City of Thunder Bay

Business Case for AMI/AMR Implementation

Findings and Recommendations Report

November 26, 2024

Diameter Services

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ACRONYMS AND TERMS

Exhibit 1: Summary of Acronyms and Terms

Term	Abbreviation	Definition
Absolute Encoder		A type of water meter register where the remote and visual reading are referenced from the same source. This ensures that the remote and visual readings will be synchronized.
Acoustic Leak Detection	ALD	Sensors that can be deployed throughout a water distribution network to listen for and create acoustic profiles that identify leak conditions. These sensors are physically attached (using ties or magnets) to water mains, valves, or hydrants. Typically, these sensors measure the amplitude and pitch of the sound in a pipe and compare these measurements to known profiles to identify anomalies. Sometimes called Leak Loggers.
Advanced Metering Infrastructure	AMI	A system that employs a network of collectors, permanently mounted throughout the service area to capture meter readings that are transmitted by radio frequency. Generally, hourly meter readings are captured daily using an AMI system.
Alert		An indication from a system that an anomaly has been detected. Alerts may be visual or audible, and may initiate automatic notifications such as pager, text, or email messages.
American National Standards Institute	ANSI	A private organization that develops and administers standards for various industries, including the allowable level of lead in drinking water infrastructure.
American Water Works Association	AWWA	An international non-profit, scientific and educational association founded to improve water quality and supply. The parent AWWA is managed by geographic “sections” including Ontario Section and Western Canada Section.
Application Program Interface	API	A set of routines, protocols, and tools for building software applications. APIs specify how software components should interact and enable easier integration or linkage between different software components.

Term	Abbreviation	Definition
Automatic Meter Reading	AMR	A system that uses meter readers who walk or drive through neighborhoods to capture meter readings via radio frequency transmissions from meters that are assigned to meter reading routes. Generally, meter readings are captured on a monthly, bi-monthly, or quarterly basis using mobile AMR.
Backflow		The reversal of water flow in which water or other substances from a residential, industrial, or institutional piping system flows back into the water distribution system.
Bring Your Own Device	BYOD	The practice of allowing the employees of an organization to use their own computers, smartphones, or other devices for work purposes. In the utility context this may also include the practice of using a single smart device for multiple applications including meter reading.
Building Control Valve	BCV	A water shut-off valve installed before the meter so the water entering the building can be shut-off.
Change-out	C/O	Used in connection with either a large or small meter change-out/replacement.
Customer Information System	CIS	The Utility's system, whether on-premises or cloud-based, to manage information relating to its customer base. Typically, the CIS includes the ability to calculate customer bills.
Customer Portal		A web browser and/or mobile application that provides access to customer-specific water usage and other related data. Some portals provide functionality such as bill payments, alert settings, notifications, and usage profiling. Also called a Web Portal.
Cut-In	C/I	Where a meter has never been installed and the plumbing requires modification to allow for the installation of a water meter.
Cybersecurity		Measures implemented to protect an information management system and network from unauthorized access, damage, or attack. Common examples include password protected computers, encryption, and use of anti-virus software.
Dashboard		A visual summary of key data points provided on a single screen enabling users to view key metrics at a glance.

Term	Abbreviation	Definition
Data Collectors		A range of mobile or fixed devices capable of receiving and storing meter reading and other remotely transmitted data. Includes Handhelds, Gateways, Collectors.
Distribution system		Networks of storage tanks, valves, pumps, and pipes that transport finished water to customer connections.
District Metered Areas	DMA	A discrete part of a water distribution network. Water flowing in and out of the DMA is strictly controlled and metered to calculate a system balance and determine water loss.
Electromagnetic Flow Meter (aka Mag Meter)		Non-mechanical water meters that use electronics to generate a magnetic field inside a pipe. Electromagnetic water meters measure the voltage induced due to movement of water through a magnetic field. The amount of voltage induced is proportional to the velocity of the water.
Federal Communications Commission	FCC	US Federal agency responsible for regulating telecommunications including radio frequency systems.
Fire Service	FS	A category of water meters designed to measure water flow for both domestic use and fire protection systems. Fire service meters can utilize turbine, compound, or ultrasonic metering technologies.
Fixed Network	FN	See AMI definition.
Geospatial Information System	GIS	A system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data. Also called Geographic Information System.
Global Positioning System	GPS	A satellite-based system that enables two- or three-dimensional positioning of objects on a map. GPS Coordinates enable location represented by Latitude, Longitude and optionally Elevation.
Green House Gas	GHG	The primary greenhouse gases in Earth's atmosphere are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). We tend to focus on the harmful types of Green House Gases – primarily CO_2.
Handheld		A portable computing device used by field service personnel to capture meter reading and other data.

Term	Abbreviation	Definition
Head End System	HES	The system that receives data from Data Collectors. Manages the data and sends it to other systems such as the CIS.
Hydraulic Modelling		A process in which a water distribution system is modeled using physical attributes and equations. The model projects key parameters including the flow rate, pressure, and capacity of the system.
Industrial, Commercial & Institutional	ICI	A type of water consumer, who typically uses large volumes of water for non-residential purposes such as businesses, schools, hospitals, and factories.
Information Management		The processes involved in the collection, storage, access, and visualization of information. In the context of an SRS, information includes the raw data generated by SRS surveillance components, alerts generated by the components, ancillary information used to support data analysis or alert investigations, details entered during alert investigations, and documentation of Water Contamination Response activities.
Intermediate Meter	IM	Water meters with sizes of 1.5” and 2”.
Large Meter	LM	Water meters with sizes of 3” and larger.
Latency		The amount of time that is added into a process based on delays in gathering information. For example, when meters are read monthly in a mobile AMR system, there is a latency of about 30 days in capturing the meter readings.
Lead Service Line	LSL	Water services that use lead piping to deliver water. Often broken into distribution-side and customer-side depending on whether the lead piping is the responsibility of the utility or the consumer.
Managed Services		The practice of outsourcing day-to-day business functions as a method of improving operational efficiency and reducing operational costs.
Mechanical Meter		Any meter that converts the mechanical force of water into a rotation of a measuring element that is calibrated to determine water volume. Examples include positive displacement, turbine, propeller, or compound types of flow meters.

Term	Abbreviation	Definition
Meter Data Management	MDM	A software system that performs long-term data storage and management for the vast quantities of data delivered by smart metering systems.
Meter Installation Software	MIS	Software that captures the details of the installation including meter serial #, transmitter identification #, account information of where the equipment was installed.
Net Present Value	NPV	Calculation of the value of an investment throughout its lifetime, discounted to today's dollars.
Network		The collection of devices deployed throughout the service area to collect data from transmitters.
Network-as-a-Service	NaaS	A method of AMI system deployment and management that enables the user to access the network via a subscription.
Non-Revenue Water	NRW	Water that is pumped into a distribution system, but not billed to its intended user. The Water Audit table below identifies the sources of Non-Revenue Water.
On-Demand Reading		A request by a data consumer to capture a current meter reading for a given water meter.
One-way communications		A communications path that only allows the flow of data in one direction. Also referred to as unidirectional or simplex communications.
Open Standard Communications Network		Provides an open architecture concept which expands the market of wireless devices that can operate over an AMI communication network. Examples of Open Standard Networks include LoRaWAN, Wi-SUN and Narrowband IoT. These networks are becoming increasingly common with lower energy requirements and increased coverage.
Positive Displacement	PD	A classification of mechanical meters including nutating disc and oscillating piston designs that measure water usage by capturing a specific volume of water and then counting the number of times the volume is filled and emptied.
Public Sector Accounting Board	PSAB	Established accounting standards for the public sector in order to report on the financial condition of various asset classes, including drinking water infrastructure.

Term	Abbreviation	Definition
Propagation Study		A map that is used to estimate the number and optimal locations of collectors required to provide network coverage for a given service area. The study will normally account for topography, density of transmitters, collector height, RF signal strength, clutter (such as buildings or trees) and other factors that can affect RF transmissions. Also called a "Prop Study".
Radio Frequency	RF	Certain electromagnetic wave frequencies that may be used as a form of communication between two or more devices. Generally categorized as licensed or unlicensed depending on the level of regulation by the FCC.
Radio Transmitter		A radio device connected to the water meter to provide meter readings for either an AMR or AMI system.
Real time		A mode of operation in which data describing the current state of a system is available in sufficient time for analysis and subsequent use to support assessment, control, and decision functions related to the monitored system.
Register		For an electromechanical meter, the device, typically at the top of the water meter that converts motion of the measuring element into units of volume. The register provides a visual and/or remote indication of the amount of water that has flowed through the measuring element.
Remote Turn On / Off		The act of remotely disconnecting or reconnecting service through a network by means of actuating an on-premises valve. Also called "remote shut off" or "remote disconnect".
Remote Shut-off Valve (aka Remotely Controlled Valve)	RSV	Allow a utility to shut off or turn on water service at a customer or premise from the information management system. These valves could aid Water Contamination Response. response action. An action taken by a utility, public health agency or another response partner to minimize the consequences of an undesirable water quality incident. Response activities may include issuing a public notification, changing system operations, flushing the system or other actions.

Term	Abbreviation	Definition
Simple Payback		A method for calculating how long it will take to recoup an investment's cost without considering the time value of money.
Small Meters	SM	Water meters with sizes from 5/8” to 1”.
Software-as-a-Service	SaaS	A method of software delivery and licensing in which software is accessed online via a subscription, rather than bought and installed on individual computers.
Supervisory Control and Data Acquisition	SCADA	SCADA systems collect data from important assets and their immediate environments. That data is displayed on a central computer screen available to technicians and managers.
Sustainability		The degree to which the benefits derived from the project justify the cost to implement and maintain the system.
Tampering		Unauthorized handling or damage of an AMI meter.
Theft		Unauthorized use of water.
Threshold		A value that is compared against current or recent data to determine whether conditions are anomalous or atypical of normal operations.
Drinking Water Service Area	DWSA	The City of Thunder Bay’s DWSA encompasses urban and semi-rural areas. A map is included in Appendix A – Map of Thunder Bay’s Drinking Water Service Territory.
Two-way Communications		A communications path that allows the flow of data in both directions. Also referred to as bi-directional or duplex communications. For AMI, this means that in addition to data being sent from the radio transmitter to headend system, the commands or queries can be transmitted from the head-end to the radio transmitter. A visually oriented interface that allows a user to interact with an information management system. A user interface typically facilitates data access and analysis.
Ultrasonic Meter		Non-mechanical water meters that send an ultrasonic wave through the fluid using two or more transducers to measure the velocity of the water and infer a volume.

Term	Abbreviation	Definition
Virtual Disconnect		A method of simulating a disconnection of service by monitoring the metered usage and setting an alert if a usage threshold is exceeded.
Water Audit		A method of identifying possible sources of water loss. The AWWA and IWA developed a water audit tool that systematically breaks sources of water loss into its components to facilitate evaluation and remediation. See Non-Revenue Water.
Water Meter		A device used to measure the consumption of water through a water line. Primary components of the water meter include the meter body, measuring element and the register.
Work Type		A term used to categorize tasks that will need to be done to enable each water meter to communicate using the proposed technology.

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1. EXECUTIVE SUMMARY AND DISCUSSION

1.1. Executive Summary

This report provides an analysis of the City of Thunder Bay's current water metering and meter reading practices and provides justification and recommendations for the upgrade of these practices. Specific focus was placed on the impacts on customer service, operational efficiency, and financial outcomes.

1.2. Discussion

The City of Thunder Bay provides drinking water and wastewater services to the community through a network that includes 37,990[1] water meters. These water meters provide the primary billing input that allows the City to determine volumetric charges for both water and wastewater services. The City of Thunder Bay invoices its customers quarterly in a combined bill that includes fixed and volumetric charges for both water and wastewater.

To determine the optimal approach to optimizing the metering system, various scenarios were evaluated including the following:

- Scenario 0: Remote Manual Reading by manually connecting to the meter from outside the customer's premises, similar to what is currently done.
- Scenario 1: Implement Automatic Meter Reading (AMR) By adding a radio frequency communication device to each meter which will be read by a vehicle equipped with a remote reader driving through the community to collect readings.
- **Recommended:**
  Scenario 2: Implement Advanced Metering Infrastructure (AMI) A much greener approach includes adding a network of communicators that transmit readings remotely to a central system completely owned and maintained by the City. This system automatically collects data, reduces meter reading costs, and reduces the health and safety risk associated with driving through the City.
- Scenario 3: Implement Advanced Metering Infrastructure (AMI) that would enable meters to be read using cellular communications. This approach reduces the need to maintain the data collection network but incurs additional operating expenses for cellular usage. This system depends on a third-party Cellular provider as well as some Corporately owned equipment.

After thorough consultation with City subject matter experts, Diameter Services recommends the implementation of Scenario 2. This option upgrades existing metering with an advanced metering system that will capture consistent and accurate readings thereby increasing revenue, and customer satisfaction by eliminating the need to call in readings or receive estimated billing. This option also

[1] As of December 31, 2023. Excludes inactive services.

makes it possible to provide enhanced water usage and billing information to customers through a web-based platform, further supporting the corporate digital strategy.

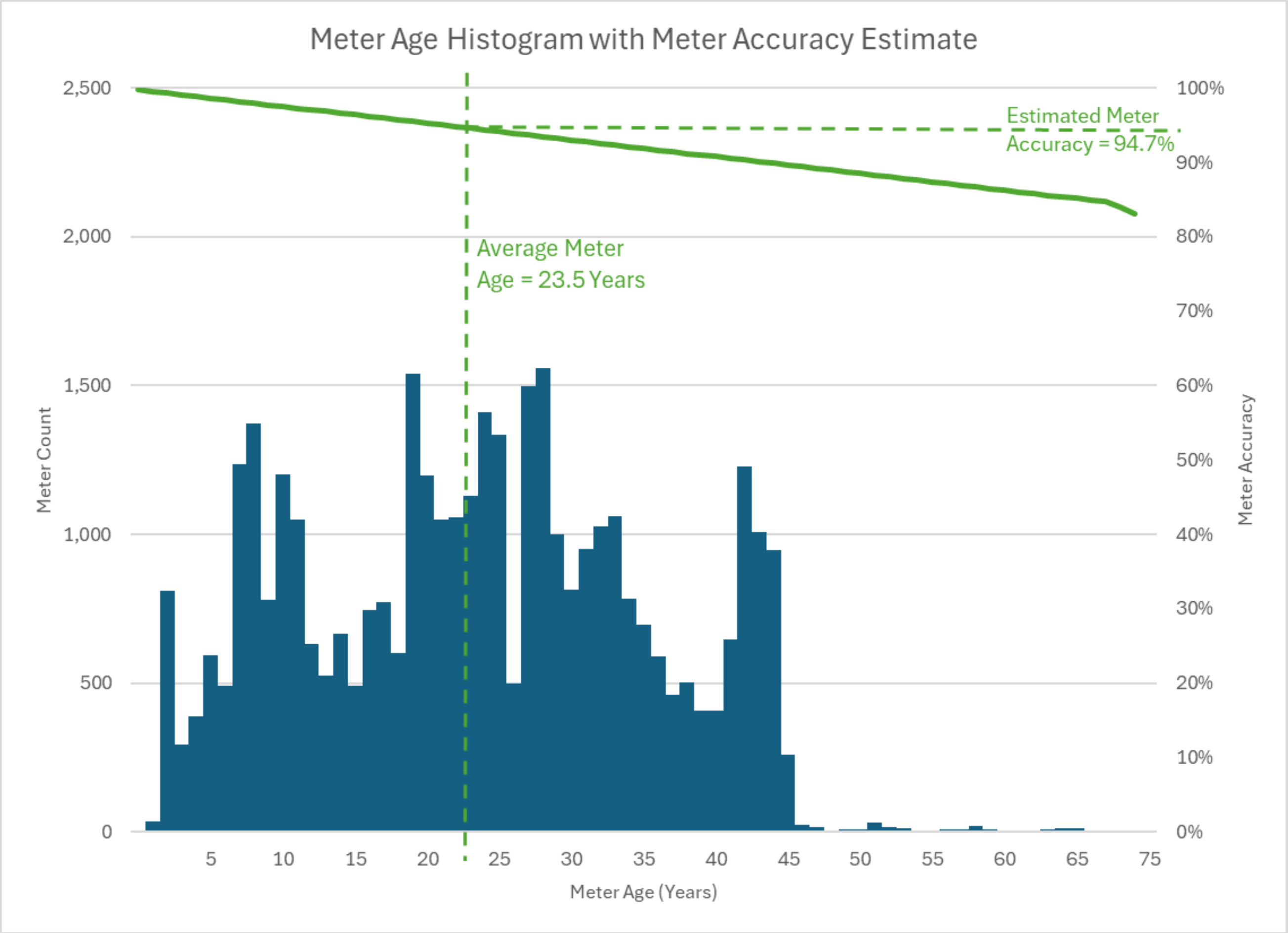
1.2.1. Meter Age

The average age of meters in the City of Thunder Bay's system is 23.5 years, with more than 4,700 meters over 40 years old. Industry practice is to replace meters when they reach 15 to 20 years of age.

Meters purchased prior to 2002 were manufactured with bronze alloy that contained 5% to 7% lead. The City's installed base includes 20,459 or 54% of its meters that contain higher levels of lead than are allowed under current regulations and should be removed from service.

Mechanical water meters, such as those currently in use by the City of Thunder Bay, degrade over time, resulting in under-registration and under-billing of water consumed. A conservative estimate of meter accuracy reveals that the City is losing $1.5 million per year in combined water and wastewater volumetric charges. This value increases with every year that these meters are left in service.

Exhibit 2: Meter Age Histogram with Estimated Average Accuracy



Generally, water meter registers cost about 60% of the cost of a completely new meter. When competitive pricing is obtained through the procurement process, if the cost of registers is higher relative to the new meter cost, the City can opt to replace more meters.

1.2.2. Meter Technology

To increase future revenue and avoid revenue loss resulting from meter wear, non-mechanical meters using either ultrasonic or magnetic flow technologies, are recommended, as opposed to the mechanical meters that are currently in use. These technologies are proven and provide a range of advancements that help to future-proof the City of Thunder Bay's investment.

1.2.3. Meter Reading

All of the City of Thunder Bay's meters are installed indoors with only 21% equipped with remote receptacles that enable them to be read without entering the premises. As a result, customers are largely responsible for submitting their own meter readings. Of the 150,000 quarterly bills issued in 2023, only 18% were generated based on a City-captured actual reading of the meter. It is industry practice to strive to capture actual readings for nearly 100% of all meters.

The fact that meters are largely read by customers adds a service burden to those customers, especially those who may have difficulty accessing the meter.

In addition, without the ability to read the meters, the City is unable to confirm that the meter has been read correctly.

1.2.4. Customer Service Benefits

One of the key benefits that customers will receive from an AMI system is the elimination of surprise bills. Under an AMI system all water meters communicate their hourly readings each day, providing greater visibility to leaks and unusual consumption that might otherwise result in a high water and wastewater bill.

1.2.5. Facilitation of Monthly Billing

Many water utilities make the decision to move to monthly billing, as monthly billing helps households manage their expenses more effectively. Smaller, more frequent bills are easier for most customers to handle than larger, quarterly bills, which may cause financial strain.

With monthly bills, unusual consumption patterns which could indicate leaks, are identified sooner. This allows both utilities and customers to address leaks quickly, preventing wasted water and higher bills.

While a decision to move from quarterly to monthly billing will be made independent of the decision to implement AMI, by implementing an AMI system the City of Thunder Bay will facilitate this change as no new staff will be required to read meters once AMI is deployed.

1.2.6. Affordability

In 2023, the City of Thunder Bay produced, treated, and pumped 16.1 million m^3 of water. Of that, only about 2/3 (10.7 million m^3) was billed to the consumer. The other 1/3 of the water produced was lost due to leakage, meter inaccuracy, unmetered usage, and other causes. Until the City of Thunder Bay takes steps to understand the causes of "Non-Revenue Water", it will be challenging to implement solutions to address this loss. Lost water effectively increases the rates that all customers pay for their water, so improving the efficiency of the system can have the impact of stabilizing rates over the long term.

AMI provides the City of Thunder Bay with data that enables tracking and troubleshooting of lost water.

1.2.7. Environmental

The City of Thunder Bay produced 16.1 million m^3 of water in 2023 and billed 10.7 million m^3 of that water, representing 5.4 million m^3 or 33% non-revenue water. Reducing this amount of lost water has significant environmental benefits for the City of Thunder Bay.

First, reducing water loss would allow the City of Thunder Bay to reduce its energy consumption. Water production, treatment, and distribution is a very energy-intensive activity, representing 33% of the City of Thunder Bay's consumption of natural gas and 53% of its electricity consumption in 2023.

Reducing energy consumption has follow-on benefits of reducing greenhouse gas emissions (GHG). The result of this energy consumption is an estimated production of 4,135 tonnes of CO_2 representing 38% of the City of Thunder Bay's total greenhouse gas (GHG) emissions[2]. For every 1 million m^3 of water produced and treated, almost 257[3] tonnes of GHG are generated.

Finally, reducing water loss effectively adds capacity to the City of Thunder Bay's treatment capabilities without the need for additional capital investment to support future growth and the needs of the community.

1.2.8. Financial Headlines

The total cost of an Advanced Metering Infrastructure deployment for the City of Thunder Bay is expected to be just under $23 million, which includes approximately $2 million in contingency to address unexpected costs for system hardware and installation.

A full analysis of the costs and benefits of each scenario showed that the recommended AMI technology would provide a simple payback of 12.5 years, which is well within the expected 20-year life of the system. Further, the net present value of this investment is expected to exceed $3.6 million, compared with a net present value of only $856 thousand for scenario 0 which is a continuation of the City's current meter reading practices.

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[2] City of Thunder Bay, "Energy Conservation & Demand Management Plan 2024", www.thunderbay.ca/en/city-hall/resources/Energy-Management/Thunder-Bay_ECDM-Report-Final_2024.06.19-signed.pdf, accessed October 15, 2024, pp. 14 & 17.
[3] Calculated based on 4,135 tonnes of GHG generated in the production of 16.1 million m^3 of water in 2023.

Project Capital Costs and Net Present Value	**Scenario 0 - Existing Manual Read Meters** With mechanical meter replacements over a 20-year period.	**Scenario 1 - AMR Drive-by** With non-mechanical meter replacements over a 2-year period.	**Scenario 2 - AMI (TB Owned)** With non-mechanical meter replacements over a 2-year period.	**Scenario 3 - AMI (Cellular)** With non-mechanical meter replacements over a 2-year period.
Financial				
Capital Costs	$12,261,355	$21,608,076	$22,954,033	$22,655,240
Payback (Years)	14.1	12.0	12.3	13.7
Net Present Value	$856,576	$3,943,271	$3,451,249	$732,967
Non-Financial				
Addresses 19 business drivers	No	Only 10/19 partially	Yes: 14 fully, 5 partially	Yes: 14 fully, 5 partially
Facilitates move to monthly billing	No	Partially	Yes	Yes

The recommendations from this report are summarized in section 1.2.9 Recommendations below and discussed in detail in section 12 Recommendations (2.2.20).

