |
| 2 | Zählwerk | counter |
| 3 | O - Ring | o-ring |
| 4 | Sicherungsring | safety - ring |
| 5 | Stahlring | antimagnetic - ring |
| 6 | Gewinding | threaded lock - ring |
| 7 | Stahlscheibe | washer |
| 8 | Druckplatte | pressure plate |
| 9 | Flügelrad | impeller |
| 10 | Gehäuse | body |
| 11 | Sieb | strainer |



Lower measurement range Q1 – Q2	Upper measurement range Q2 – Q4
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www.zenner.com

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