1.2.9. Recommendations

WITH RESPECT to the City of Thunder Bay's decision to automate its meter reading system, we recommend the implementation of Advanced Metering Infrastructure (AMI) technology that would be owned by the City;

AND THAT the radio transmitters used in the AMI system be Installed on the exterior wall of the buildings where possible;

AND THAT the City of Thunder Bay should implement an AMI system that is independent of local utilities Synergy North and Tbaytel due to technology limitations;

AND THAT the non-mechanical meters such as ultrasonic or magnetic flow meters be utilized for any future meter replacements;

AND THAT 33,491 water meters should be replaced, 4,499 existing meters should be upgraded with AMI-compatible registers, and any meters purchased since January 2024 should be retrofitted with an AMI radio transmitter;

AND THAT the AMI system be deployed at an accelerated pace of less than three (3) years from completion of procurement to project completion to maximize financial and customer service benefits;

AND THAT the procurement be managed through a request for proposals, not a bid or tender:

AND THAT the complete system be procured under a single, turnkey RFP that holds a single party accountable for the success of the installation and the performance of the system;

AND THAT the impacted City resources be deployed to other value-added activities within the City of Thunder Bay as the AMI system is deployed;

AND THAT the City of Thunder Bay's meter shop to be responsible for intermediate & large meters, while the contractor will be installing small meters;

AND THAT the City of Thunder Bay's Waterworks Bylaw 68-2018 Section 7.22 be amended such that the builder is responsible for wire run from the meter to the exterior wall of new construction;

AND THAT the City of Thunder Bay should continue to expand the use of the AWWA water audit software and its methodologies for water loss reduction;

AND THAT the City of Thunder Bay deploy a customer portal that supports full AMI functionality.

2. ORGANIZATIONAL AND PROJECT GOALS

2.1. Introduction

The City of Thunder Bay retained Diameter Services to review the City's current meter reading system and examined the benefits of upgrading to either an Automated Meter Reading (AMR) system or an Advanced Metering Infrastructure (AMI) system. The purpose of this engagement as stated in the City's RFP is "…is to prepare a Business Case Report that will inform the City's decisions regarding timing and implementation of an AMI/AMR system. The first priority upon undertaking this project will be to complete a comparative analysis that evaluates and recommends either an AMI or AMR based metering system.…"

A business case of this nature is most successful when:

1. **The goals identified in the business case align with the City of Thunder Bay's goals: The** City of Thunder Bay as a whole and the Water Authority itself has stated goals that can specifically align with the results of this project. The Business Drivers outlined in this report and their respective rankings will reflect Thunder Bay's desire to "modernize how it delivers services by taking advantage of digital technologies for both internal and customer facing services". The role of both AMR and AMI technologies in addressing those Business Drivers is discussed.

2. **Functionality of the system meets the needs of the Water Authority and the communities and citizens it serves:** Just because a technology allows for certain functionality does not necessarily mean it addresses the needs of a utility and the communities it serves. The AMR and AMI business driver assessment (ranking) allows Thunder Bay to identify those technology features that address the specific and relevant needs. Both AMR and AMI are assessed to show how well each technology meets the functional need.

3. **Capital cost estimate should match the real costs:** The capital costs used in the business case should include the full scope to successfully implement the recommended approach. This cost should be revisited as the City of Thunder Bay progresses through the technology upgrade process (i.e., after procurement and at key milestones during installation phase).

4. **Benefits should extend outside just the meter to cash process:** The business drivers need to look beyond the meter to cash process. This may include benefits to the City of Thunder Bay and to the customer that may be more difficult to calculate but offer improved efficiencies, service levels or societal benefits such as a reduction in CO_2 emissions.

Understanding existing challenges and establishing priorities is fundamental to benchmarking the success of any water meter replacement and meter reading technology review. It is important that the business case clearly show the expected impact to the customer as well as to the City of Thunder Bay.

As a part of this exercise, the City of Thunder Bay and Diameter Services looked beyond the meter reading and billing functions to discover some of the broader challenges faced by the City. This process provided the opportunity to address how an AMR or AMI system will help the City of Thunder Bay address these challenges.

Current challenges and opportunities present with the City of Thunder Bay include:

- System Capacity concerns
  - plant capacity
  - seasonal issues
  - potential impact on current and future growth
- Water loss / Non-Revenue Water (NRW)
  - unmetered water users
  - unauthorized water use is difficult to identify and enforce.
  - significant City of Thunder Bay work related to leaks and pressure
  - some users on flat rate billing
- Education
  - teach residents on water use, patterns, and learn about habits
- Reduce water bill estimates
  - currently over 50% of water bills are estimated
- Customer service
  - customers are unaware of leaks
  - customer reads are not called in
  - customers receive bills in the thousands of dollars to account for inaccurate estimates or changes in use.
  - aging population lacking internet access
- Staffing capacity
  - significant resources are used to address estimate issues, attend properties, and shut off services
- Opportunity to move to more frequent billing.
  - support monthly billing to manage customer payment and budgeting
  - faster receipt of revenue (cashflow)
  - identify issues faster (e.g. leaking plumbing fixtures)
  - minimize escalations to council / senior managers
- Timeliness of data and information
  - Near real-time
  - monitor portions of the distribution system (e.g. pressure)
  - efficient resource management
- Water efficiency and conservation support
- Time savings
  - less rework of bills and consumption
  - less staff time associated with manual meter reading
- Transparency and customer satisfaction

- Potential savings
  - reading and billing process
  - reduction in energy use from the reduction of non-revenue water
  - reduction in greenhouse gas emissions that will result from lower energy usage
- Data driven analytics

2.2. Organizational Goals and Strategies

The goal(s) of the project as outlined in the RFP included “aging and under-reporting meters, challenges in obtaining water meter readings from consumers, the inability to provide customers with detailed usage and leak detection information, and the inefficient use of staff time in obtaining reads and maintaining an aging system” were central themes in discussions with the City of Thunder Bay. These themes, either directly or indirectly, impacted virtually every aspect of this project including customer service, cost reduction and the ability to protect and maintain the City of Thunder Bay’s water source to name just a few examples.

The AMR/AMI business case project aligns with several of Thunder Bay’s corporate visions and strategies, as first mentioned in its Program and Service Review (2020) “The Automatic Meter Reading program (AMR) was mentioned in Phase One as an opportunity to raise efficiencies in meter reading and revenue recovery”.

A key exercise is to build alignment to the City of Thunder Bay’s existing strategic initiatives and how AMR/AMI can be strategically leveraged to support these plans. Strategic documents examined included:

- City of Thunder Bay Digital Strategy
- Climate-Forward City: Thunder Bay Net-Zero Strategy
- 2023 Annual Report Drinking Water Quality
- Maamawe, Growing Together City of Thunder Bay Strategic Plan 2023-2027

City of Thunder Bay Digital Strategy
From the Program and Service review, AMR technology was also identified in the Thunder Bay Digital Strategy report (2021) as part of the Digital Infrastructure workstream as a technology to adopt, subject to a business case review. The Digital Strategy report emphasizes the importance of customer focussed, efficient, accessible, digitally powered services. The development of the Digital Strategy was identified as a priority for City of Thunder Bay Council. The Digital Strategy includes a Vision for the City of Thunder Bay’s information; technology and digital programs and the project team examined the alignment of AMR/AMI with these visions resulting in 5 of the 5 visions aligning with AMR/AMI.

Vision	Description	Alignment with AMR/AMI Project
1	Collaboration is at the heart of digital success.	Yes

Vision	Description	Alignment with AMR/AMI Project
2	City Services to the community are the core of the City of Thunder Bay.	Yes
3	Providing efficient, accessible, easy-to-use, cost-effective and digitally powered services is of core importance.	Yes
4	The City should design its services around customers, not around internal needs.	Yes
5	The City intends to modernize how it delivers services by taking advantage of digital technologies for both internal and customer-facing services.	Yes

The Digital Strategy also included 5 main workstreams of which the project team determined a strategic alignment with AMR/AMI for all 5 workstreams.

Major Workstreams	Description	Alignment with AMR/AMI Project
1	Digital Workplace	Yes
2	Digitalized Business Processes	Yes
3	Digital Infrastructure	Yes
4	GIS Data and Analytics	Yes
5	Digital Services	Yes

The AMR/AMI project was also deemed to support the following areas identified in the Digital Strategy:

- Integrated technologies
- Multiple transactions from different departments
- End-to-end, real-time transactions
- Efficient, simple, and easy-to-use processes
- Modernizing the employee experience
- Data and information providing insights to improve efficiency and improve services.

Climate-Forward City: Thunder Bay Net-Zero Strategy
The project team examined the strategic links between AMR/AMI and the City of Thunder Bay's Net-Zero Strategy. The AMR/AMI project can help to support the Net-Zero Strategy in two fundamental areas:

Objective 16: Municipal water and wastewater processes are increasingly efficient, specifically E.31: 30% increase in water and wastewater pumping efficiency. AMR/AMI can support the City of Thunder Bay's priority action "identify opportunities to reduce energy use in water and wastewater pumping process".

2023 Annual Report Drinking Water Quality

Thunder Bay's annual Drinking Water Quality report (2023) commits the Thunder Bay Water Authority to operating and maintaining a safe, clean potable water supply to the Citizens of Thunder Bay. Part of the commitment includes "participating and encouraging water conservation initiatives." The project team deemed that the AMR/AMI project can help to support 3 of the 4 Quality Management System Policy commitments.

Commitments	Description	Alignment with AMR/AMI Project
1	Operating and maintaining a safe, clean, continuous potable water supply to the citizens of Thunder Bay	Yes
2	Meeting or exceeding applicable legislative and regulatory requirements	Yes
3	Participating in and encouraging water conservation initiatives	Yes
4	Implementing a Quality Management System consisting of policies, standard operating procedures, staff competency, and emergency contingency and response planning	N/A

Maamawe, Growing Together City of Thunder Bay Strategic Plan 2023-2027

Lastly, Thunder Bay's Strategic Plan 2023-2027 "Maamawe, Growing Together" provides a summary of City-wide values and promises that summarize the shared view of the City's future. The Strategic Plan contains 4 key pillars, Maamawe – Growing together, Safety and well-being, Growth, and Sustainability, which all contain aspects that are satisfied by this initiative. Perhaps most relevant to this project was the following statement under the growth pillar:

> "Implement better ways of serving the public that focus on continuous improvement and delivering positive outcomes for the City."

The project team deemed that the AMR/AMI project can help to support 3 of the 4 Values, 3 of the 4 Promises as well as 8 Strategic Directions and Goals.

Values	Description	Alignment with AMR/AMI Project
1	Accountability	Yes

Values	Description	Alignment with AMR/AMI Project
2	Continuous Improvement	Yes
3	Teamwork	Yes
4	Respect	N/A

Promise	Description	Alignment with AMR/AMI Project
1	Truth and Reconciliation	N/A
2	Safety and Wellbeing	Yes
3	Prosperity	Yes
4	Sustainability	Yes

Goal	Objective	Alignment with AMR/AMI Project
1 Growth	Facilitate the development of new housing supply options.	
2 Growth	Deliver customer-centered, digitally powered City Services as indicated in the Digital Strategy.	Yes
3 Growth	Implement better ways of serving the public that focus on continuous improvement and deliver positive outcomes for clients.	Yes
4 Safety and Well-Being	Deliver public education on climate action and climate resilience opportunities as identified in the Net Zero Strategy.	Yes
5 Sustainability	Invest in green and climate-resilient infrastructure to meet the long-term needs of our community.	Yes
6 Sustainability	Accelerate initiatives to reduce our greenhouse gas emissions.	Yes

Goal	Objective	Alignment with AMR/AMI Project
7 Sustainability	Identify the community services that are priorities and provide them at a level we can sustain.	Yes
8 Maamawe – All Together	Integrate Indigenous perspectives in City services, programs and places.	Yes

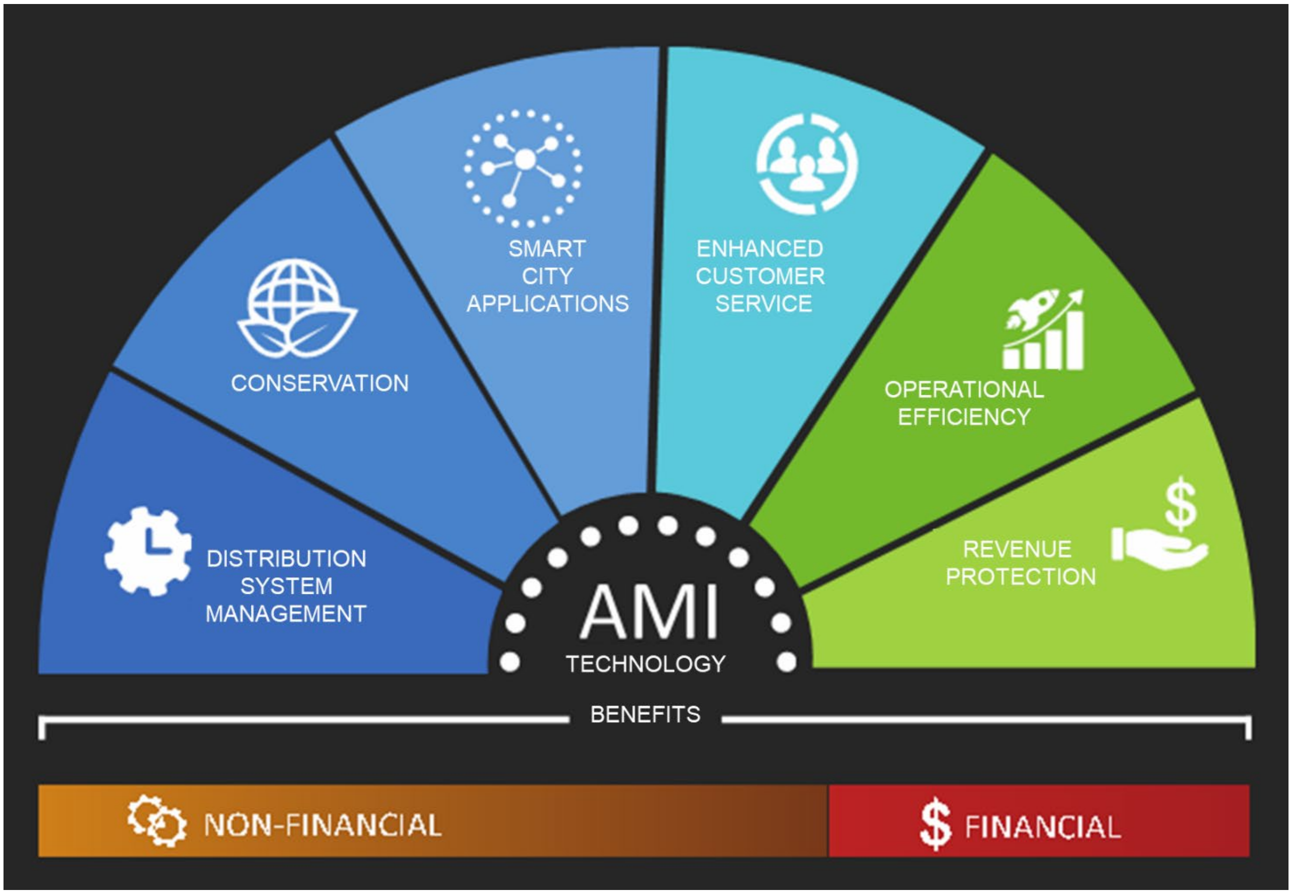
All of the previously mentioned challenges/opportunities in combination with the AMR/AMI alignment with existing goals and strategies form the justification of this project and contribute to demonstrating the value of this project.

3. BUSINESS DRIVERS

3.1. Connecting Project Goals with AMR/AMI Business Drivers

In collaboration with the City of Thunder Bay, the Diameter Services team reviewed, assessed and ranked 36 different AMI/AMR business drivers. To frame the overall analysis, Diameter Services has identified six categories where AMI/AMR technology can offer benefits:

Exhibit 3: Business Driver Categories



1. **Revenue Protection (RP)**

   Ability to identify areas of revenue improvement, reduce theft and tampering, respond more quickly to stopped meters, and an improved ability to apply the right meter technology to customer applications.

2. **Operational Efficiency (OE)**

   Improvements in response time to maintenance issues; reduced meter reading costs and hazards; reduced exceptions and estimated bills, and fewer additional trips into the field to collect data.

3. **Improved Distribution System Management (DS)**

Improvements in the utility's ability to manage its distribution system through district leak detection, dynamic water balance, system wide leak detection, discrete water quality monitoring and more efficient code enforcement.

4. **Enhanced Customer Service (CS)**

   Improvements in customer service through the ability to provide customers' consumption information, online access to consumption, alerts to avoid high water bills or damage, and customer leak detection.

5. **Societal Benefits (SB)**

   Improvements in water conservation and carbon emissions.

6. **Smart Utility/Smart City (SC)**

   Improvements to areas beyond water consumption by leveraging the network for other organizational needs. These use cases typically apply to local governments and might involve street light controls, wastewater collection monitoring, waste bin monitoring, or traffic monitoring.

3.2. Evaluating Business Drivers

AMI and AMR technology have different features and functionality. The movement to a specific technology should be driven by evaluating the importance of various business drivers and selecting the technology that best addresses those drivers. When features or functionality within the AMI/AMR technology address a challenge or improve delivery of water service, it is considered a **business driver.**

The Diameter Services team reviewed 36 different business drivers with Thunder Bay staff to determine the organization's needs and identify the best technology fit. The development and assessment of the business drivers provides a definition of the actions Thunder Bay should expect to implement, first by identifying what is important to the utility followed by matching the technology that supports these actions.

AMI/AMR technology will improve a water utility's operations in a number of areas; some can be easily calculated, while others will show a qualitative improvement in a respective area. AMI/AMR technology should be considered a tool that the utility uses to improve how the utility operates. As noted in the introduction, Thunder Bay currently has a combination of manually collected water readings, customer provided water readings, and a significant amount of water bills calculated on estimated consumption. The areas of improvement often do not have a direct financial improvement but are still critical to the utility achieving the broader goals of the organization.

To evaluate business drivers, Diameter developed a scoring system that allowed Thunder Bay to establish the importance of each business driver and by extension the goals of the project.

Importance to the water utility is defined and scored using the table below.

Exhibit 4: Business Drivers Score and Importance to the City of Thunder Bay

Score	Importance	Description
0	Not Important	The City will not implement the business driver in the future

1	Future	The City may implement the business driver
2	Important	The City will implement the business driver immediately
3	Essential	The City will implement the business driver immediately and it is critical to the project

AMI and AMR technologies function differently, have different operational impacts on the utility and provide different benefits partially due to the differences in data each provides. Depending on the technology, Thunder Bay will be able to either fully achieve, partially achieve, or in some cases do not achieve specific business drivers. This system of scoring is designed to accomplish two things. First it prioritizes those business drivers that are most important to Thunder Bay and secondly, it helps to define the technology alternatives that provide required functionality, which is key to developing cost/benefit results. The following criteria is used in this determination:

Exhibit 5: Scoring: Ability to Support the Business Driver

Score	Ability to Support the Business Driver	Description
○	Does not support a Driver	The business driver as described cannot be implemented using this technology.
◖	Partially supports a Driver	The business driver as described can be partially implemented using the technology.
●	Fully supports a Driver	The business driver as described can be fully implemented using the technology.

3.3. Business Driver Assessment Summary

A complete list of the business drivers and recommendation rationale are detailed later in this section which will describe the business drivers along with each technology's ability to achieve the goals of the driver.

As a preface to that in-depth discussion, and to provide a high-level overview of the workshop findings, an overview is provided below, which is designed to provide a quick snapshot of the business drivers and related priorities for the AMI/AMR project. Note that Diameter omits some drivers that, in consultation with the Thunder Bay project team, do not apply and therefore are not listed as a driver.

ID	Revenue Protections (RP)	Score
RP 1	Zero Consumption - Tampering	2
RP 2	Zero Consumption - Stopped Meter	1
RP 3	Zero Consumption (Turned off for Non-payment)	1
RP 4	Zero Consumption (Empty Pipe Alert)	2

RP 5	Run your Water' Accounts (Known frozen services)	2
RP 6	Detect Misapplied Meters	1
RP 7	Support for Leak forgiveness Program	2
RP 8	Water Meter Accuracy Decline - separate analysis	2
ID	**Operational Efficiency (OE)**	
OE 1	Reduce Regular Meter Reading Costs	3
OE 2	Same Day Final Reads / Re-reads	1
OE 3	Improve Meter Reading Safety	2
OE 4	Meter Reading Reliability - Reduce Re-reads	3
OE 7	Remote Turn-off / Turn-on	1
ID	**Improved System Distribution Management (DS)**	
DS 1	District Metering	2
DS 2	Water Balance Calculation Frequency	1.5
DS 3	Acoustics Leak Detection (ALD) - Main Break Monitoring - Drop and Place	2~~1~~
DS 6a	Detect Backflow Events (Residential)	1
DS 6b	Detect Backflow Events (ICI)	1
DS 7	By law Enforcement	1
DS 8	Pressure Monitoring (on a limited basis – 500 devices)	3
DS 9	Temperature Monitoring - Frozen Services	1
DS 10	Hydraulic Modelling	2
DS 12	Wastewater Monitoring	1
DS 13	Water Quality Monitoring	1
ID	**Customer Service Enhancements (CS)**	
CS 2	Customer Engagement - Interactive	3
CS 3	Customer Engagement - Progressive	3
CS 4	Leak Detection - Small	2
CS 5	Leak Detection - Broken Pipe	2
CS 6	Vacation Monitoring	0
CS 7	Customer Portal Adoption / Paperless Billing	3
ID	**Societal Benefits (SB)**	
SB 1	Conservation Program Support	2
SB 2	Climate Change - Reduced CO_2	3
SB 3	Climate Change - Reduced Energy	3

SB 4	Smart Water - Sewer System	1

The following provides a summary of the business driver assessment summarizing only those ranked as Important (Score of 2) or Essential (Score of 3).

ID	Revenue Protections (RP)	Score	AMI	AMR
RP 1	Zero Consumption - Tampering	2	●	◐
RP 4	Zero Consumption (Empty Pipe Alert)	2	◐	○
RP 5	Run your Water' Accounts (Known frozen services)	2	●	◐
RP 7	Support for Leak forgiveness Program	2	◐	○
RP 8	Water Meter Accuracy Decline - separate analysis	2	**N/A**	**N/A**
	Operational Efficiency (OE)			
OE 1	Reduce Regular Meter Reading Costs	3	●	◐
OE 3	Improve Meter reading safety	2	●	◐
OE 4	Meter Reading Reliability - Reduce Re-reads	3	●	◐
	Improved System Distribution Management (DS)			
DS 1	District Metering	2	●	○
DS 3	Acoustics Leak Detection (ALD) - Main Break Monitoring - Drop and Place	2	◐	○
DS 8	Pressure Monitoring (on a limited basis – 500 devices)	3	◐	○
DS 11	Hydraulic Modelling	2	●	◐
	Customer Service Enhancements (CS)			
CS 2	Customer Engagement - Interactive	3	●	◐
CS 3	Customer Engagement - Progressive	3	●	◐
CS 4	Leak Detection - Small	2	●	◐
CS 5	Leak Detection - Broken Pipe	2	●	○
CS 7	Customer Portal Adoption / Paperless Billing	3	●	◐
	Societal Benefits (SB)			
SB 1	Conservation Program Support	2	●	○
SB 2	Climate Change - Reduced CO2	3	◐	○
SB 3	Climate Change - Reduced Energy	3	●	○

3.4. Detailed Non-Financial Business Driver Assessment

Ref	Importance	Business	Driver & Description	Utility	AMI Technology Assessment
	Revenue Protection	**(RP)**			

RP1	**(2)
	Important**
		Zero Consumption - Tampering	Common sources of Unauthorized Use of Water:
			• Residential customers: removal of register head or meter (zero consumption for full days in the middle of a billing period).
			• Commercial customers: opening of authorized meter bypasses (zero or reduced consumption compared to other similar industries or previous consumption periods).
			AMI technology allows a utility to detect potential unauthorized water use in several ways:
			• Abnormal consumption: by way of detecting consumption (or a reduction in consumption) in accounts where the City of Thunder Bay would be expecting the opposite behavior. Examples include:
			  ○ A commercial property (for example a laundromat) that requires water to operate suddenly has zero consumption during peak times.
			  ○ A property is vacant and should be zero consumption but unexpectedly shows consumption.
			  ○ At a commercial property, the bypass is opened thereby reducing consumption through the meter.
			  ○ Empty pipe alarm (specific to Ultrasonic and Mag meters) – there is no water in the meter and an alarm is sent, typically with the next reading. This would be useful to identify cases where a meter has been removed from service. Empty pipe alarm (specific to Ultrasonic and Mag meters) – there is no water in the meter and an alarm is sent.
				Discussion Points:
				• Would there be any financial benefits or efficiencies with consumption-based algorithms?
				• Potentially capturing lost revenues due to tampers.
				• Alerts to property owner (high) or low consumption?
				
				Discussion Outcomes:
				• Unauthorized consumption – Multi-res example
				• Register removal, spacer – can be worse when time between billing and readings in relatively long (quarterly) as in Thunder Bay
				• Comments from the workshop: "Tampering is more prevalent than we know, but staff do not really have the authority to do much."
				• Opening bypass on ICI meters can result in a significant amount of lost revenue.
				• Remove the register and fill a pool as an example.
					AMR (PART) – AMR supports zero consumption flags that could be captured on a monthly basis. However, the AMR flag is limited and cannot support deeper analysis of consumption behavior.
					• Zero consumption is a binary Yes / No flag.
					• Limitation due to resolution.
					• Cannot determine patterns.
					
					AMI (FULL) – The utility can analyze consumption behavior and use anomalies to create special stopped meter or tamper reports to initiate action.
					• Hourly data reduces the need for "eyes on meters".
					• Can build algorithms to find certain types of consumption patterns.
					• Grouping function in software enables comparison of similar meters (e.g., carwashes, multi-residential applications).

RP2	**(1) Nice to Have**	**Zero Consumption - Stopped Meter**	• Positive displacement meter can become jammed and stop registering consumption, requiring replacement. • Applicable to residential, light commercial or the low side of compound meters used in high consumption ICI applications. • Impact will be greatest for ICI meters with Compound meters where the low side becomes inoperable.	**Discussion Points:** • What kind of meters failures occur? • Are these estimated when they are found? **Discussion Outcomes:** • 224 Stopped meters in 2023. • Due to City of Thunder Bay's current meter reading access issues, where only about 17% of meters are actually read by City staff each quarter, stopped meters can remain unidentified for multiple billing cycles, resulting in lost revenue and billing disputes. • Detect by reviewing billing journal to identify 0 consumption & stopped meters.	**AMR** (ZERO) - Resolves after the billing cycle. Lost revenue could be between 30 and X days. **AMI** (FULL) – Can set up a flag (e.g., 5-day) and potentially reduce the number of days these meters do not record revenues. • Utility moves from reactive to proactive. • Reduced latency of response leads to reduced Apparent Losses. • Eliminates uncertainty as to when a meter stopped functioning and how much consumption the property-owner has incurred.

Ref	Importance	Business	Driver & Description	Utility	AMI Technology Assessment
				• Charge based on estimate – realize City of Thunder Bay won't recapture all lost revenue. • All stopped meters lead to field visits. • AMI will reduce latency in responding. • Algorithms can trigger response – can be customer-group specific.	• Stopped meters that go unaddressed for a longer period result in a hardship on the property-owner if the City of Thunder Bay issues an estimated catch-up bill to address the unmetered water.
RP3	**(1) Nice to Have**	**Zero Consumption – Turned off for Non-Payment**	Zero consumption: identifying those properties where the utility is expecting zero consumption. When consumption occurs, then the utility should be notified. Some examples of this occurring include: • Detector check monitoring: detect any consumption that occurs on detector check meters and monitor the amount of water, ensuring the water demand flow rate is not going through the un-metered portion of the meter. • Monitor detector check meters (Fire Services) • Ensure customers are not using fire service for domestic purposes.	**Discussion Points:** • What effort is associated with monitoring turned off customers? • Do customers turn the water back on? **Discussion Outcomes:** • The Utility would not know water has been turned back on after shut-off. • Not that many disconnects – transfer to tax handles this.	**AMR** (PART) – Meters can be monitored but reaction would be every 30 days (depending on read frequency) after the bill is produced. **AMI** (FULL) **–** Meters can be monitored as often as daily depending on how frequently the radio transmitter sends data to the data collectors. Customers using fire service for domestic purposes could be identified prior to bills are produced.

RP4	**(2)
	Important**
		Zero Consumption – Empty Pipe Alert	• Detect meters removed from service.
			• Additional considerations:
			  • Would require non-mechanical meters to be in place with the capability.
			  • AMI Radio Transmitter and Meter Manufactures would need to be the same.
				Discussion Points:
				• Do meters get pulled or stolen and replaced with spacers?
				
				Discussion Outcomes:
				• Applies to non-mechanical meters.
				• Another potential water theft situation.
					AMR (ZERO) – It is unlikely an AMR radio would read this flag from the meter.
					
					AMI (PART) – Depending on the manufacturer of the product this feature may or may not be available.
					• Requires AMI transmitter ability to recognize the flag and non-mechanical Meter's ability to produce a flag.
					• Likely requires meters and AMI system to be supplied by the same vendor.

RP5	**(2) Important**	**"Run your water" Accounts**	Customers who need to run water during winter months due to risk of freezing. Effectively tracking this consumption can reduce apparent losses based on the number of customers and the amount of consumption they use in this period.	**Discussion Points:** • Does this happen in the City of Thunder Bay? • Are there ICI customers who have this issue? **Discussion Outcomes:** • Depends on the particular year – i.e., the severity of the winter. • There can be over 100 frozen services each year. • Customers are charged an estimate during that period. • Thunder Bay has fairly deep service lines and monitor the frost level frequently. • The properties susceptible to freezing are generally known by the City of Thunder Bay.	**AMR** (PART) – Limited ability to capture hourly data to capture amount of constant flow. **AMI** (FULL) – With hourly consumption data the City of Thunder Bay can monitor the flow rate of running water at a particular account, track the amount of water not being consumed for apparent loss calculation and provide the appropriate "forgiveness" to customers.
RP6	**(1) Nice to Have**	**Detect Misapplied Meters**	Misapplication of meters can result in lost revenue and increased meter repairs. Some examples include: • Turbine meters installed where a compound is needed. • Compound meters are oversized, or significant flow is going through at the cross-over point.	**Discussion Points:** • Understanding the detailed usage pattern of a customer can help to determine the appropriate meter for the application. For example, is a 3" meter appropriate instead of a 6"? Is a compound or turbine meter best for the application?	**AMR** (PART) – Can be performed manually. Field visit required. Most radio transmitters have the ability to download hourly data for an individual meter, so specific analysis can be conducted to properly size the meter.

Ref	Importance	Business	Driver & Description	Utility	AMI Technology Assessment
			Type 1: Compound meters, uneven wear results in either the high or low side of the meter to wear out and record much less accurately. Rule of thumb 70% high side, 30% low side (smaller the consumption buckets the better; hourly vs every 30 days). **Type 2:** Compound meters, cross over: identify those meters where a significant amount of a customer's water demand flow rate around the cross-overflow rate with reduced meter accuracy. Where a large % of flow is being measured at the cross over. Could lead to a 5% to 10% accuracy loss. Hourly consumption analysis can detect this. **Type 3:** Low flow on turbine meters: meters that have a significant amount of a customer's consumption below the optimal flow rate for a turbine meter.	• Do you typically match service size with meter size? • If so, there may be some small benefit based on the number of large meters. **Discussion Outcomes:** • System can provide more data to enable proper sizing of meter. • Customer identifies their expected flow profile & customer gets to pick one of the City of Thunder Bay-spec'd meters that meets their usage. • Usage of property may change – e.g. change in cooling system away from water cooled. • Currently try to educate engineers on sizing, by using pricing as a driver to not oversize.	**AMI** (FULL) **–** No field visit required. **Type 1&2:** Consumption of both high and low dial on the compound meter can be compared to determine the percentage of flow through each register. **Type 2 & 3:** Hourly consumption can be calculated to determine approximate flow rates. Then the flow rates where the meter is operating can be compared to the meter's rated accuracy at those flow rates to determine if meter right-sizing would be beneficial (i.e., avoiding lower accuracy flow such as low flow or cross-over flows that are less accurate.)

RP7	**(2) Important**	**Support for Leak Forgiveness Program**	• Where a significant customer side leak occurs, there is a leak forgiveness program in place.
			• Pinpoint major leak to a specific event or date.
			• May lead to lower forgiveness payouts over time.
				Discussion Points:
				• Reduce the total pay-out dollars due to Alerts catching these issues sooner.
				• Data provides support for decisions that are made.
				• Initially, this may result in more people qualifying for the program and getting assistance as one requirement of program is that the last reading must be an actual reading. Often properties don't qualify because the homeowner did not call the last reading in so the leak may have occurred for longer than 1 billing period.
				• Could also help customer in detecting leak sooner to minimize the impact/bill due to leak.
				
				Discussion Outcomes:
				• Looking at AMR and AMI technologies. AMR is typically too far after the fact to pinpoint to a specific date,
				• There are really two aspects of AMI that can provide support:
				  o Pin-point major leak to a specific event or date.
				  o May lead to fewer people qualifying.
				• Customer portals can be very beneficial. And some utilities will start to restrict or remove their leak forgiveness programs.
				• Provides incentive for Portal sign up, i.e., In order for a customer to qualify for leak protection they must be signed up for the portal.
				• Big cases receive political attention.
					AMR (ZERO) – Not applicable.
					
					AMI (PART) – Would help calculate how long and how much water leaked on a customer service.
					• Customer Portal could provide a more efficient way of managing these types of programs.
					Customers who request assistance through Leak Forgiveness would be required to sign up for the Customer Portal and take responsibility for future leaks.

RP8	**(2) Important**	**Meter Accuracy Decline**	• Different meter types (positive displacement, non-mechanical) have different measurement accuracies over their lifecycles.	**Discussion Points:** • Positive Displacement meters tend to slow down over their lifecycle • Non-mechanical (e.g. ultrasonic and magnetic meters) do not lose accuracy over their lifecycle. **Discussion Outcomes**:	**AMR** (FULL) – Not applicable. **AMI** (FULL) **–** Not applicable.

Ref	Importance	Business	Driver & Description	Utility	AMI Technology Assessment
				• Cost analysis was made by factoring in the revenue gain of non-mechanical versus the increase in cost of non-mechanical meters. • Currently, Thunder Bay is losing approximately $1.5M per year due to meter inaccuracies. • Estimated to improve revenue by $2.12M per annum after full meter replacements are completed.	
	Operational Efficiency (OE)				

OE1	**(3)
	Critical**
		Reduce Regular Meter Reading Costs	Reduces the cost to collect meter readings.	**Discussion Points:**
				• Annual costs: meter readers, maintenance, equipment, and support costs.
				
				Discussion Outcomes:
				• All customers are read and billed quarterly.
				• Readings are a combination of:
				  ○ Customer provided – 68,413 (45.6%)
				  ○ Actual – 24,525 (17.8%)
				  ○ Estimated – 54,934 (36.6%)
				• 3 FTE meter reading staff
				• 3 staff-owned vehicles are used for meter reading
				• 5 Trimble Nomad handhelds, 6 Neptune Pocket Pro readers
				• Annual meter reading costs estimated at $210,967 in 2023
					AMR (PART) – AMR mobile allows meter readings to be collected by driving in close proximity to the property. Typically, meter readings are collected for billing purposes, although some mobile AMR systems can allow daily and hourly readings to be collected at the cost of some system performance (driving speeds). Mobile data collection will also collect leak detection, tamper, and backflow flags. This provides a Yes / No response that can be incorporated into reports and CIS.
					
					AMI (FULL) – Allows for all meter readings to be collected via an AMI system. Hourly readings are transmitted in a single digital package on a frequency determined by the City of Thunder Bay. Usually a 20-year warranty provides up to 4 times daily transfer of readings. Eliminate 95% of manual reading.

OE2	**(1) Nice to Have**	**Same Day Final Reads**	• Collect Same day (off cycle) meter readings to facilitate Move In / Move Outs • AMI technology allows reading during off cycles eliminating the need to send out a meter reader. • AMI and MDM technology will allow customers to be grouped; in this case a zero-consumption group which can alert the City of Thunder Bay when consumption occurs at the property prior to the new customer setting up a new water account.	**Discussion Points:** • How many resources are dedicated to this work? • How long does it take to perform a final reading? • Are there any segments of the City of Thunder Bay's population that have a higher likelihood of off cycle reading? (e.g., university, rentals) **Discussion Outcomes:** • Final reads: 3,100 ownership sales, 402 tenant moves. • Small % of overall number of reads (5%) • Requires a field visit on the day of the reading request.	**AMR** (PART) – Still require a field visit. • Certain types of system may be able to produce a daily read through Mobile • Would require some software to store it.) **AMI** (FULL) **–** No field visit required. On-demand readings will eliminate out of cycle manual readings to accommodate the account closing or moving in dates. Virtual shut off groupings will alert the Utility to customers using water prior to setting up an account with the Utility.

OE3	**(2)
	Important**
		Improve Meter Reader Safety	• Meter readers are subject to a wide range of possible safety issues including vehicle accidents, slips & falls, repetitive movements, dogs, environmental (air quality, weather), and high crime areas.	**Discussion Points:**
				• Reduce lost time injuries related to meter reading, which could include:
				  ○ Vehicle accidents.
				  ○ Dog attacks, slips/falls, snakes, spiders etc.
					AMR (PART) – AMR reduces the number of meter readers in the field and decreases some safety aspects of manual meter reading (slips and falls,

Ref	Importance	Business	Driver & Description	Utility	AMI Technology Assessment
			• Reducing the exposure of personnel to these risks can significantly improve meter reader safety, ultimately reducing lost time injuries. • AMI technology will virtually eliminate liability associated with employees reading meters in the field. • It is important to highlight that improving meter reading safety may not drive functionality, but it is still a business driver that supports safety initiatives.	o High crime areas. o Environmental: Heat, air quality during environmental events, storms. o Repetitive motion injuries. • Potential Liability Issues? • Does the City of Thunder Bay have concerns in this area? • Is this a contributing factor to implementing technology? • Are there any protocols in place to ensure the safety of the meter readers? **Discussion Outcomes:** • ~24,500 handheld reads annually, and meter readers typically do not enter the home for regular reads. • In some cases, meter reading staff are put at risk when reading meters in high crime areas. Such situations are currently mitigated by scheduling in the morning or pairing up with another member of staff. • Thunder Bay has a vehicle tracker system in place.	dog bites). However, it increases vehicle safety risks to meter readers and citizens. **AMI** (FULL) – Virtually eliminates all readers in the field.
OE4	**(3) Critical**	**Meter Reading Reliability / Elimination of Estimates**	• Reduce the time to re-read missed readings. • Use an estimated read due to inability to get a meter reading within the billing window.	**Discussion Points:** • What % of meter reader resources perform these re-reads? • How much time do the estimated bills take? • What % of time is spent on these tasks? **Discussion Outcomes:** • 294 re-reads due to too many estimates. • 57,446 estimates in 2023. • 2 successive estimates trigger a field visit read. • Have led to significant high water bill situations (Multiple $1000's)	**AMR** (PART) – Missed reading can occur depending on route travelled. **AMI** (FULL) – Missed readings will be significantly reduced with AMI. Furthermore, AMI will provide early notice if meter readings are not captured, allowing the City of Thunder Bay to be proactive and address reading issues before they result in estimates.
OE7	**(1) Nice to Have**	**Remote Turn-off / Turn-on**	To address non-payment, some utilities shut off water service to the customer. This can be a challenging and potentially dangerous situation for the utility employee. As a result, some cities have considered the use of Remote Shut-off Valves (RSV) to encourage payment. • A two-way AMI technology can allow a water utility to remotely shut off valves or valve enabled water meters. This would eliminate the need to send a technician out to shut off the water. • Remotely shut-off valves typically operate in three stages: o No flow o Trickle flow o Full flow • In addition to the technical challenges, this approach also has social and budget implications. Is the approach considered targeting disadvantaged groups if only services of slow paying customers are equipped with a valve? Does the City of Thunder Bay incur the cost of installing a device	**Discussion Points:** • Who performs turn-ons / offs? • How many people are dedicated to this? • Of the shut-offs that are occurring, are they happening in a certain area or associated with certain customers? • Would charging customers the cost of a meter technician to turn the water back on a reasonable policy? • Are there policies around the timeliness of restoring service once payment is made? • Does the City of Thunder Bay have equitability concerns? Would shut-off valves be installed on all meters or a subset of the population? **Discussion Outcomes:** • 144 shut offs in 2023. • Significant administrative time in making calls around non-payment. • Concern that some customers would circumvent the shut-off process. • Difficult technology to implement and the use of this technology can be seen as targeting certain customers.	**AMR** (ZERO) – No benefits. **AMI** (FULL) – Possible with the following conditions: • Two-way with reasonable latency (sub-hour). • Most designs incorporate a valve into a non-mechanical meter. • Others use a secondary device that would require a longer laying length. • RF encryption should be employed to prevent unauthorized use.

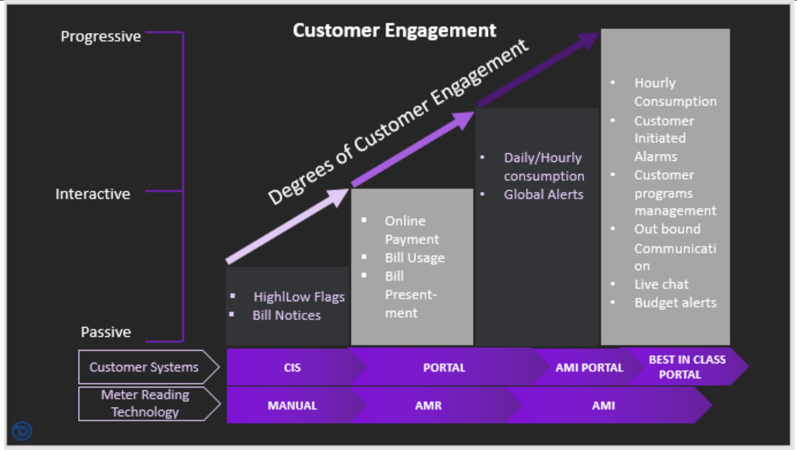
Ref	Importance	Business	Driver & Description	Utility	AMI Technology Assessment
			on every home to address the minority of customers where a valve is justified?		
	Improved System Distribution	**(DS)**			
DS1	**(2) Important**	**District Metering**	• Identify and monitor real losses on the distribution system. • Perform NRW calculation on a subset (or district) of customers within a given geographic area. • Requires all distribution mains to be metered to measure water in and out of a districted metered area (DMA). • An AMI system takes all the identified customers within the DMA and subtracts consumption from the master / district meters.	**Discussion Points:** • Does the City of Thunder Bay have DMAs? • Real Losses: • Water Losses: **Discussion Outcomes:** • Currently Thunder Bay does not have DMAs. • Enhances analysis and timeliness of data. • Requires further investment. *Note: Not a true DMA, but the installation of bulk meters for the lines serving the certain communities could reduce NRW by identifying the amount of water provided.*	**AMR** (ZERO) – Not able to perform with AMR data. Does not allow this type of program to be implemented. **AMI** (FULL) – Requires: • Master meters on distribution network. • Hourly readings from all meters. • Meter Data Management (MDM) can group and calculate water loss. • Meter consumption can be grouped and compared to master meters within most high-quality MDM software if the master meters are in place.
DS2	**(1.5) Nice to Have / Important**	**Water Balance Calculation Frequency**	• Water utilities perform a water balance (AWWA Water Audit Software) to calculate NRW across their system. • With hourly AMI consumption data for all customers, this type of water balance could be performed both more accurately and on a more frequent basis, allowing utilities to identify and react to significant changes in NRW percentage. • Dynamic water balance could be implemented either on the entire system or just smaller more problematic parts of the system.	**Discussion Points:** • What is the variable production cost of water (to be applied to real losses)? • How often is this calculation performed? **Discussion Outcomes:** • Thunder Bay has utilized the AWWA water audit tool on occasion, but it is not a standard practice. • This will help monitor where we are losing water, however this does not tell us where the losses are. • Currently at 32% NRW, and this will help break this down. Ontario typically sees 20%-30% on average. • Aging infrastructure is an important topic for all water utilities. • Categorizing the losses will allow Thunder Bay to decide on what approach to use. • Note that reducing water loss has carry-on benefits through the reduction in energy consumed to treat and pump water as well as the greenhouse gases generated from that energy.	**AMR** (ZERO) – Not able to perform this calculation. Would not allow this type of program to be implemented. **AMI** (FULL) – Requires: • Meters on all water sources and to be set up as a revenue meter. • MDM can group and calculate water loss. Consumption information can be summed up and monitored on a frequency of the utility's choosing (monthly, weekly, daily) and can be compared to SCADA. MDM may be able to interface with SCADA to perform water loss calculation in a report or user interface, but this functionality is still in development within the system available.

DS3	**(2) Important**	**Acoustic Leak Detection (ALD)**	• Acoustic Leak Detection (ALD) uses sensors to find and characterize sounds in the water system that are caused by leaks. • Typically, 1 ALD is required for every 10 meters (Dependent on distribution system & the technology used.) • Different approaches can be implemented: ○ Permanent – sensors/loggers are permanently attached to the water system and transmit daily leak status. These devices may use a stand-alone communication network or may be read using an AMI network (vendor-specific). ○ "Lift & Shift" – sensors are installed in an area and monitored for a period before being moved to another location. ○ Leak Sensors and Headphones – crews are deployed with listening devices to survey an area.	**Discussion Points:** • Does the City of Thunder Bay have an acoustic leak detection program? • What approach? • What is spent on this per year? • Potential to install permanent loggers that can be read through AMI system. **Discussion Outcomes:** • Thunder Bay utilizes a Hydrant AI leak and pressure monitoring system, currently on a pilot program basis. • Potential for Thunder Bay to reduce technologies related to ALD • The system identifies general location of potential leaks, but ground proofing is still required. • Pressure and transient monitoring are very valuable.	**AMR** (ZERO) – Not applicable. Does not allow this type of program to be implemented. **AMI** (PART) **–** Can help facilitate these programs. Requires: • Acoustic ALD • Additional software to map it. The utility could install radio transmitters and acoustic monitoring devices on the water systems which would be collected by the AMI system along with the readings.
DS6a **DS6b**	**(1) Nice to Have** **(1) Nice to Have**	**Detect Backflow Events (Residential)** **Detect Backflow Events (ICI)**	• ICI customers often require backflow detection devices (single check, double check, reduced pressure detector, etc.) installed on certain types of water services and customers. Once installed, the devices need to be tested annually to ensure they continue to operate correctly. Depending on who is responsible for testing, the validation process may be more difficult. An AMI system can monitor certain accounts to ensure reverse flow does not exceed forward flow, indicating a backflow device is not operating correctly. These alerts or alarms then allow a water utility to monitor and respond quickly to backflow events. • Monitor those properties that have backflow. Often 5% to 10% of backflow devices can fail per year. Helps validate property owner testing programs and reduces cross contamination risks.	**Discussion Points:** • Certain meters can monitor any backflow (i.e., backflow detection) but most require more backward flow than forward flow to register the event. • What is the City of Thunder Bay's policy on backflow preventers? • Who is responsible for testing and reporting the results? What is the frequency – annually? **Discussion Outcomes:** • Who is responsible for testing and reporting the results? What is the frequency – annually? • Important to know when they occur. • Residential is fairly low risk for distributions system. • Robust backflow program in place for ICI customers. • High pressure across the City of Thunder Bay (well above average) • Sensitivity of equipment – false positives – water flows backward when hot water tank expands. • May create more issues / unnecessary concerns.	**AMR** (PART) – Reverse flow could be monitored using the flags produced by the AMR register/ transmitter. The drawbacks are that AMR will not tell you when the reverse flow occurred, how much water flowed back through the meter, and you cannot set thresholds that would filter out very small reverse flow events. **AMI** (FULL) **–** The utility could set up reports based on hourly consumption information to monitor the backflow. If an event occurred, they would be able to tell when and how much water came back into the system. Can monitor it in real time. Can set thresholds (minimize false positives).
DS7	**(1) Nice to Have**	**Bylaw Enforcement**	• Support by-law compliance with water restrictions: ○ Water bans. ○ Odd / even lawn watering provisions. ○ Support seasonal water pricing. • Often bylaw enforcement is dependent on customer complaints or utility personnel driving through neighborhoods to identify customers who are in violation of a water enforcement ban. • AMI technology can allow for monitoring of customer consumption and highlight those who may be violating the ban. Depending on the fines issued, this may increase utility revenues. Repeat offenders could also be flagged on a separate report to monitor them more closely.	**Discussion Points:** • Does the City of Thunder Bay have regular water restrictions? • Does the City of Thunder Bay enforce bylaws? • Potential to Increased fines – would these be considered a financial improvement? • Under mandatory curtailment orders, fines can be levied. **Discussion Outcomes:** • Previous program of Odd & even watering days (15 years ago) • It might be useful if the capacity is stretched in the summer. • Climate change can exacerbate the capacity concern. • May be an issue if housing development occurs. • Would require policy change – may result in higher bills for irrigation usage.	**AMR** (ZERO) – Not applicable. Does not allow this type of program to be implemented. **AMI** (FULL) **–** MDM requires reports / alerts that can identify and compare odd / even days and compare. The utility could set up reports that would monitor customers during water restriction events.

				• Consider TOU for watering that doesn't conform to rules. • The burden of proof is quite high and may be difficult to actually take action.	

DS8	**(3)**
	Critical
		Pressure Monitoring	• Monitor Pressure across the distribution system. Changes in pressure may:
			  o Indicate potential leaks.
			  o Reduce pressure - lower real water loss.
			  o Respond to customer complaints.
			• Pressure readings can be taken across a water system on a daily (or more frequent) basis. The pressure readings will either come from a pressure gauge or a non-mechanical water meter that is compatible with the selected AMI technology.
			• Pressure readings can be used for a few purposes:
			  o Better respond to customer pressure complaints.
			  o Monitor pressure for fire protection.
				Discussion Points:
				• Changes in pressure may:
				  o Indicate potential leaks.
				  o Reduce pressure to lower real water loss.
				  o Respond to customer complaints.
				• Does the City of Thunder Bay receive pressure complaints?
				• Would additional pressure information help distribution management?
				
				Discussion Outcomes:
				• Pressure drops are critical to be aware of.
				• Can identify areas that need PRVs – help guide investments.
				• Pressure runs high → leaks and fixture issues.
				• Low pressure – critical control point – pressure drops.
				• Some complaints about low pressure – may be as a result of a main break or other issues.
				• Could help with hydraulic model calibration.
					AMR (ZERO) – Not applicable. Does not allow this type of program to be implemented.
					
					AMI (PART) **–** Would require:
					• Water meter that transmits pressure or 3rd party pressure monitor that is compatible with the RF network.
					• Meter and AMI manufacture to be the same.
					• Likely need to API to interface with hydraulic modelling software.
					AMI technology needs to either have a radio transmitter that can communicate and pull pressure readings from a pressure device or the AMI technology in combination with a water meter capable of monitoring pressure (manufacture specific).

DS9	**(1)** **Nice to Have**	**Temperature Monitoring – Frozen Services**	• Monitor temperature on shallow services. • Be able to proactively respond to freezing temperatures.	**Discussion Points:** • To what extent is freezing an issue? **Discussion Outcomes:** • Some benefit for pipe freezing concerns. • Pipes are buried deep in Thunder Bay. • How would data be used if conditions are getting close to freezing levels (frost level). • Known areas/properties where freezing is a risk – no real value in knowing more detail.	**AMR** (ZERO) – Not applicable. **AMI** (PART) **–** Would require: • Water meter that monitors and transmit temperature (C715) • Meter and AMI manufacture to be the same. • Alerts to be emailed within a reasonable timeframe
DS11	**(2)** **Important**	**Hydraulic Modelling**	• Using more detailed consumption information (specific time of day or seasonal) to allow the model to better model the system.	**Discussion Points:** • How often does Thunder Bay update or use the Hydraulic Model? With 8 pressure zones, would more pressure information be valuable? **Discussion Outcomes:** • Current Model is Info Water. • More data to feed to model will better calibrate the model. • New developments, shutdowns.	**AMR** (PART) – Improve monthly consumption forecasts. **AMI** (FULL) **–** Using data to predict different types of behavior. • Current relies on API's – ad hoc reports, not a direct connection.
DS12	**(1)** **Nice to Have**	**Wastewater Monitoring**	• Using the network to monitor wastewater overflow. • Using the network to monitor tank and reservoir levels. • AMI Vendors have endpoints devices that can be connected to other control devices (different product that connects to water), allows a 4-20mA connection.	**Discussion Points:** • How is this performed currently? Would there be any benefit to having an AMI network support this function? **Discussion Outcomes:** • Not all residents have wastewater. • Combined System down to less than 1km	**AMR** (ZERO) – Not applicable **AMI** (PART) **–** Endpoints that connect. to 4-20mA.

				• I&I greatly reduced after the combined sewer work. • System almost all gravity fed – only 4 lift stations. • Interested in tying in level sensors – need to do an I&I study (CLA requirement). • AMI would help to create a baseline and peak usage.	• Some meter vendors offer 4-20mA connection.
DS13	**(1) Nice to Have**	**Water Quality Monitoring**	• Using the network to monitor water quality (pH, chlorine, etc.) • Still very much a field in development for many vendors.	**Discussion Points:** • Would more frequent readings be of value to the City of Thunder Bay? • How common are water quality complaints? • What type (colour, pressure, taste). **Discussion Outcomes:** • Staff sample at flushing and sampling points. • Station sampling as well. • Monitor chlorine residuals.	**AMR** (ZERO) – Not applicable **AMI** (PART) – Radio transmitters that accept 4-20 mA output. • Still in development for many vendors. • There are marketing materials, but how proven they are is uncertain.
			Enhanced Customer Service (CS)		
CS1	**Not scored, see CS2, CS3 below**	**Customer Engagement** **General**	 • Utilities often start with lower levels of customer engagement usually defined as reactive responses to customer complaints or passive notices included on water bills. • As a utility starts to allow for on-line web access to water bills (for viewing and payment), this provides a higher level of service and engagement for the customer; however, the utility is reliant on the customer to initiate the engagement.	**Discussion Points:** • Thunder Bay is already at this level of customer engagement. **Discussion Outcomes:** • Critical to maintain what is happening now and improve on it as part of the AMI initiative. • 500 calls / month • New customer portal – Diane testing • Can pay bills online. • Improvement – up to level with Enbridge • Currently moving from Passive to Interactive • Aging population – may not use system. • Live chat – enables multiple communications at once.	**AMR** (FULL): AMR readings will support a passive engagement where the customer can decide to view their billable consumption. This level of engagement is usually driven more by the Customer Information System than meter reading technology. **AMI** (FULL): Would achieve the goal on a passive customer engagement. But not really required.
CS2	**(3) Critical**	**Customer Engagement** **Interactive**	• As a utility applies AMI technology that includes a customer portal, the engagement becomes more interactive. • Customers can access better consumption graduality (hourly buckets as compared to monthly) and potentially be sent consumption flags (continuous leak, intermittent leak) allowing them to better understand their consumption behavior. • The utility can also start to establish global leak flags that allow notifications to be proactively sent to all customer		**AMR** (PART): AMR readings will support a passive engagement where the customer can decide to view their billable consumption. Displaying consumption flags could enhance the level of engagement especially when a continuous leak flag could be displayed for a customer complaining of a high bill.

			meeting certain consumption conditions (i.e., 500% of daily average consumption over a 5-day period) via the customer portal credentials (Email, text).		Some interactive engagement but likely would fall short in several areas. Requires a portal. **AMI** (FULL): AMI technology would allow customers to view hourly consumption to better understand their consumption behavior. This would depend on the AMI vendor's ability to provide a consumption customer portal that would receive customers' credentials from the existing customer portal or payment provider. Typically, the AMI consumption portal will include some global consumption alerts but may not distinguish between customer type or meter size (where consumption patterns may be significantly different). • Alerts and consumption views would allow more interactive. More advanced Portal is likely required
CS3	**(3) Critical**	**Customer Engagement** **Progressive**	As a utility moves towards "best in class" customer engagement, it allows: • customers to personalize their own leak or bill notifications, • provide workflows that help customers proactively investigate consumption, • consumption algorithms that can identify different types of consumption behavior (continuous overnight consumption, leaking toilet or irrigation system, on-even water ban violators) with a high degree of accuracy and provide workflows that help adjust this behavior.	**Discussion Points:** • Best in class customer portals. • AMI functionality related to consumption, leaks. • Conservation program management. • Communications **Discussion Outcomes:** • Enables customers to detect leaks. • Strong link to Council priorities (enabling customer service, digital strategy). • Paperless billing is a strong incentive. • Improving staff tools to provide enhanced service is a corporate goal. • Customers will have access to enhanced tools.	**AMR** (PART): AMR readings will support a passive engagement where the customer can decide to view their billable consumption. Displaying consumption flags could enhance the level of engagement especially when a continuous leak flag could be displayed for a customer complaining of a high bill. Some interactive engagement but likely would fall short in several areas. Requires a portal. **AMI (FULL):** AMI technology and a best-in-class customer engagement platform would provide the "personalized" service through customized alerts, and resolution workflows. The customer engagement portal would be connected to the existing customer portal seamlessly through the passing of customer credentials, completely invisible to the customer. • Improve engagement from utility. • Improve engagement from the customer.

CS4	**(2) Important**	**Leak Detection - Small**	• Two types of customer side leak detection:
			  ○ Continuous / intermediate consumption
			    ▪ High consumption for a short period of time (300% over a 3-day period)
			  ○ Utility set threshold
			    ▪ Customer set thresholds
			    ▪ Water budgets
			• Provides the utility with an improved ability to respond to customers' high-water bill complaints.
				Discussion Points:
				• This type of customer side leak detection would allow customers to avoid large bills.
				• Small leak detection might be set up to trigger an alarm over a few days vs. a broken pipe which could trigger a more immediate alarm because of higher flows.
				
				Discussion Outcomes:
				• Likely 1000s occurring throughout the distribution system.
					AMR (PART) – Would only do continuous leak detection. Need bill print adjustment or a portal to display.
					
					AMI (FULL) **–** A combination of AMI and customer portal will achieve this.
					
					Will provide hourly consumption data to use for consumption alerts that includes:

			• AMR equipment includes algorithms that determine a continuous or intermittent leak. Different types of yes/no flags can provide a billing agent with indication that a leak has occurred at a property. • AMI system has the enhanced capability to detect in near real time. • This reactive approach helps a utility better service its customers.	• Litre precision allows for very fine / slow leak detection. • Would avoid a significant % of large water bills	• Continuous leaks over a utility defined period of time. • Intermittent leaks over a utility defined period of time. • High consumption (X% over daily average consumption) over a utility defined number of days. Utility-defined threshold that eliminate customers with very small leaks from being notified.
CS5	**(2) Important**	**Leak Detection – Broken Pipe**	• Provides a utility with the ability to set global alerts to initiate customer service or field personnel to contact a customer because it appears a pipe has broken based on the volume of water going through the meter. • Would provide a "real time" alert if the consumption match ~80% of the service capacity for a 1-to-4-hour period.	**Discussion Points:** • Would this be of value? • How many broken pipe complaints does the City of Thunder Bay receive in a year? **Discussion Outcomes** • There have been significant high bills from unintended use • Some situations involve senior management and political representations	**AMR** (ZERO) – Not applicable. **AMI** (FULL) **–** Set global leak thresholds and great alerts for when consumption meets 75% or greater hourly flow based on the service size. • Available on most • Bubble up/Wake up functionality would be important
CS6	**(0) Not Important**	**Vacation Monitoring**	• Allow a customer to set a vacation alert that will tell them if water is being used when it should not be. This would be set up through a customer portal which allows for an alert to be sent. • Customer established zero consumption alarm. • Where consumption exceeds a customer-defined amount, they receive an alarm.	**Discussion Points:** • Would this be of value to your customers? • Does the City of Thunder Bay have many seasonal residences or snowbirds? **Discussion Outcomes:** • Concern around infringing on privacy • With an advanced customer portal, this could be entirely customer controlled • Has not been a concern up to this point	**AMR** (ZERO) – Technology does not provide enough data to achieve this functionality. **AMI** (FULL) – Customer driven zero consumption monitoring. Customers can set thresholds for alerts to be sent to them. Alerts include: • Vacation/vacant notice • Customer driven zero consumption monitoring. • AMI and Customer Portal would be critical.
CS7	**(3) Critical**	**Customer Portal Adoption / Paperless Billing**	• Move customer from printed bills to paperless bills. • Added functionality to the Customer Portal can increase participation • Cost benefit of reducing printed bills.	**Discussion Points:** • Would this be of value to your customers? **Discussion Outcomes:** • Important to digital strategy. • Going paperless also builds database of email addresses. • Enables better communication. • There will be a specific customer portal discussion to assess the capabilities of Infor Dynamic	**AMR** (PART) – Technology can provide improved data presentment from current data collection system. **AMI** (FULL) – AMI with Portal can offer enhanced functionality that provides incentive to register for portal.
Water Conservation / Societal Benefi					

ts (WC)					
SB1	**(2) Important**	**Water Conservation Program Support**	• User consumption data to support: o Reduction of peak water demand o Measure impact of conservation initiatives (Low flow device programs, top dressing, outreach programs, etc.) • There are several different types of water conservation programs that focus on changing customers' water consumption behavior. The types of programs that are implemented within a utility really depend on the challenges faced, customers groups (residential, commercial, and industrial) and the type of usage the utility is targeting (indoor usage, outdoor usage). AMI technology can promote water conservation by providing information to customers which enables them to change their behavior. • The greatest benefit - the ability to target customers meeting a specific consumption profile and to measure the effects water conservation programs have on reducing water consumption. As a result, program dollars can be better targeted and utilized towards programs that are proven to be the most effective.	**Discussion Points:** • AMI by itself doesn't initiate conservation but does help support conservation programs and understand program effectiveness. • City of Thunder Bay conservation programs – can technology better support these programs? • Water conservation solutions to align with climate change, drought, stormwater, and land use planning. **Discussion Outcomes:** • Focus has been on the customer, and how can the utility assist with conserving water. • A customer portal can be a very useful tool in communicating water conservation practices. • Included in Thunder Bay's Quality Management report as a Utility goal.	**AMR** (ZERO) – Not applicable. **AMI** (FULL) – Hourly and daily consumption data can be used to support conservation initiatives. Using hourly consumption data in combination with grouping and report functionality from an MDM, water conservation programs can be measured for their impact on water reduction.
SB2	**(3) Critical**	**Climate Change / Greenhouse Gas Reduction (GHG)**	• Ability to avoid increased CO2 and other GHG emissions (no truck rolls to collect reads with AMI). Every vehicle taken off the street results in a 10,215 lb or 4,643 kg reduction in CO2 per year. • Real water loss represents lost energy to pump water that never reaches the consumer. • Reduce NRW → reduce energy → reduce GHG.	**Discussion Points:** • Does this tie to some of the goals already discussed? • Water conservation solutions to align with climate change, drought, stormwater, and land use planning. **Discussion Outcomes:** • Thunder Bay has a goal to be carbon neutral by 2050. • The with the City of Thunder Bay's Energy Analyst helped determine energy consumption and GHG footprint.	**AMR** (ZERO) – Not applicable. **AMI** (PART) – AMI is effect in helping address Water Loss Management, customer leaks and Apparent Losses results directly in energy savings. Further, the ability to understand customer demand patterns as well as system demands might change water pumping strategies and contribute to energy savings if water can be pumped during "off peak" times.
SB3	**(3) Critical**	**Climate Change / Energy Cost Reduction**	Real water loss represents lost energy to pump water that never reaches the consumer. • Reduce NRW → reduce energy.	**Discussion Points:** • Would this be a benefit? **Discussion Outcomes:** • Thunder Bay has a goal to be carbon neutral by 2050. • It is important to understand how water pumping is powered to assess the carbon footprint. • Thunder Bay has an Energy Analyst to assist in analyzing.	**AMR** (ZERO) – Not applicable. **AMI** (FULL) • Eliminates vehicles from the meter reading process. • Reduction of water loss → less energy consumed → less GHG produced.
			Smart Cities (SC)		

SC4	**(1)** **Nice to Have**	**Wastewater Monitoring**	• Using the network to monitor wastewater overflow. • Using the network to monitor tank and reservoir levels. • AMI Vendors have radio transmitters devices that can be connected to other control devices (different product that connects to water), Allows a 4-20mA connection.	**Discussion Points:** • How is this performed currently? • Would there be any benefit to having an AMI network support this function? **Discussion Outcomes:** • It is important to ensure we look at all accounts that do not have wastewater service (approximately 10%) • Combined sewers have essentially been eliminated. • Thunder Bay does not have a sewer overflow problem. .	**AMR** (ZERO) – Not applicable. **AMI** (FULL) **–** Radio transmitters the accept 4-20 mA inputs. • Some AMI vendors enable this capability, typically using a specialized radio transmitter or interface that converts 4-20mA single to a standard encoder protocol.

4. DATABASE ASSESSMENT AND WORK TYPE RECOMMENDATIONS

4.1. Introduction

The data analyzed represents the City of Thunder Bay's meter population as of December 31, 2023.

Two levels of data granularity were considered. The first is at the account level and represents one record per water service. The second, at the meter reading level, represents the quarterly meter reading data for each of the accounts, so it has on average four readings for every metered service.

The raw data provided by the City of Thunder Bay was not altered. Diameter added new columns of data that enabled further clarification or classification of records. These new columns are identified in the database.

Since a decision to update the metering and meter reading system will only impact volumetric revenue, the water or wastewater charges shown in the analysis represent only the volumetric portion of the charges, exclusive of fixed charges that may also be assessed.

For the purposes of the analysis, the term "work type" is used to categorize tasks that will need to be done to enable each water meter to communicate using the proposed technology. For example, in some cases the work type will be the replacement of the meter and the installation of a radio transmitter. In other cases, the water meter may have residual value and does not need to be replaced.

4.2. Water Meter Assessment

4.2.1. Meters by Size and Type

The City of Thunder Bay's existing installed base consists of 37,990 active meters. Note that 209 records with "Account_Status" of "I" for Inactive, were excluded from the analysis.

The table below shows the City of Thunder Bay's meter count by meter size (in mm) and meter type.

Exhibit 6: Meter Count by Size and Type.

Meter Count	Meter Type				
Row Labels	Positive Displacement	Turbine	Compound	Fire Service Compound	Grand Total
SM	**37,001**				**37,001**
15	10,325				10,325
15x20	25,344				25,344
20	585				585

Meter Count Row Labels	Meter Type Positive Displacement	Turbine	Compound	Fire Service Compound	Grand Total
25	747				747
IM	**605**	**233**	**1**		**839**
40	318	138			456
50	287	95	1		383
LM		**136**	**13**	**1**	**150**
75		87	6		93
100		37	3		40
150		4	2		6
200		3			3
250		5	2	1	8
Grand Total	**37,606**	**369**	**14**	**1**	**37,990**

4.2.2. Meters and Annual Consumption by Size

The table below shows the meter count and the annual consumption of water for each meter size. This information is helpful to understand the proportion of the City of Thunder Bay's total water consumed by meter size as well as the average annual consumption by meter size.

Exhibit 7: Meter Count and Consumption by Meter Size

Row Labels	Meter Count	Annual Consumption (m^3)	Annual Consumption (m^3) per Meter
SM	**37,001**	**5,826,152**	**157**
15	10,325	1,390,174	135
15x20	25,344	3,804,146	150
20	585	177,072	303
25	747	454,760	609
IM	**839**	**1,678,013**	**2,000**
40	456	719,530	1,578
50	383	958,483	2,503
LM	**150**	**3,110,003**	**20,733**
75	93	615,822	6,622
100	40	874,828	21,871
150	6	33,720	5,620
200	3	590,981	196,994
250	8	994,652	124,332

Row Labels	Meter Count	Annual Consumption (m^3)	Annual Consumption (m^3) per Meter
N/A[4]	**0**	**117,944**	**0**
N/A	0	117,944	0
Grand Total	**37,990**	**10,732,112**	**282**

*

4.2.3. Meters by Customer Type

The table below shows the City of Thunder Bay's meter count by account type and meter type.

Exhibit 8: Meter Count by Account Type and Meter Type.

Meter Count	Meter Type				
Row Labels	**Positive Displacement**	**Turbine**	**Compound**	**Fire Service Compound**	**Grand Total**
RESIDENTIAL	**33,813**				**33,813**
COMMERCIAL	**3,469**	**162**	**1**		**3,632**
MEDIUM TO LARGE COMMERCIAL	**199**	**82**	**6**	**1**	**288**
MULTIRESIDENCE	**72**	**75**	**2**		**149**
INSTITUTIONAL	**40**	**41**	**4**		**85**
LARGE INDUSTRIAL	**13**	**9**	**1**		**23**
Grand Total	**37,606**	**369**	**14**	**1**	**37,990**

The total annual consumption by account type, along with the volumetric water and wastewater charges are shown in the table below. Charges are calculated based on the City of Thunder Bay's published "2023 Sewer & Water Rates". Fixed charges are excluded. Sewer charges are based on 90% of the volumetric water charge.

Exhibit 9: Meter Count and Revenue Impact by Account Type

Row Labels	Meter Count	Annual Consumption (m^3)	Water Charge	Sewer Charge	Total Charge	Average Annual Charge
RESIDENTIAL	**33,813**	**4,775,468**	**$9,283,510**	**$8,355,159**	**$17,638,669**	**$522**
COMMERCIAL	**3,632**	**1,968,473**	**$2,358,231**	**$2,122,408**	**$4,480,638**	**$1,234**

[4] The data provided by the City includes 292 accounts that are noted not to include a meter. Many of these accounts are listed as having a private hydrant, water delivery, or flat rate. Two of these accounts, both for an industrial customer, account for the 117,944m^3 consumption in the table above.

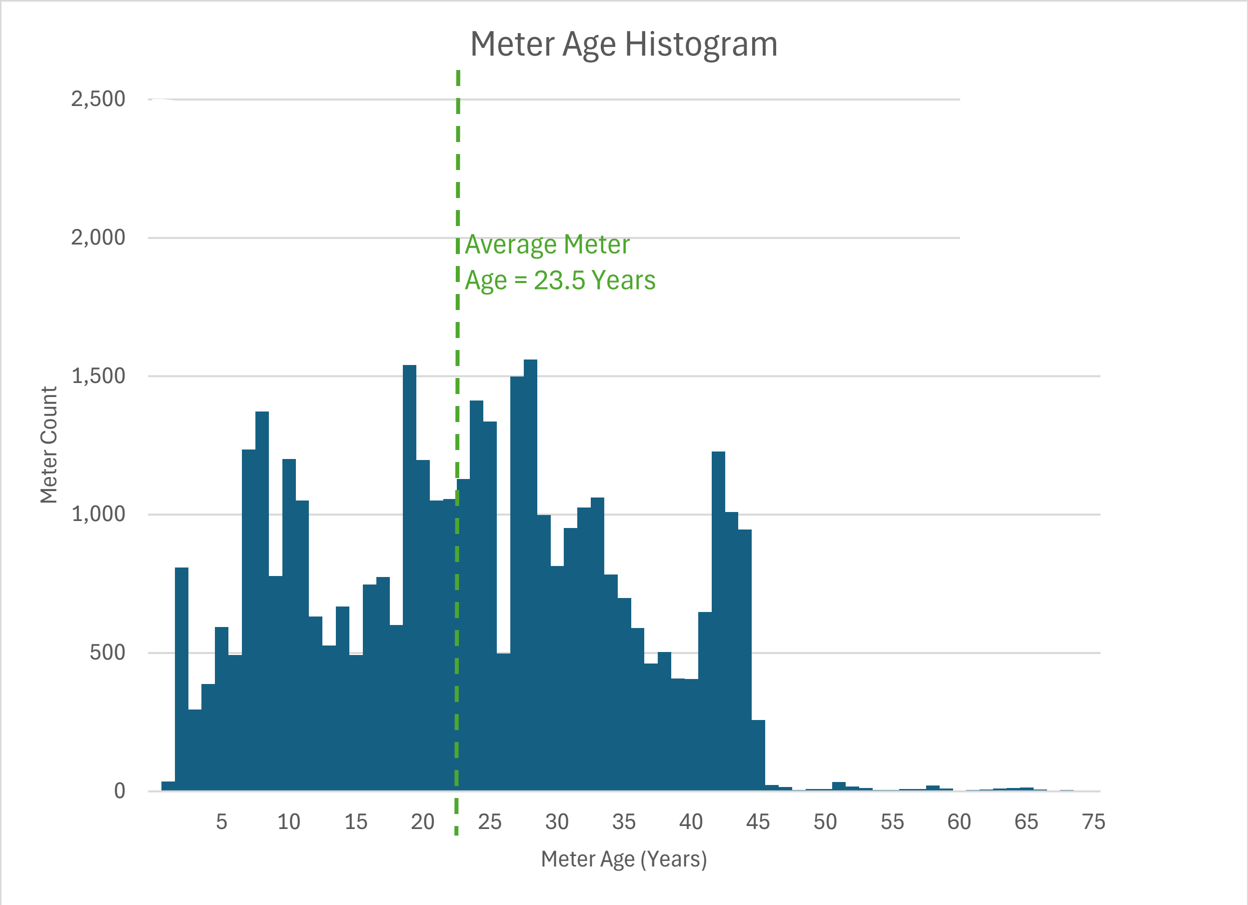
Row Labels	Meter Count	Annual Consumption (m³)	Water Charge	Sewer Charge	Total Charge	Average Annual Charge
MEDIUM TO LARGE COMMERCIAL	288	1,159,720	$1,389,345	$1,250,410	$2,639,755	$9,166
MULTIRESIDENCE	149	652,263	$781,411	$703,270	$1,484,681	$9,964
INSTITUTIONAL	85	687,467	$823,585	$741,227	$1,564,812	$18,410
LARGE INDUSTRIAL	23	1,488,721	$1,783,488	$1,605,139	$3,388,627	$147,332
WATER DELIVERY	0	0	$0	$0	$0	
PRIVATE HYDRANT	0	0	$0	$0	$0	
Grand Total	37,990	10,732,112	$16,419,569	$14,777,612	$31,197,182	$821

4.2.4. Meter Age

The graph below illustrates the age of the City of Thunder Bay's meter population, showing a count of meters for each year since the meters were installed. On average, the City of Thunder Bay's meter population is 23.5 years, with some meters greater than 40 years old.

While practices vary, general industry practice is to replace meters when they reach 15 to 20 years of age to ensure optimal accuracy relative to replacement cost.

Exhibit 10: Meter Age Histogram Showing Meter Count by Age



4.2.5. Why Meter Age is Important

Water meter age is generally reflective of usage. As cumulative consumption increases, mechanical meters wear resulting in accuracy decline, causing the meters to under-register. The decline in meter accuracy for a population of meters is generally steady and predictable.

The industry standard estimate is that mechanical water meters, such as those in use throughout the City of Thunder Bay, will lose 6% measurement accuracy for every 20 years of service. For the purposes of this analysis, a more conservative assumption of 4.5% accuracy decline over 20 years was assumed, so as not to overstate the impact of a meter replacement program.

4.2.6. Estimated Water Meter Accuracy

Based on the age of the City of Thunder Bay's meter population, it is estimated that the City's overall meter accuracy is 94.7%. This level of accuracy results in annual water loss of 500,000 m^3 of water, valued at $1.5 million based on combined water & sewer volumetric charges.

Exhibit 11: Meter Age Histogram with Overlayed Meter Accuracy Estimate

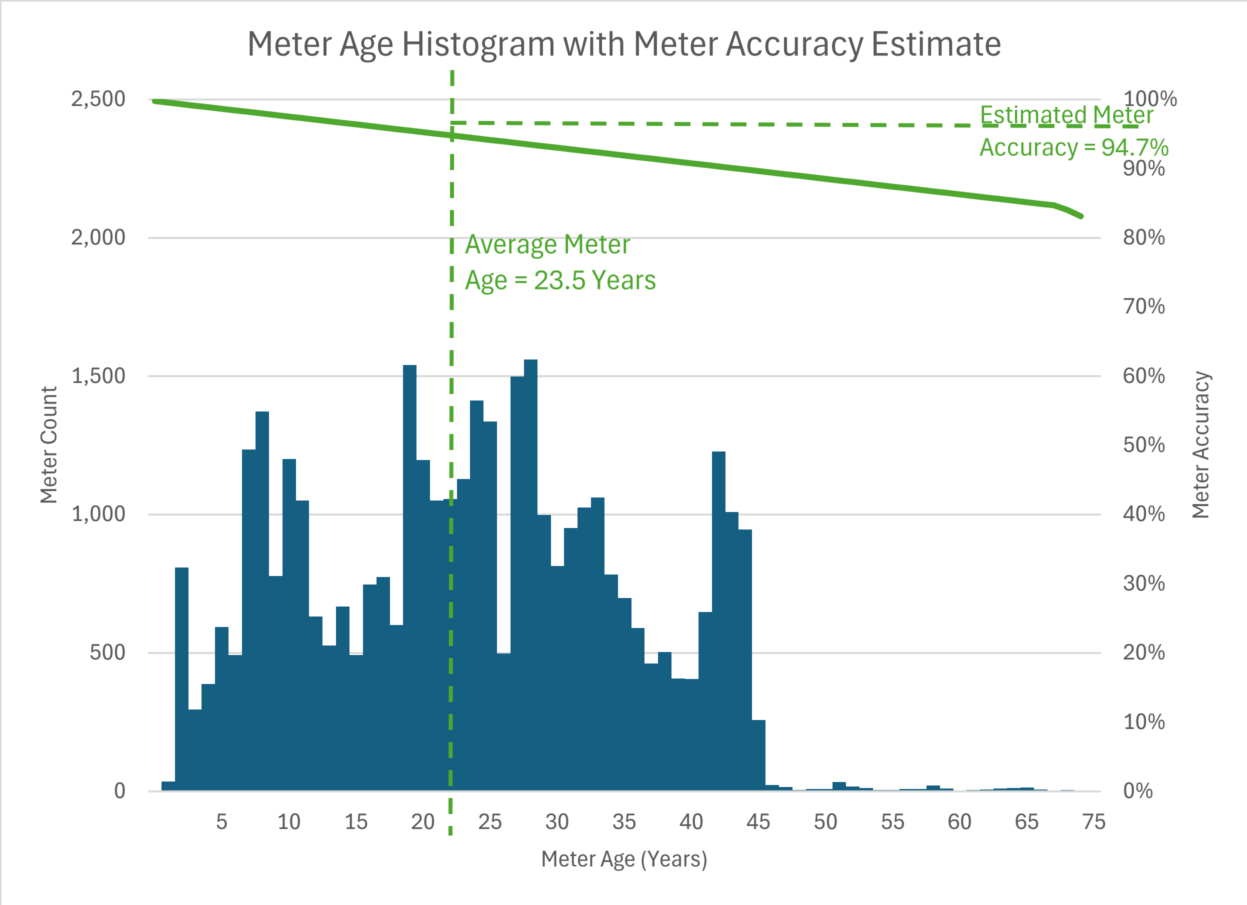
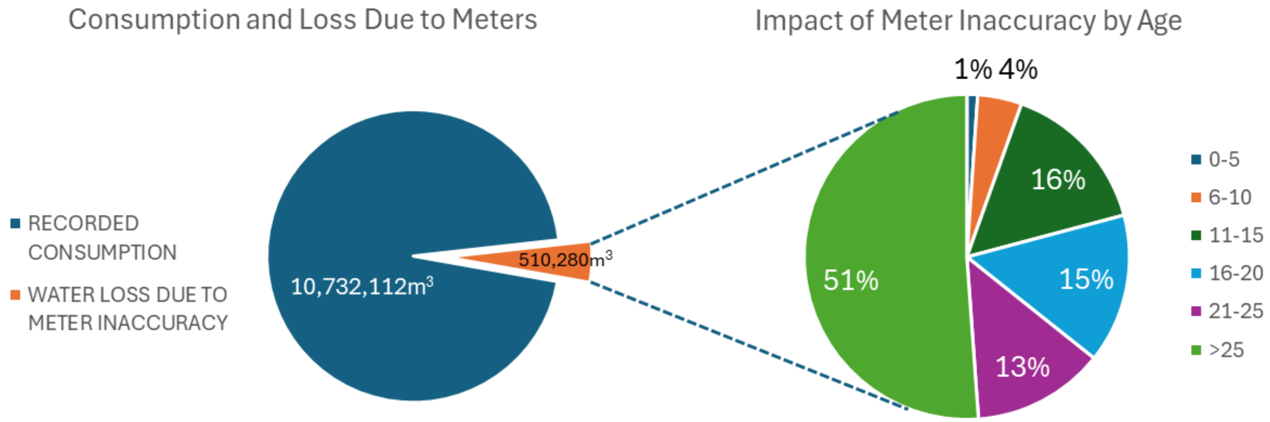


Exhibit 12: Meter Count by Work Type with Meter Accuracy, Water Loss and Revenue Loss

Work Types	Meter Count	Ave. Meter Age	Annual Consumption (m^3)	Water Loss (m^3)	Total Charge	Est. Revenue Loss
REPLACE	**33,491**	**25.8**	**10,014,433**	**501,214**	**$28,980,933**	**$1,515,880**
PRE-2002	20,459	32.7	3,940,168	305,449	$12,551,032	$980,075
PRE-2014	11,533	16.4	5,267,391	184,337	$14,147,479	$502,875
PAYBACK<5	1,219	7.5	773,264	11,275	$2,162,450	$32,388
ZENNER	267	2.0	33,610	152	$119,972	$542
N/A	13	5.2	0	0	$0	$0
UPGRADE	**4,499**	**6.0**	**717,679**	**9,066**	**$2,216,249**	**$28,316**
UPGRADE	4,499	6.0	717,679	9,066	$2,216,249	$28,316
Grand Total	**37,990**	**23.5**	**10,732,112**	**510,280**	**$31,197,182**	**$1,544,196**

Exhibit 13: Water Loss due to Meter Accuracy by Meter Age Group



4.2.7. Lead Content

Avoiding lead exposure is a critical health issue that water utilities throughout North America are addressing. While there are many potential sources of lead in our drinking water, it should be noted that older, bronze-body water meters typically contain between 5% and 7% lead.

Meter manufacturers generally converted production from leaded bronze to lead-free bronze alloys between 2001[5] and 2005. Regulations followed to enforce this change in the market in 2008[6].

The removal from service of any meters that pre-date this change will have the benefit of further reducing any potential lead exposure in the community.

4.3. Meter Reading Data Assessment

4.3.1. Introduction

In addition to the meter-level data, the City of Thunder Bay provided quarterly meter reading data. This allowed the analysis of total consumption, volumetric revenue, and meter reading source information.

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[5] Neptune converted to no-lead bronze in 2001, Badger in 2005.
[6] NSF/ANSI/CAN 60 and 61 Through History states: “In December 2008, Annex G was introduced to NSF/ANSI 61, which set parameters for meeting 0.25% lead content requirements. This allowed product manufacturers to show compliance with laws with lead content requirements, such as California law AB 1953. The requirements of Annex G were moved to NSF/ANSI 372. Annex G became only a reference to NSF/ANSI 372 if lead content verification methods were required.” https://www.nsf.org/knowledge-library/nsf-ansi-can-60-61-history, accessed November 7, 2023.

4.3.2. Meter Reading Sources

With most of the City of Thunder Bay's meters located in basements with no remote reading capability, the City relies heavily on customers to provide readings (45.6%) and when those readings are not provided, estimates are made by the City (36.6%). As a result, only 17.7% of all readings were actually generated by a City meter reader.

The table below provide details on the breakdown of meter readings and their sources.

Exhibit 14: Meter Reading by Source Detail for 2023

Source	Definition	Count	%
Customer	Interactive Voice Response - customer reading	37,152	24.8%
Customer	Customer enters reading via WEB interface	21,354	14.2%
Customer	Customer Phoned in reading	8,944	6.0%
Customer	FINAL reading - homeowners call in - out & in reads	1,749	1.2%
Customer	CARD read - customer sends in card with reading	963	0.6%
Readings Subtotal		**70,162**	**45.6%**
Estimate	Estimate	54,776	36.5%
Estimate	Manual Estimate calculation	154	0.1%
Estimate	FLAT rate	4	0.0%
Subtotal		**54,934**	**36.6%**
Actual	HandHeld	24,525	16.4%
Actual	Correction	294	0.2%
Actual	Actual reading from the meter shop team	44	0.0%
Actual	Meter Exchange	1	0.0%
Actual	Vacant premises	1	0.0%
Subtotal		***24,865***	***17.7%***
Total:		**149,961**	**100.0%**

For comparison purposes, most water utilities measure their meter reading performance against a standard approaching 100% of all meters in each reading cycle.

4.3.3. Zero Consumption Meters

In 2023, there were 86 meters that showed zero consumption for the entire year. Zero consumption is typically caused by one of three different reasons:

- Vacant property
- Unauthorized use of water
- Meter malfunction

Diameter has provided a list of these meters to the City of Thunder Bay for follow up.

4.4. Work Type Recommendations

4.4.1. Introduction

In order to determine the cost of a metering program, it is important to break the work by work type and determine which meters need to be replaced, which can be upgraded, and which can be retrofitted. The evaluation outlined in section 4.2 Water Meter Assessment has resulted in the recommendation to replace approximately 33,500 meters and upgrade the remaining 4,500 meters.

The table below provides a summary of the logic.

Exhibit 15: Work Type Summary

Work Type	Description	Logic	Meter	Register	Radio
REPLACE	The existing meter has limited residual value and will be replaced with a new meter and installation of a radio on the outside of the building.	• Meters pre-2014: lead content of meters (pre-2002) + lower accuracy *(Qty = 32,005)* • Payback <5 years: meters post-2014 that have high enough revenue loss to justify replacement *(Qty = 1,219)* • Zenner meters: these meters are not compatible with high resolution encoders *(Qty = 267)*	 		

Work Type	Description	Logic	Meter	Register	Radio
UPGRADE	The existing meter body has residual value and will be upgraded with a new register and installation of a radio on the outside of the building.	• Meters purchased prior to January 2024 that do not meet qualifiers for replacement *(Qty = 4,499)*			
RETROFIT	The existing meter is AMI-compatible and will be retrofitted with the installation of a radio on the outside of the building.	• The specification for meters purchased by the City of Thunder Bay after January 2024 was changed to ensure that these meters are “AMI compatible” and can be retrofitted with a radio transmitter. *(Qty = 0 since no meters in 2023 database are AMI-compatible.)*			

4.4.2. Water Meter Replacements

Meter replacement entails the full replacement of the existing meter body and register with a new meter and high-resolution register and installation of an AMR/AMI radio transmitter.

Diameter recommends replacing meters that are 10 years old and older as these meters have little residual value. Furthermore, by the end of a 20-year system upgrade, these meters will be approaching 30 years of age.

Additionally, the City of Thunder Bay has a population of meters that, based on their high annual consumption, should be considered for replacement as well. A secondary analysis was performed to identify meters where replacing the meter resulted in a payback of less than 5 years, and these meters should also be targeted for replacement.

In a previous meter bid, the supplier provided approximately 500 Zenner meters, 267 of which had been installed as of January 2024. These meters are not upgradeable with high-resolution encoder registers, and therefore do not support migration to AMR or AMI. Diameter recommends that these meters be replaced, even though they have only been in service for about 2 years.

4.4.3. Water Meter Upgrades

A water meter upgrade entails reuse of the existing meter body, with the retrofit of a high-resolution register and installation of a radio transmitter. Diameter recommends the upgrade of existing meters that are less than 10 years old and that do not have high annual usage.

It should be noted that the City of Thunder Bay can alter this strategy and increase the number of replacements if the price differential between a replacement meter and a replacement register is low.

4.4.4. Water Meter Retrofits

A water meter retrofit would be considered where the water meter has residual value, and a high-resolution encoder register that is capable of supporting an upgrade to AMR or AMI.

No meters in the City of Thunder Bay's meter population as of January 2024 are recommended for retrofit.

Note that meters the City of Thunder Bay has purchased since January 2024 can be upgraded to AMR or AMI. It is our understanding that these meters are currently being deployed and would be included in future meter database exports, should an AMI/AMR project proceed to the next stage.

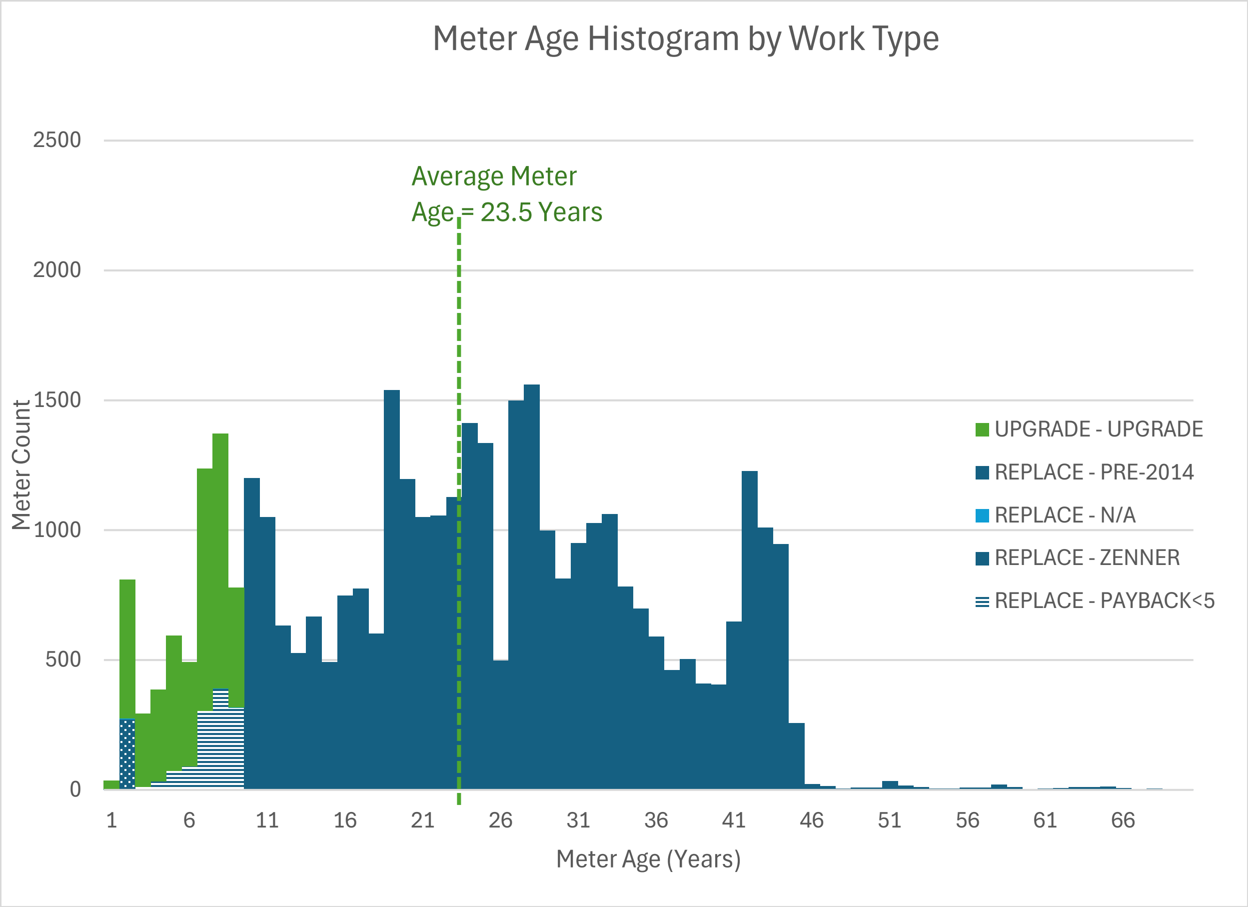
4.4.5. Work Types

Based on the criteria outlined above, and analyzing Thunder Bay's meter inventory, the following work types have been determined.

- Replace 33,491 meters
- Upgrade 4,499 existing meters with AMI-compatible registers
- Retrofit any new meters purchased since January 2024 with a radio transmitter since these meters are already AMI-compatible.

Graphically, the work types are shown below in Exhibit 16: Meter Age Histogram by Work Type.

Exhibit 16: Meter Age Histogram by Work Type



5. CAPITAL AND LIFECYCLE COST ESTIMATES

5.1. Introduction

The financial assessment builds on the database analysis. The financial model that was developed incorporates both the initial capital costs and the financial and operational impacts on the key Utility functions including: meter reading, meter maintenance, customer service and billing, Information Technology (IT) and distribution system management. The financial model allows the City of Thunder Bay to compare the financial implications of the key technologies that are the most applicable. Each technology has been set up as a different scenario.

5.2. Scenarios

The financial model compares three technology scenarios to the existing meter reading scenario at the City of Thunder Bay. The three scenarios area 1. AMR Mobile (Drive By), 2. AMI (Thunder Bay owned), 3. AMI (Cellular). For comparison purposes, the scenarios, technology, and key assumptions are detailed below:

Exhibit 17: Financial Model Scenarios

Scenarios	Description
Scenario 0 – Existing Situation – Manual Meter Reading with meter replacements over a 20-year period.	This scenario assumes that the City of Thunder Bay will replace 2,000 meters per year. This scenario also assumes that a remote reading device will be installed during the replacement and Thunder Bay will assume responsibility for reading all meters.
Scenario 1 – AMR Drive By	This scenario assumes that City of Thunder Bay will install radio transmitters as well as perform meter replacements over a 31-month period (6-month startup, 25-month production). This will allow Thunder Bay to read all meters using a mobile data collector solution. Water meters would be replaced according to the replacement criteria (Section 4.4.5).

Scenarios	Description
Scenario 2 – AMI Thunder Bay Owned	This scenario assumes that Thunder Bay will install radio transmitters as well as perform meter replacements over a 31-month period (6-month startup, 25-month production). This assumes a standalone AMI system is deployed across the City's entire service territory. Water meters would be replaced according to the replacement criteria (Section 4.4.5).
Scenario 3 – AMI Cellular Network	This scenario assumes that Thunder Bay will install radio transmitters as well as perform meter replacements over a 31-month period (6-month startup, 25-month production). It further assumes the network infrastructure would be owned by a third party and operate across a cellular (or similar) network. Thunder Bay would pay a monthly fee to access the network. Water meters would be replaced according to the replacement criteria (Section 4.4.5).

5.3. Revenue Improvement

One way to improve revenue is to replace aging meters. As mechanical water meters become older their component parts wear and the meter becomes less accurate over time.

Testing all meters is not practical due to the cost and disruption of customers. There are, however, industry estimates based on large-scale testing that can be applied to provide an approximation of the metering system's accuracy.

It is a common assumption that mechanical meter accuracy declines at a rate of 6% over a 20-year period. In order to take a conservative approach to the meter accuracy improvements associated with the project, we have downgraded this approximation by 75%. In other words, we only assume that meter accuracy will decline by 4.5% over 20 years.

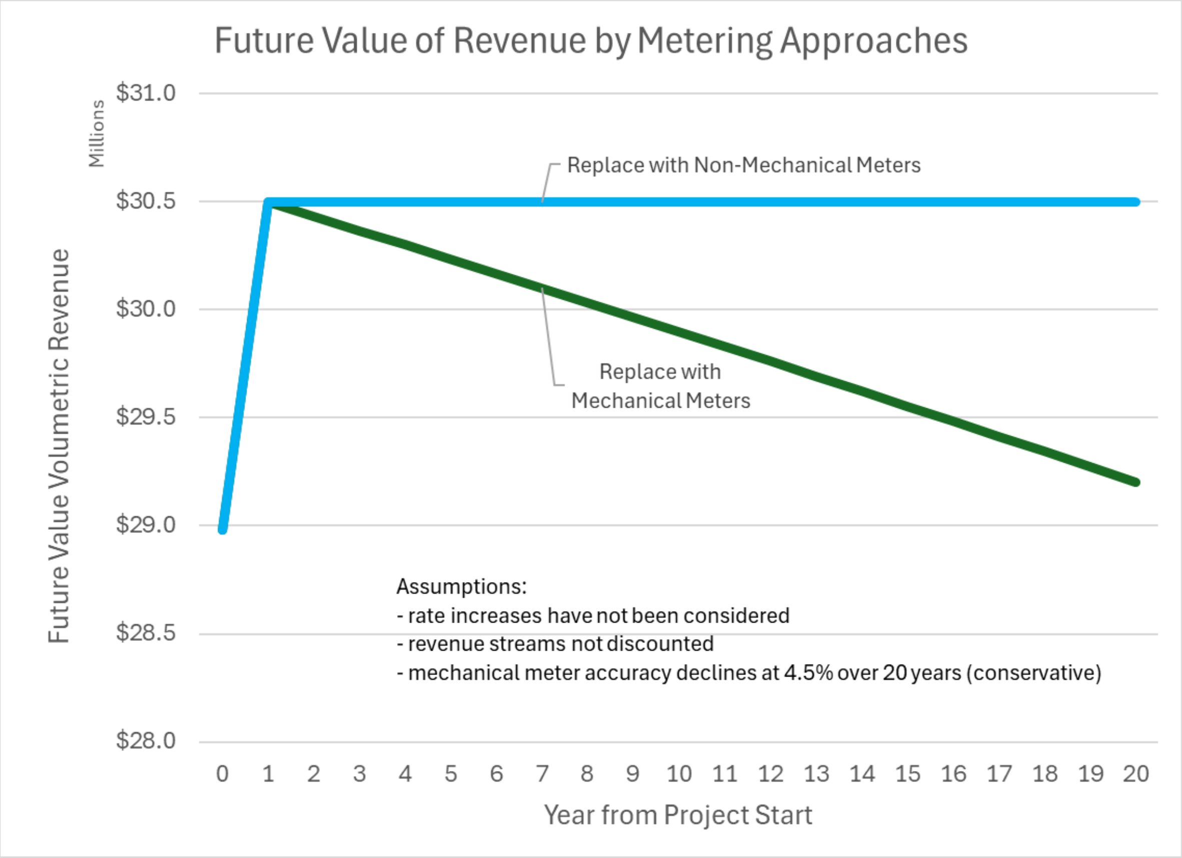
5.4. Revenue Improvement Calculation

The chart below shows the annual revenue improvements that can be expected by replacing the City of Thunder Bay's existing mechanical water meters with new mechanical meters. While mechanical meters generally have a life expectancy of about 20 years before needing to be replaced, the goal of the revenue improvement calculation is to show the accuracy improvement / revenue impact of the meters that will be changed.

It is expected that 33,491 meters will be changed as part of this project and the average age of those meters being replaced is 25.8 years old. While replacement mechanical meters are generally very close to 100% accurate upon installation, they too will wear and experience the same accuracy loss over time as the meters being replaced. That is, in 25.8 years the new meters will be no more accurate than the meters being removed as part of this project.

A graph is provided below to show the revenue projection over 20 years when installing mechanical meters and non-mechanical meters. For clarity, rate increases have not been considered. In 2023, the City of Thunder Bay's meters generated approximately $29 million in volumetric water and sewer revenue. As noted earlier, a conservative estimate of mechanical meter accuracy is that they decline 4.5% over 20 years. Once the City of Thunder Bay's meters are replaced with new non-mechanical meters which will capture roughly 100% of the available revenue, the expected volumetric revenue will increase to about $30.5 million per year. This is true for both mechanical and non-mechanical meters. While non-mechanical meters will retain their accuracy, mechanical meters will wear over time and result in the same 4.5% accuracy loss over 20 years. As noted in Section 6.7.8, non-mechanical meters require battery power and have an expected life of 20 years.

Exhibit 18: Revenue Projection Over 20 years



5.5. Operational Impacts

Some operational cost calculations can be easily determined. If these costs are eliminated, there is a direct impact on the utility's operational budget. Other costs can be more difficult to estimate, especially when they are based on time estimates or a theoretical efficiency calculation. Both types of costs are included in the operational financial impact calculations.

The financial impact calculation for each technology scenario is expected to deliver an estimate; some savings may be tangible, and others may be intangible if they create efficiencies where headcount reductions may not be desired. The assumed changes, and the overall financial impact of these changes, are summarized by function: meter reading, customer service and water billing, and meter maintenance, distribution system management and IT support costs.

The assumptions and calculations for each functional area are detailed below.

5.5.1. Meter Reading Impact

The City of Thunder Bay's current meter reading process obtains water meter readings by three methods: manually obtained water readings by City staff, customer provided reads, and estimated meter reads. Meter reading frequency is quarterly and has an annual cost of $210,967, based on 2023 data.

The estimated meter reading costs and financial impact for Scenario 0 (Current Scenario) as compared to Scenarios 1, 2, and 3 when using AMR / AMI is summarized below.

Exhibit 19: Meter Reading Cost Impact by Scenario

	Scenario 0 - Existing Manual Read Meters	**Scenario 1 - AMR Drive-by**	**Scenario 2 - AMI (TB Owned)**	**Scenario 3 - AMI (Cellular)**
Meter Reading Costs	$210,967	$69,303	$0	$0
Financial Impact	$0	$141,664	$210,967	$210,967

** The financial impact is what was used in the cashflow analysis.*

Note: A positive number is considered a "savings", a negative number is considered a "cost".

Scenario 1 would reduce the City of Thunder Bay's meter reading costs by $141,664 while Scenarios 2 and 3 would eliminate the entire $210,967 meter reading costs.

5.5.2. Water Billing and Customer Service

Within the customer service and water billing functions, there were several areas identified that could be impacted by the application of AMR / AMI technology. Some of these situations include estimated administration costs. Where technology may reduce the amount of effort required to resolve, we have calculated this as a cost reduction. In fact, it may be unlikely that the City of Thunder Bay will reduce their costs by these amounts, therefore they represent productivity improvements (efficiencies) or reductions.

An explanation of the situations is as follows:

- Water Bill Estimates: where the billing agent could not obtain a valid reading, and they are required to estimate the water bill based on past consumption.
- High bill complaint: where a customer calls to complain about a high-water bill. This requires a truck roll in some instances and call center time with the customer.
- Zero Consumption: where consumption has not changed between the current and past reading.
- Non-Payment: costs associated with collecting payments.

Following review with the City of Thunder Bay's customer service and billing department project team members, the estimated impact that new technology will have on the above activities is summarized in the table below by Scenario.

Exhibit 20: Water Billing and Customer Service Impact by Scenario

Assumptions	Scenario 1 - AMR Drive-by	Scenario 2 - AMI (TB Owned)	Scenario 3 - AMI (Cellular)
Change of Ownership (final read)	5% reduction	90% reduction	90% reduction
Meter Read High/Low bills	10% reduction	50% reduction	50% reduction
Meter Read High/Low bills - truck rolls	10% reduction	50% reduction	50% reduction
Meter Reading Corrections	90% reduction	90% reduction	90% reduction
Bill arrears activities	5% reduction	50% reduction	50% reduction
City Review Customer Provided Reading (IVR)	100% reduction	100% reduction	100% reduction
City Review Customer Provided Reading (WEB)	100% reduction	100% reduction	100% reduction
City Review Customer Provided Reading (PHONE)	100% reduction	100% reduction	100% reduction
City Review Customer Provided Reading (CARD)	100% reduction	100% reduction	100% reduction
Bill Dispute	10% reduction	90% reduction	90% reduction
Water Leak Credit process	10% reduction	65% reduction	65% reduction
Water invoices mail out	10% reduction	25% reduction	25% reduction
Estimates - too many consecutive	90% reduction	100% reduction	100% reduction
Non-working meters	50% reduction	50% reduction	50% reduction
Meter Exchanges	50% reduction	50% reduction	50% reduction

Based on Diameter's experience in working with other water utilities, it is expected that AMI data will allow the City of Thunder Bay to find other efficiencies within this department by better identifying and implementing improved customer service functions.

Exhibit 21: Water Billing and Customer Service Financial Impact by Scenario

Customer Service	**Scenario 0 - Existing Manual Read Meters**	**Scenario 1 - AMR Drive-by**	**Scenario 2 - AMI (TB Owned)**	**Scenario 3 - AMI (Cellular)**
Change of Ownership (final read)	$30,976	$14,713	$1,549	$1,549
Meter Read High/Low bills	$1,769	$796	$442	$442
Meter Read High/Low bills - truck rolls	$9,496	$8,546	$221	$221
Meter Reading Corrections	$2,600	$260	$260	$260
Bill arrears activities	$4,423	$4,201	$2,211	$2,211
City Review Customer Provided Reading (IVR)	$98,585	$0	$0	$0
City Review Customer Provided Reading (WEB)	$56,664	$0	$0	$0
City Review Customer Provided Reading (PHONE)	$39,556	$0	$0	$0
City Review Customer Provided Reading (CARD)	$4,259	$0	$0	$0
Bill Dispute	$3,317	$2,985	$332	$332
Water Leak Credit process	$995	$896	$348	$348
Water invoices mail out	$174,754	$157,279	$131,066	$131,066
Estimates - too many consecutive	$637	$64	$0	$0
Non-working meters	$6,864	$3,432	$3,432	$3,432
Grand Total	**$434,894**	**$193,172**	**$139,861**	**$139,861**
Financial Impact	**$0**	**$241,721**	**$295,033**	**$295,033**

Note: A positive number is considered a "savings", a negative number is considered a "cost".

5.5.3. Water Meter Maintenance

Applying technology to the City of Thunder Bay's water meter maintenance group may impact several tasks that are the responsibility of the department. In reviewing these tasks with City of Thunder Bay staff, financial benefit can be calculated and would be considered an efficiency gain where staff would be freed up for other tasks. Other areas, such as the loss of water/wastewater revenue due to zero consumption or reduced truck rolls, would be considered a positive budgetary impact.

The benefits that had value and their respective impacts are identified below:

Exhibit 22: Water Meter Maintenance Impact by Scenario

	Scenario 0 - Existing Manual Read Meters	**Scenario 1 - AMR Drive-by**	**Scenario 2 - AMI (TB Owned)**	**Scenario 3 - AMI (Cellular)**
Radio Transmitter - Maintenance/replacement (Labour)	N/A	0.4% of installations	0.4% of installations	0.4% of installations
Radio Transmitter - Maintenance/replacement (Product)	N/A	0.4% of installations	0.4% of installations	0.4% of installations
Turn-Off - Too many estimates (Labour)	No Impact	50% reduction	90% reduction	90% reduction
Turn-Off - Too many estimates (Truck roll)	No Impact	50% reduction	90% reduction	90% reduction
Turn-off (For Repair)	No Impact	90% reduction	90% reduction	90% reduction
Turn-off (For Repair)	No Impact	90% reduction	90% reduction	90% reduction
Turn on (For Repair)	No Impact	25% reduction	40% reduction	40% reduction
Turn on (For Repair)	No Impact	25% reduction	40% reduction	40% reduction
Exchange Meter	No Impact	75% reduction	75% reduction	75% reduction
Exchange Meter	No Impact	75% reduction	75% reduction	75% reduction
Exchange Meter	No Impact	75% reduction	75% reduction	75% reduction

The financial impacts are calculated in the table below. Some of the line items impact efficiencies whereas others have a financial impact. For example, radio transmitter maintenance/replacements is a task City of Thunder Bay staff currently does not undertake but will be required with AMR/AMI. This will not have a budgetary impact since no new staff will be required for this task but there is labour involved in the new work affecting efficiencies. Product for radio transmitter replacements will have a budgetary impact. Billing issues and High Consumption phone calls are expected to be reduced creating an efficiency gain whereas lost revenues associated with meters showing "zero consumption" or reduced truck rolls have a budgetary impact on the City of Thunder Bay.

Exhibit 23: Water Meter Maintenance Financial Impact by Scenario

	Scenario 0 - Existing Manual Read Meters	**Scenario 1 - AMR Drive-by**	**Scenario 2 - AMI (TB Owned)**	**Scenario 3 - AMI (Cellular)**
Radio Transmitter - Maintenance/replacement (Labour)	$0	$6,078	$6,078	$6,078
Radio Transmitter - Maintenance/replacement (Product)	$0	$14,132	$14,132	$14,132
Turn-Off - Too many estimates (Labour)	$1,911	$955	$191	$191
Turn-Off - Too many estimates (Truck roll)	$13,674	$6,837	$1,367	$1,367
Turn-off (For Repair)	$9,287	$929	$929	$929
Turn-off (For Repair)	$66,472	$6,647	$6,647	$6,647
Turn on (For Repair)	$9,287	$6,966	$5,572	$5,572
Turn on (For Repair)	$66,472	$49,854	$39,883	$39,883
Exchange Meter (Labour)	$2,335	$584	$584	$584
Exchange Meter (Truck roll)	$16,713	$4,178	$4,178	$4,178
Exchange Meter (Product)	$17,600	$4,400	$4,400	$4,400
Grand Total	**$203,752**	**$101,561**	**$83,963**	**$83,963**
Financial Impact	**$0**	**$102,191**	**$119,789**	**$119,789**

Note: A positive number is considered a “savings”, a negative number is considered a “cost”.

5.5.4. Distribution System Management

Meter reading technology can be used to better manage and potentially monitor system-wide NRW. Consumption data that an AMI system provides is an opportunity for utilities to focus on reducing NRW. District metering, for example, enables the utility to compare water being consumed in a district during a specific time period (e.g. 2 a.m. to 4 a.m.), with the water being provided to the district over the same time period so water losses can be determined. This requires not only a district meter with an AMI transmitter but also time stamped interval data (15 minute or hourly data) at the district meter as well as the consumption points with the appropriate resolution so water losses can be calculated.

A second way for a utility to improve distribution system management would be to structure the AMI fixed network to collect acoustic leak detection sensors, allowing the City of Thunder Bay to identify when and where a distribution system leak is occurring.

The proposed meter changeouts will generate the greatest benefit in reducing apparent losses by improving meter accuracy. Additionally, with daily consumption information, utilities can identify unauthorized water consumption much sooner through meters which have potentially stopped or where bypasses may have been opened.

Water Loss Management using AMI and more accurate metering would allow the City of Thunder Bay to have an impact on NRW (Both real and apparent water losses). The NRW calculation is detailed in the table below.

Exhibit 24: Distribution System Management Estimated Real and Apparent Water Losses

Description	Variables	Value
Total Water Produced (m^3)	16,142.000	
Total Water Billed (m^3)	10,757,185	$31,291,026
Non-Revenue Water (m^3)	5,384,815	
Real Losses *Value calculated based on marginal cost of water production*		
Real Losses (m^3) estimate	4,722,181	$849,993[7]
Real Losses (%)	29.3%	
Apparent Losses *Value calculated based on lost water & sewer volumetric revenue*		
Metering Inaccuracies (m^3) estimate	501,214	$1,515,880
Metering Inaccuracies (%)	5.0%	
Unauthorized Consumption (m^3) estimate	161,420	$596,221[8]
Unauthorized Consumption (%)	1.0%	
Total		**$2,962,093**

Preparing a water audit report, similar to the one above, on a frequent basis would allow the City of Thunder Bay to better measure changes in NRW. The ability to identify events contributing to water losses can help the City of Thunder Bay focus better on reduction efforts. The impact technology can have on reducing both real and apparent water losses is estimated in the table below.

[7] It is industry practice to calculate real water losses based on the marginal cost to produce the water which is $0.18 per m^3.
[8] Apparent losses represent water that was delivered to the consumer but did not generate revenue for the City. Apparent losses are valued based on the revenue that the City would have received if the consumer paid for the water received. Therefore, apparent losses are valued at the average water and sewer rate paid by the consumer.

Exhibit 25: Distribution System Management Impact by Scenario

	Scenario 0 - Existing Manual Read Meters	**Scenario 1 - AMR Drive-by**	**Scenario 2 - AMI (TB Owned)**	**Scenario 3 - AMI (Cellular)**
Current Real Losses	29.3%	29.3%	29.3%	29.3%
Improvement in Real Losses	No impact	No impact	No impact	No impact
Current Apparent Losses: Meter Inaccuracies	5.0%	5.0%	5.0%	5.0%
Improvement in Apparent Losses (meter replacements)	No impact	100%	100%	100%
Apparent Losses (meter replacements)	5.3%	0.0%	0.0%	0.0%
Current Apparent Losses: Unauthorized Consumption	1.0%	1.0%	1.0%	1.0%
Improvement in Apparent Losses	No impact	5%	20%	20%
Apparent Losses (leveraging technology)	No impact	0.95%	0.8%	0.8%

The financial impact of achieving these NRW for water targets is calculated in the table below. These amounts are used in the net present value calculation.

Exhibit 26: Distribution System Management Financial Impact

Non- Revenue Water	**Scenario 0 - Existing Manual Read Meters**	**Scenario 1 - AMR Drive-by**	**Scenario 2 - AMI (TB Owned)**	**Scenario 3 - AMI (Cellular)**
Real Losses	$849,993	$849,993	$849,993	$849,993
Apparent Losses: Meter Inaccuracies	$1,515,880	$0	$0	$0
Apparent Losses: Unauthorized Consumption	$596,221	$566,410	$476,977	$476,977
Total Non-Revenue Water	$2,962,093	$1,416,403	$1,326,969	$1,326,969
Total Financial Impact	**$80,000**	**$1,545,691**	**$1,635,124**	**$1,635,124**

Note: A positive number is considered a “savings”, a negative number is considered a “cost”.

5.5.5. IT Operational Costs

Meter reading software and equipment currently in use by the City of Thunder Bay requires very little IT support to operate and maintain.

The introduction of AMI technology will require additional IT support due to the number of software applications being added and the interfaces that need to be supported. Most of the water AMI vendors are moving (or have moved) to a Software as a Service (SaaS) model, which significantly reduces the responsibilities of Thunder Bay IT staff. For this reason, we have assumed all software will be SaaS where the license cost is calculated on an annual basis based on the number of transmitters. The table below summarizes the IT support assumptions:

Exhibit 27: IT Support Assumptions by Scenario

IT Software Activities	Scenario 0 - Existing Manual Read Meters	Scenario 1 - AMR Drive-by	Scenario 2 - AMI (TB Owned)	Scenario 3 - AMI (Cellular)
Manual Meter Reading Software	Assumes 100% of costs	Assumes 100% of costs	Assumes 20% of costs	Assumes 20% of costs
AMI Collection Software (SaaS)	Not Required	Not Required	$2.20 / Endpoint / Year	Not Required
Cellular Reading Charge	Not Required	Not Required	Not Required	$11.52 / Year
Customer Portal SaaS	Not Required	Not Required	Not Required	Not Required
RF License	Not Required	Not Required	Not Required	Not Required
Handheld Support Cost	Assumes 100% of costs	Assumes 20% of costs	Assumes 20% of costs	Assumes 20% of costs
Network maintenance	Not Required	Not Required	$3,750 / Collector / Year	Not Required

The financial improvements or additional expenses (negative savings) are summarized below.

Exhibit 28: IT Financial Impact by Scenario

IT Software Costs	Scenario 0 - Existing Manual Read Meters	Scenario 1 - AMR Drive-by	Scenario 2 - AMI (TB Owned)	Scenario 3 - AMI (Cellular)
Manual Meter Reading Software	$3,211	$3,211	$642	$642
AMI Collection Software (SaaS)	$0	$0	$83,578	$0
Cellular Reading Charge	$0	$0	$0	$437,645
Customer Portal SaaS	$0	$0	$0	$0
RF Licence	$0	$0	$0	$0
Handheld Support Cost	$6,000	$1,200	$1,200	$1,200
Network maintenance	$0	$7,500	$93,750	$0
Grand Total	**$9,211**	**$11,911**	**$179,170**	**$439,487**
Total Financial Impact	$0	**($2,700)**	**($169,959)**	**($430,276)**

Note: A positive number is considered a "savings", a negative number is considered a "cost"

5.5.6. Summary of Operational Impacts

The financial impact of AMI technology plays a big role in the benefit to the utility. The table below summarizes the departmental financial impact detailed above. Each scenario outlines the operational cost change to what is deployed today and is the value put into the net present value calculation.

Exhibit 29: Operational Financial Impact Summary

Operational Cost Category	Scenario 0 - Existing Manual Read Meters	Scenario 1 - AMR Drive-by	Scenario 2 - AMI (TB Owned)	Scenario 3 - AMI (Cellular)
Operational - Meter Reading	$0	$141,664	$210,967	$210,967
Operational - Meter Maintenance	$0	$102,191	$119,789	$119,789
Operational - Customer Services	$0	$241,721	$295,033	$295,033
Operational - System Management Improvements	$80,000	$1,545,691	$1,635,124	$1,635,124
Operational - IT Costs	$0	-$2,700	-$169,959	-$430,276
Total Financial Impact	**$80,000**	**$2,028,568**	**$2,090,954**	**$1,830,637**

Note: A positive number is considered a "savings", a negative number is considered a "cost"

5.6. Capital Costs

The capital cost of Scenarios 1, 2, and 3 assume the project will be done as a single continuous project with no delays or pauses in the deployment as this would lead to increased costs (i.e. Project Management). Where finance capacity is unavailable, alternative deployment strategies can be explored. Scenario 0 assumes meter changeouts are carried out over a 20-year period at the rate of 2000 per year.

The capital cost assumes the project is done with external resources. Project support is provided through a combination of internal and external (consulting) support resources.

Capital Costs assume the Procurement Phase, Startup, Proof of Concept and Main Deployment will be done over a 41-month timeframe.

5.6.1. Project Scope

A project of this nature is not a typical engineering project. It is a combination of products, services and software applications that need to be supported by both internal and external resources. When planning for an AMR/AMI project, the main cost categories would include:

- Installation Costs
- AMI/AMR Supply and Implementation Costs including software licensing and implementation
- Water Meter Supply Costs
- Project Support – Consulting Costs
- Project Support – Internal Resource Costs
- Contingency

At the end of the cost section, we compare total capital costs (all categories) for the three replacement criteria to provide some understanding of the cost impacts of the different strategies.

The financial model has several variables and assumptions. The scenarios may differ based on the type of technology being deployed.

5.6.2. Installation Cost

With any water meter project, there are always complications that can prevent the meter replacement or radio transmitter installation from happening. These issues usually include the water meter being enclosed behind a finished wall, valves not being operational, plumbing fittings that need to be replaced, or changes to the meter pit or pit lid to complete the work. The ability to convert as close to 100% of the water meters to the new technology as possible is a fundamental measurement of a successful program. To achieve this level of completion, the City of Thunder Bay needs to allow the installation contractor to overcome most of the above issues. Allowing for carpentry, plumbing, and valve replacement will support the project in achieving over 97% completion. Not including this work in the project would likely reduce the conversion to below 90%.

The table below summarizes the installation cost for all scenarios. It should be noted that these costs are expected to be the same regardless of technology.

Legend:
SM = Small Meter (15mm – 25mm)
IM = Intermediate Meter (40mm – 50mm)
LM = Large Meter (75mm and greater)
C/O = Changeout

Exhibit 30: Capital Cost - Installation Cost Summary

	Scenario 0 - Existing Manual Read Meters	**Scenario 1 - AMR Drive-by**	**Scenario 2 - AMI (TB Owned)**	**Scenario 3 - AMI (Cellular)**
ALL	$9,500	$589,293	$623,022	$614,848
SM - C/O	$2,787,310	$3,069,215	$3,069,215	$3,069,215
SM Extra Work	$1,949,260	$2,236,450	$2,236,450	$2,236,450
INT - C/O	$289,750	$286,450	$286,450	$286,450
INT Extra Work	$44,480	$51,405	$51,405	$51,405
LM - C/O	$242,150	$241,130	$241,130	$241,130
LM Extra Work	$62,625	$70,600	$70,600	$70,600
Grand Total	**$5,385,075**	**$6,544,543**	**$6,578,272**	**$6,570,098**

Meter change-outs for small meters (SM - C/O) for 15mm, 20mm and 25mm meters, intermediate meters (40mm and 50mm) and large meters (75mm and above) include the installation portion of the change out. Note that register upgrade installation costs are included for Scenarios 2 and 3.

The Extra Work where required (based on assumptions) is for valve replacement, plumbing, wire replacement, carpentry, freezing pipe in lieu of curb stop operation (if allowed), meter pit repairs, excavation, confined and crawl space entry. Since there can be multiple Extra Work line items at a single installation – such as valve replacement, minor construction/remediation work and crawl space entry at the same location – the number of Extra Work line items is expected to exceed the number of meters being changed out.

5.6.3. AMI Technology Cost

Scenarios 1, 2, or 3, are applicable to any AMR or AMI system manufacturer. The AMI/AMR project costs are summarized below by category. Note that Scenario 0 is not applicable for this table as there are no technology costs associated with that Scenario.

Exhibit 31: AMI Technology Cost Summary

	Scenario 0 - Existing Manual Read Meters	Scenario 1 - AMR Drive-by	Scenario 2 - AMI (TB Owned)	Scenario 3 - AMI (Cellular)
SM - Radio	N/A	$4,069,900	$4,069,900	$4,626,325
IM - Radio	N/A	$92,220	$92,220	$105,275
LM - Radio	N/A	$24,582	$24,582	$29,085
Fixed Network Collectors	N/A	$0	$807,500	$0
Handheld	N/A	$16,600	$10,800	$10,800
Mobile	N/A	$94,000	$0	$0
Implementation	N/A	$7,500	$160,000	$160,000
Software	N/A	$15,000	$0	$0
Training	N/A	$5,000	$27,500	$27,500
Hardware	N/A	Not required. Covered under service agreement.		
Grand Total	**$0**	**$4,324,802**	**$5,192,502**	**$4,958,985**

The software implementation costs would be associated with interfacing to the Infor IPS CIS, the chosen Customer Portal and the AMI data collection software / MDM. The interface costs also include those required during the installation phase between Infor IPS and the installer's Meter Installation System (MIS). Interface costs are vendor associated costs and do not include the City of Thunder Bay's effort required in the interface development. While the interface costs are based on similar municipal projects, it should be noted that given the current Infor IPS implementation, higher than average efforts may be required.

The additional cost of building a standalone AMI network (Scenario 2) is associated with the data collectors required for this scenario. Scenario 2 assumes vendors could leverage existing properties and/or towers from the City of Thunder Bay properties and Scenario 3 assumes existing cell towers would be utilized.

5.6.4. Water Meter Supply Cost

Existing water meter replacement criteria is defined by meter age and the presence of a high-resolution register. It is understood that in the City of Thunder Bay case, only meters installed in 2014 or later are to be retained since they are fitted with encoder registers with the appropriate resolution. Based on this meter replacement criteria, the meter supply costs only (not including AMI technology costs) are summarized below:

Exhibit 32: Capital Cost Water Meter Supply Cost Summary

	Scenario 0 - Existing Manual Read Meters	Scenario 1 - AMR Drive-by	Scenario 2 - AMI (TB Owned)	Scenario 3 - AMI (Cellular)
Small Meters	$4,797,975	$4,913,625	$4,913,625	$4,913,625
Intermediate Meters	$285,260	$520,450	$520,450	$520,450
Large Meters	$550,825	$566,840	$566,840	$566,840
Grand Total	**$5,634,060**	**$6,000,915**	**$6,000,915**	**$6,000,915**

Scenario 0 meter supply costs include remote reading devices but do not assume non-mechanical meters. The remaining costs for Scenarios 1, 2, and 3 assume non-mechanical meters, as detailed in Chapter 13 - Recommendations. All scenarios have an additional $67,000 in meter accessories (additional parts) for large meter replacements.

5.6.5. Project Support – Internal Resources Costs

The internal City of Thunder Bay costs were calculated based on salary and benefit information provided.

The following table provides an explanation of the FTE (Full Time Equivalent) effort associated with each type of role during the project.

Exhibit 33: Internal Project Support Impact

Project Support Assumptions	Scenario 0 - Existing Manual Read Meters	Scenario 1 - AMR Drive-by	Scenario 2 - AMI (TB Owned)	Scenario 3 - AMI (Cellular)
Project Manager	Current staffing allocation	During Startup and Project: 100% FTE for 28 months	During Startup, POC, and Project: 100% FTE for 31 months	During Startup, POC, and Project: 100% FTE for 31 months
Curbstop Operation	Current staffing allocation	During Startup and Project: 25% FTE for 28 months	During Startup and Project: 25% FTE for 28 months	During Startup and Project: 25% FTE for 28 months
Data Collector Coordination	N/A	N/A	During Startup and Project: 75% FTE for 6 months	N/A
AMI/AMR Analyst/Champion	N/A	N/A	During Startup and Project: 25% FTE for 28 months	During Startup and Project: 25% FTE for 28 months
IT SME - Applications	N/A	During Startup: 100% FTE (2) for 6 months	During Startup: 100% FTE (2) for 6 months	During Startup: 100% FTE (2) for 6 months
IT SME - Interface	N/A	During Startup: 100% FTE (2) for 6 months	During Startup: 100% FTE (2) for 6 months	During Startup: 100% FTE (2) for 6 months
Public Outreach	Current staffing allocation	During Startup and Project: 15% FTE for 25 months	During Startup and Project: 15% FTE for 25 months	During Startup and Project: 15% FTE for 25 months
Billing and Customer Service Supervisor	Current staffing allocation	During Startup, POC, and Project: 100% FTE for 31 months	During Startup, POC, and Project: 100% FTE for 31 months	During Startup, POC, and Project: 100% FTE for 31 months
Billing and Customer Service Billing Agent	Current staffing allocation	During Startup, POC, and Project: 100% FTE for 31 months	During Startup, POC, and Project: 100% FTE for 31 months	During Startup, POC, and Project: 100% FTE for 31 months

The internal project support costs over the duration of the project are summarized in the table below.

Exhibit 34: Internal Project Support Financial Impact

Internal Support Costs	Scenario 0 - Existing Manual Read Meters	Scenario 1 - AMR Drive-by	Scenario 2 - AMI (TB Owned)	Scenario 3 - AMI (Cellular)
PM	$140,833	$335,833	$335,833	$335,833
CIS Support	$120,867	$133,817	$208,475	$208,475
Communications	$36,000	$33,750	$33,750	$33,750
Facilities	$0	$0	$33,750	$0
IT Support	$0	$200,000	$250,000	$250,000
Meter Department	$71,183	$63,556	$63,556	$63,556
Grand Total	**$368,883**	**$766,956**	**$925,364**	**$891,614**

Some of the above roles, such as the Meter Department (field support), may be budgeted already within existing positions. If this is the case this additional cost may not be required within the financial plan. Note that Scenario 0 costs were condensed into the same project timeline as Scenarios 1 to 3 for comparison purposes only.

5.6.6. Project Support – Consulting Costs

The AMI/AMR subject matter expert consulting services costs for the entire project are summarized below:

Exhibit 35: Project Consulting Support Cost

Consulting Costs	Scenario 0 - Existing Manual Read Meters	Scenario 1 - AMR Drive-by	Scenario 2 - AMI (TB Owned)	Scenario 3 - AMI (Cellular)
Phase 2 - Procurement	N/A	$167,500	$193,750	$193,750
Phase 3 - Start Up	N/A	$233,750	$275,000	$275,000
Phase 4 - POC	N/A	$148,750	$175,000	$175,000
Phase 5 - Installation	N/A	$750,000	$750,000	$750,000
Phase 5 - Field Inspections	N/A	$325,000	$325,000	$325,000
Phase 6 - Close Out	N/A	$25,000	$25,000	$25,000
Disbursements	N/A	$92,500	$92,500	$92,500

Grand Total	N/A	**$1,742,500**	**$1,836,250**	**$1,836,250**

The procurement includes the development of a single procurement document and process. Where the procurement is broken into more than one procurement additional cost may apply.

Program management assumes a full-service project lead that includes contract management, interfacing support, installation Contractor management, public outreach, meeting management, key performance indicator monitoring and quality assurance.

5.6.7. Contingency

A project of this nature does require some contingency for unexpected installation, meter costs, or AMI technology costs. Given recent high inflation levels, Diameter has provided a 10% contingency on the supply of meters and radio transmitters. A 15% contingency on installations was applied to accommodate for slightly higher pricing due to the relative distance of the City of Thunder Bay from other population centres.

Exhibit 36: Capital Cost Contingency

Project Contingency Assumptions	Scenario 0 - Existing Manual Read Meters	Scenario 1 - AMR Drive-by	Scenario 2 - AMI (TB Owned)	Scenario 3 - AMI (Cellular)
Meter and AMR/AMI supply – 10%	$0	$1,060,072	$1,156,442	$1,133,090
Installation – 15%	$806,337	$893,288	$893,288	$893,288
Grand Total	**$806,337**	**$1,953,360**	**$2,049,729**	**$2,026,378**

5.6.8. Summary of Capital Costs

The table below provides a capital cost estimate based on a non-mechanical water meter.

Exhibit 37: Capital Cost Summary by Category

Capital Summary	Scenario 0 - Existing Manual Read Meters	Scenario 1 - AMR Drive-by	Scenario 2 - AMI (TB Owned)	Scenario 3 - AMI (Cellular)
Install	$5,385,075	$6,544,543	$6,578,272	$6,570,098
Meter Supply	$5,634,060	$6,000,915	$6,000,915	$6,000,915

Capital Summary	Scenario 0 - Existing Manual Read Meters	Scenario 1 - AMR Drive-by	Scenario 2 - AMI (TB Owned)	Scenario 3 - AMI (Cellular)
Meter Accessories	$67,000	$67,000	$67,000	$67,000
AMR/AMI Supply	$0	$4,324,802	$5,192,502	$4,958,985
CIS Support	$0	$208,000	$304,000	$304,000
Consulting	$0	$1,742,500	$1,836,250	$1,836,250
Project Support	$368,883	$766,956	$925,364	$891,614
Contingency	$806,337	$1,953,360	$2,049,729	$2,026,378
Grand Total	**$12,261,355**	**$21,608,076**	**$22,954,033**	**$22,655,240**

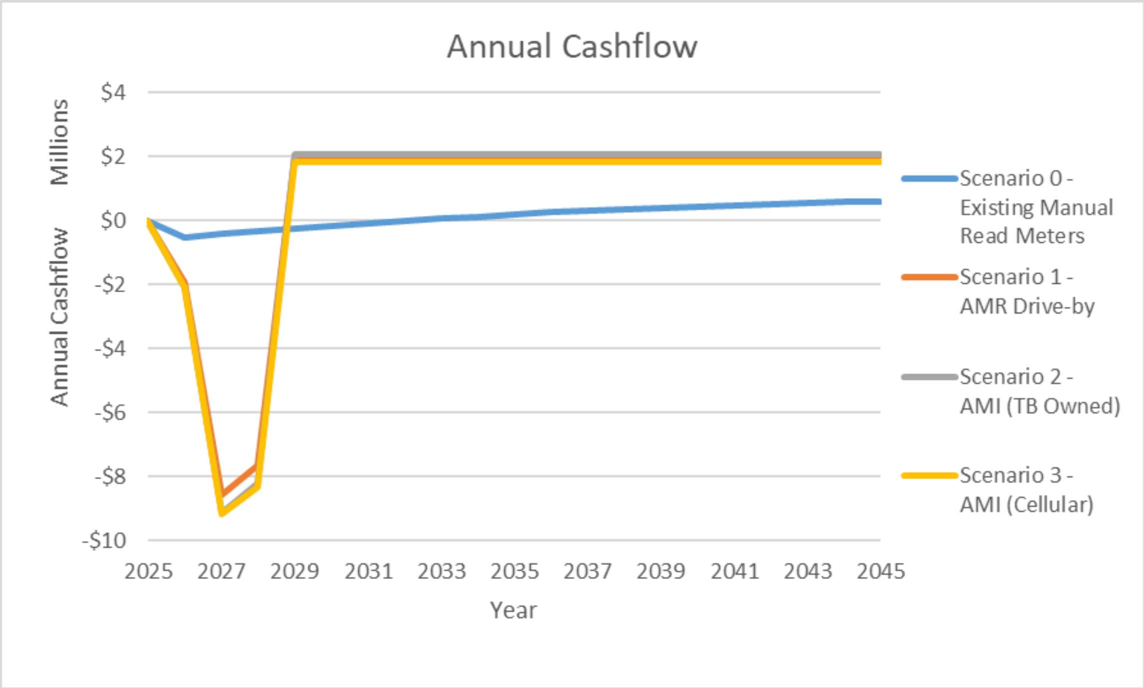
The above costs were used in the Cashflow analysis and spread out according to the deployment schedule.

5.6.9. Cashflow

Both the capital costs and operational financial impacts were considered in developing a long-term financial cashflow model.

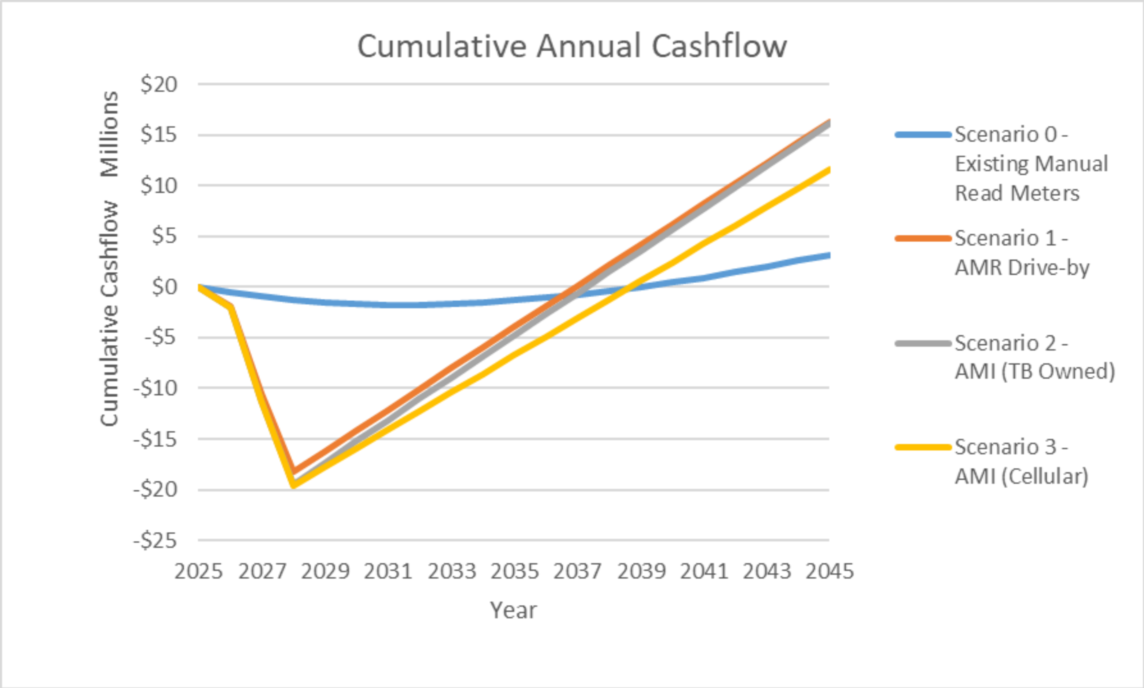
The graph below, in Exhibit 38: Annual Cashflow by Scenario, shows the annual impact of each scenario. The capital-intensive approaches in Scenarios 1, 2, and 3 see a significant investment in capital in the first 3 years, which results in an improvement in operating benefits over the remaining life of the system. We can see that the investment in AMR is nearly as much as the investments in AMI.

Exhibit 38: Annual Cashflow by Scenario



Considering the cumulative impact on cashflow over the 20-year life of the system, we can see that the operating costs of the Scenario 3, cellular AMI, have a significant impact on the overall cashflow of the project and extend the breakeven point by approximately 14 months.

Exhibit 39: Cumulative Annual Cashflow by Scenario



5.6.10. Results

Combining the financial impact estimated by area (meter reading, customer service and billing, meter maintenance, distribution system management, and IT) and the capital costs allows the total life cycle cost to be calculated. The Net Present Value (NPV) provides a good comparison between scenarios; an NPV of zero or greater would mean that over the 20-year life of the system, the capital cost was paid off by the annual benefits of revenue and operational improvements.

The table below shows a positive NPV for all Scenarios. Based on NPV solely, Scenario 1 (AMR) has the highest NPV based on slightly lower capital costs. Scenario 3 (AMI Cellular) is expected to be the worst-case scenario because of the high operational costs of cellular radio transmitters. The difference in the NPV between Scenario 2 (AMI TB Owned) and Scenario 3 is a result of the additional infrastructure costs required in Scenario 2.

Scenario 2 is the recommended approach for the City of Thunder Bay.

Exhibit 40: Capital Cost and NPV for the Entire Project using Mechanical Meters

Summary	Scenario 0 - Existing Manual Read Meters	Scenario 1 - AMR Drive-by	Scenario 2 - AMI (TB Owned)	Scenario 3 - AMI (Cellular)
Capital Costs	$12,261,355	$21,608,076	$22,954,033	$22,655,240
NPV	**$856,576**	**$3,943,271**	**$3,451,249**	**$732,967**

Combining the financial analysis with the non-financial implications of each scenario, we summarize the options below.

Exhibit 41: Financial and Non-Financial Implications by Scenario

Scenarios	Financial Implications	Non-Financial Implications
Scenario 0 – Existing Situation – Manual Meter Reading with mechanical meter replacements over a 20-year period.	• Lowest capital investment • Modest improvement in meter accuracy over time	• Does not address the essential or important business drives • Does not facilitate a move to monthly reading
Scenario 1 – AMR Drive By with non-mechanical meter replacements over a 2-year period	• High capital investment, comparable to AMI • Significant improvement in meter accuracy	• Only partially addresses 10 of 19 essential or important business drivers • Only partially facilitates a move to monthly reading

Scenarios	Financial Implications	Non-Financial Implications
Scenario 2 – AMI City Owned with non-mechanical meter replacements over a 2-year period	• High capital investment, comparable to AMR • Significant improvement in meter accuracy	• Fully or partially addresses all business drivers • Facilitates a move to monthly reading
Scenario 3 – AMI Cellular Network with non-mechanical meter replacements over a 2-year period	• High capital investment, comparable to AMR • Significant improvement in meter accuracy • High operating costs for monthly cellular charges impact project's return	• Fully or partially addresses all business drivers • Facilitates a move to monthly reading

Advanced Metering Infrastructure (AMI) provides a myriad of benefits to help improve a water utility's performance in areas such as metering, customer service, water loss management, pressure and backflow management. In addition, one of the major benefits of AMI is to help the City of Thunder Bay with its "customer experience" associated with the provision of water services. While there is tangible value in doing so, measuring the dollar value of a "happier customer' is challenging and therefore is not included in the NPV calculations but contribute to achieving the City of Thunder Bay's business drivers and customer service strategy.

As a result, Scenario 2, which includes a City-owned AMI system with non-mechanical meter replacements implemented over a 2-year period, is the recommended approach for the City of Thunder Bay.

6. OVERVIEW OF AMI/AMR AND METROLOGY

6.1. Introduction

This chapter provides a detailed discussion of the functionality, benefits, and implications for the City of Thunder Bay relating to Advanced Metering Infrastructure (AMI) and Automatic Meter Reading (AMR) technologies.

Meter reading technologies are discussed in more detail below and includes the following:

- Radio Frequency (RF)
- Automatic Meter Reading (AMR) Technology
- Advanced Metering Infrastructure (AMI) Technology
- Meter Data Management (MDM) Software
- Customer Engagement Portal (CEP)
- Water Meters & Registers
- Other Devices

Note that this section is a general overview of the types of technologies available on the market today and not a review of vendor-specific technologies. The latter will be conducted as part of the Procurement process. As such, items such as radio transmitter safety, and data security – which vary by vendor – will be discussed in more detail at the time of RFP preparation and review of proposals submitted.

6.2. Radio Frequency (RF)

6.2.1. Radio Frequency Overview

The use of radio frequency technologies is a proven approach to the wireless communication of meter reading data in North America since the late 1980s. RF is used in Automatic Meter Reading (AMR), Advanced Metering Infrastructure (AMI), and cellular AMI systems. Tens of millions of AMR or AMI devices using RF technology have been deployed in the North American water utility market[9] with even more in use by electric and gas utilities.

6.2.2. Radio Frequency Emissions

Radio waves are considered a form of electromagnetic radiation. Electromagnetic radiation is categorized as follows:

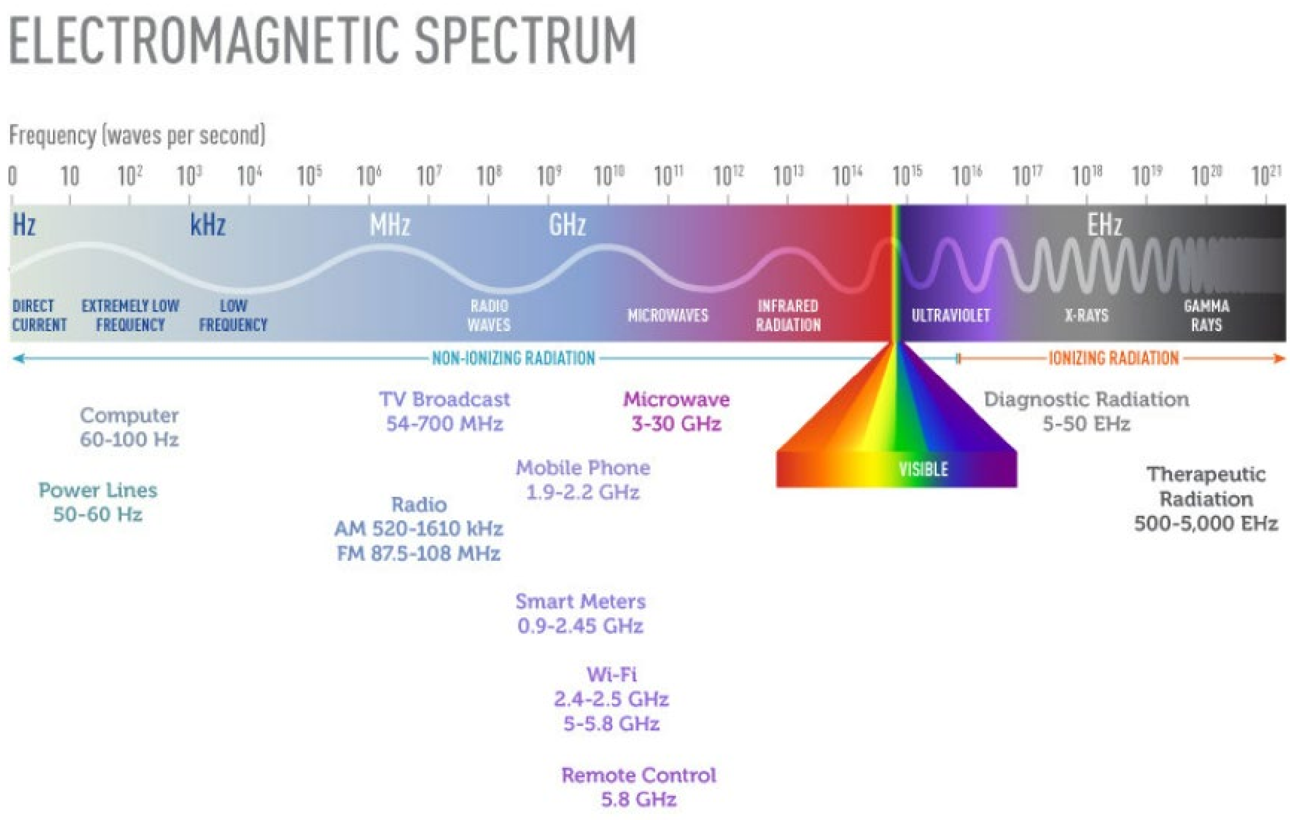
- Ionizing – High-energy radiation including x-rays, gamma rays and ultraviolet rays. These forms of radiation have enough energy to remove an electron from (ionize) an atom. This can damage the DNA (genes) inside of cells, which can sometimes lead to cancer.

[9] Diameter Services, based on data from The Scott Report through 2019 and estimated unit shipments from 2019 through 2022.

- Non-ionizing – Lower energy radiation that has enough energy to move atoms in a molecule around or cause them to vibrate, but not having enough energy to damage DNA directly. AMR/AMI radio transmitters and cell phones fall into this category.

“Because the amount of RF radiation you could be exposed to from a smart meter is much less than what you could be exposed to from a cell phone, it is very unlikely that living in a house with a smart meter increases risk of cancer.”[10]

Exhibit 42: Electromagnetic Spectrum[11]



Radio transmitters (noted in the graphic above as “Smart Meters” emit less radio frequency energy than commonly used wireless devices such as cell phones, baby monitors and microwave ovens. Unlicensed frequency devices have a power limitation of 1W per transmission while licensed frequency radio transmitters can provide up to 2W of power.

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[10] American Cancer Society, https://www.cancer.org/healthy/cancer-causes/radiation-exposure/smart-meters.html, accessed November 13. 2023.
[11] National Cancer Institute, sourced from https://www.cancer.org/healthy/cancer-causes/radiation-exposure/radiofrequency-radiation.html, accessed November 13, 2023.

The US Federal Communications Commission (FCC) implemented standards in 1985 to limit human exposure and protect against thermal effects of RF emissions. The FCC has adopted maximum permissible exposure (MPE) limits for radio transmitters of all types including smart meters. This rule limits RF products to 0.6mW.cm2, but most smart meter products only operate at 2% to 5% of this limit ensuring a large factor of safety.

Innovation, Science and Economic Development Canada (ISED) has similar requirements and only technologies that meet FCC and ISED standards will meet the specifications that will be included in the City of Thunder Bay's AMR/AMI Project.

The Health Canada website states the following regarding "smart meters" which is another name for AMI endpoints:

> *"There are no health risks from exposure to Radio Frequency (RF) Electric & Magnetic Fields (EMF) from smart meters. These devices must meet standards to ensure they do not exceed radio frequency EMF exposure limits.*
>
> *As with any device that emits radio frequency EMF, you will absorb some of the energy emitted by smart meters if you are nearby. The amount of energy you absorb depends largely on how close your body is to a smart meter.*
>
> *Your exposure to radio frequency EMF from smart meters is very low. This is because:*
>
> - *smart meters emit relatively low power signals,*
> - *there is distance between your body and smart meters,*
> - *smart meters transmit data in short bursts, not continuously, and*
> - *when smart meters are not transmitting a signal, they do not emit radio frequency "EMF"*[12]

The following link contains further information from Heath Canada as it relates to Smart Meters:

> https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/everyday-things-emit-radiation/smart-meters.html.

Furthermore, Diameter recommends installing radio transmitters outdoors. While the reason for this recommendation is not radio transmission safety, it may address concerns of some residents.

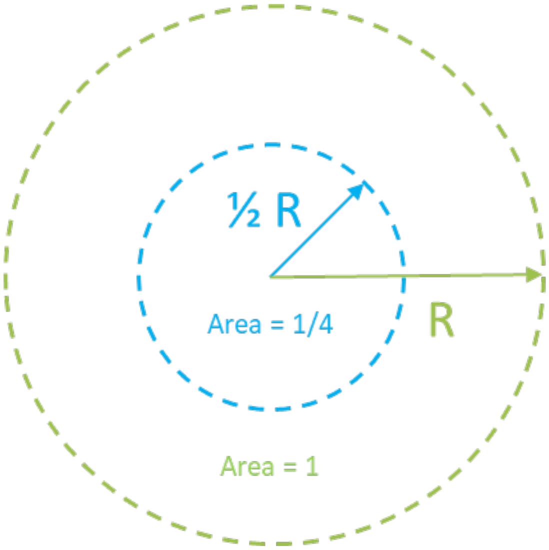
[12] Health Canada, https://www.canada.ca/en/health-canada/services/health-risks-safety/radiation/everyday-things-emit-radiation/smart-meters.html, accessed November 15, 2022.

6.2.3. Radio Transmitter Installation

Radio frequency signals can be impacted by a range of factors, not the least of which being obstructions between the transmitter and the receiver. To maximize system performance, radio transmitters should, where possible, be installed on the exterior wall of the building. Installation of the radio transmitter inside a wall, and often below grade, will likely have a significant impact on AMI system performance.

For illustration, if the range of the radio transmitters is cut in half (from R to ½ R), the area covered by that radio transmitter is reduced by ¾ (from 1 to ¼). As a result, four times as many data collectors are required to achieve the same system performance.

Exhibit 43: Impact of Reduction in Range on System Performance



6.2.4. Implications for the City of Thunder Bay

Even with substantiated evidence that supports the safety of AMI and AMR devices, some customers will voice concerns about the safety of the products. A small percentage of the City of Thunder Bay's customers will never be completely convinced that these products are safe to use. A very vocal minority can have a major impact on the deployment of an AMI/AMR project.

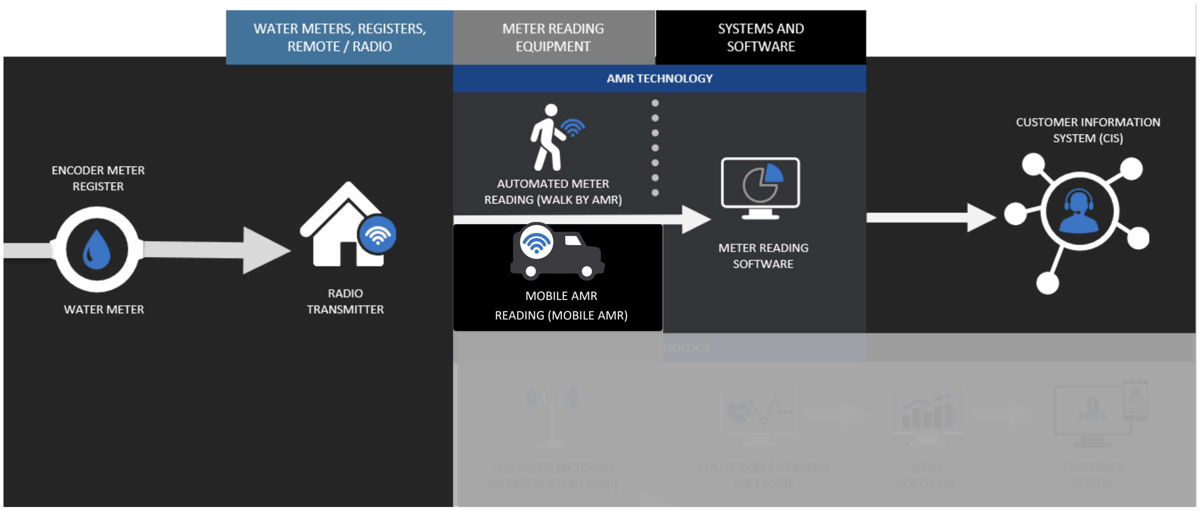
While this concern will be voiced by a small number of customers, the City of Thunder Bay should plan for this issue to arise and have a public outreach plan that includes information on the safety of the selected system and frequently asked questions. Further, the City of Thunder Bay will likely need to consider a compliance plan and opt-out program that addresses those few customers who refuse to allow a meter and radio transmitter to be installed.

6.3. AMR Technology

6.3.1. Technology Overview

The diagram below shows the critical components of an AMR system.

Exhibit 44: Walk-by System Diagram



6.3.2. Functionality

AMR technology collects meter readings from a radio transmitter that is attached to the water meter register and transmits the readings via RF to the handheld meter receiver. The readings will automatically associate with each property through the radio transmitter identification number. A meter reader travels through the meter reading area, either in "walk-by" mode using a handheld data collector or in a vehicle using a mobile data collector. This technology eliminates some of the inherent risks relating to meter reading on private property while increasing reading accuracy.

Regardless of how the readings make it into the data collector, at the end of each day, the readings are uploaded to the City of Thunder Bay's Customer Information System (CIS) via manufacturer-specific meter reading/route management software. This software not only collects meter readings to provide to the CIS but receives the meter reading routes assigned to the field devices from the CIS. This same software may have the ability to download and upload reads/routes from the field in some cases.

6.3.3. Features and Benefits

Radio transmitters provide several features and benefits that are not available with direct read or touch pad technology. These features are the same regardless of the device that reads them (AMR walk-by or AMR mobile).

Typically, the radio transmitter will read the meter every 15-minutes and store 96 readings per day in its internal memory. Algorithms in the radio transmitter use this data to create alerts including those listed below:

6.3.3.1. Continuous Use (aka Leak) Flag

If the radio transmitter identifies that all or most of the 96 readings show water consumption, a flag will be set to alert that continuous usage is suspected at the meter.

6.3.3.2. Reverse Consumption Detection Flag

If the radio transmitter identifies negative consumption, caused by water flowing backwards through the meter, a reverse flow flag will be set. Some systems distinguish between major and minor reverse flow conditions depending on the volume of recorded reverse flow.

The reverse flow flag can be a sign of plumbing issues that could result in contamination of the water supply. It could also be a sign of meter tampering if the customer attempted to show lower consumption by reversing the meter in the service.

6.3.3.3. Low Radio Transmitter Battery Flag

Most manufacturers' radio transmitters monitor expected battery life of their radio transmitter and issue alarms prior to expected device failure. There are two basic approaches to these alarms, neither of which are perfect, but may be useful if the City of Thunder Bay understands the technology's shortcomings.

It should be noted that a battery failure in the radio transmitter does not result in lost water, as the meter is typically still capturing consumption, even if the radio transmitter is not sending these readings. The consumption will still be captured by the meter and an accurate reading will be transmitted once the radio transmitter is replaced.

- Monitoring the voltage level of the battery and sending an alarm a short period of time before it is expected to no longer function (3 to 12 months). This may provide some notice to the City of Thunder Bay to initiate a work order to replace the radio transmitter/battery unit before the battery failure, so that fewer readings are missed. One drawback to this approach is that the standard battery technology, Lithium-ion tends to have a very stable voltage until the end of its useful life, so this approach may not provide much warning of coming failure.
- Time-based flags are used by some manufacturers to alert several months before the 20-year expected life. This approach also has its drawbacks in that it does not measure the actual voltage, it assumes that the device has operated in a statistically predictable manner. This approach cannot fully account for influences like temperature extremes, component variations or usage variations such as demand readings or over-the-air firmware upgrades.

6.3.3.4. Tamper Flag

Radio transmitters can determine if there is a communication error between the radio transmitter and the encoder register. Some systems can decipher between a cut wire, an incorrectly wired register, and a programming error/issue with the register. This flag may indicate potential meter tampering or other maintenance issues. These flags would initiate a response in the field to investigate and resolve the issue.

6.3.3.5. Data Logging

Certain manufacturers’ radio transmitters store the daily and hourly readings for the last 30 to 90 (dependent on manufacturer) days. This additional information can be used to resolve customer complaints. This data logging feature can provide the same type of hourly reading information an AMI system produces for individual customers who may request this information.

6.3.4. Implications for the City of Thunder Bay

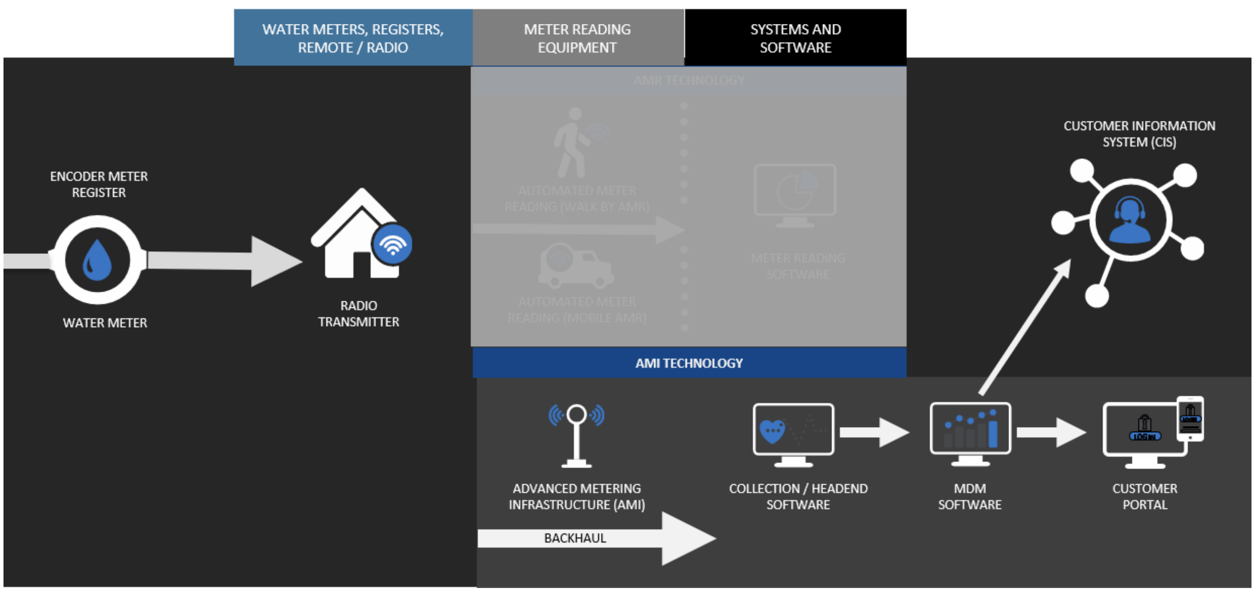
AMR would improve meter reading efficiency and effectiveness for the City of Thunder Bay over the current manual reading approach. Meter reading access issues, the need for customers to submit readings, and the need to estimate bills would largely be eliminated by AMR technology. Meter reader safety would also improve, as the need to enter customer property would be eliminated.

6.4. AMI Technology

6.4.1. Technology Overview

The diagram below shows the critical components of an AMI system.

Exhibit 45: AMI System Diagram



In an Advanced Metering Infrastructure, radio transmitters are read by permanently installed receivers or data collectors. These data collectors are strategically deployed in the geographic area by mounting them on poles, towers, or utility-owned buildings. The data collectors are connected to the collection software using a wide area network (WAN). The type of WAN utilized may vary but fiber, or cellular would-be typical examples. The collectors constantly receive data from the radio transmitters deployed and provide the information to the head-end data collection software.

For comparison, the big difference between AMR and AMI technologies is in the amount and timeliness of the information provided by each system. For example, an AMI radio transmitter reads the water meter register on an hourly basis (720 reads / month) compared to just once (1 read / month) with AMR mobile technology. And with AMI, these hourly readings are received daily along with relevant flags as opposed to every 30 days with AMR mobile. Reading transmissions are time-stamped as they are captured by the network.

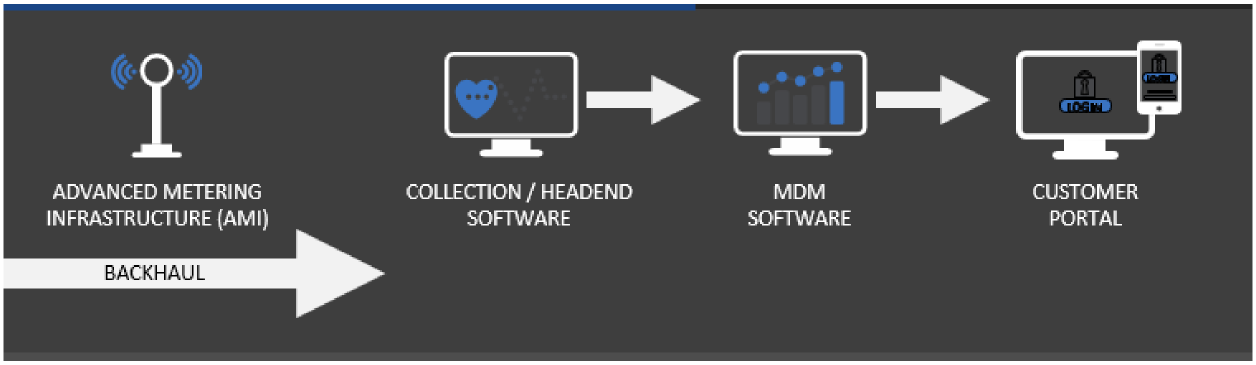
Interestingly, while AMI provides greater volumes of data compared to AMR, AMI networks typically have less radio noise than does AMR. This stems from the fact AMR radios are constantly broadcasting a meter reading (roughly every 8 – 15 seconds) in case the mobile collector is in the vicinity. To preserve battery life, AMI radio transmitters are programmed to transmit data daily or perhaps a few times per day.

6.4.2. Functionality

For comparison, AMR readings are collected when a meter reader's receiver, whether in a vehicle or in the meter reader's hand, passes within range of the radio transmitter. An AMI system collects these meter readings constantly and passes this data back to the utility at least once per day.

To accomplish this an AMI system comprises a Data Collection Network, Collection Software (also known as headend software), Meter Data Management (MDM) software, and often a Customer Portal application. The Customer Portal is not technically part of an AMI system, but it provides a valuable interface enabling customers to benefit from the AMI system with access to enhanced data, analytics, and alerts.

Exhibit 46: AMI Network Components



These four components have some unique considerations that should be understood when selecting an AMI solution best suited to a water utility. An AMI system can be deployed where the software applications are presented as a single application. This relatively simple configuration is less complex, allowing the system to be set up quickly. However, it may lack some of the functional elements required by certain utilities. Larger water utilities may find that best-in-class functionality is desired and will maximize the features available to the customer. This more complex configuration may lead to the water utility selecting an AMI Network and Headend software separate from the

MDM and Customer Portal. Often the Customer Portal is procured separately to ensure a best-in-class application has all the functionality the utility wants to provide for their customers.

Understanding the key considerations related to each component (Data Collection Network, Collection software, Meter Data Management Software, Customer Portal Software) is detailed in the sections below.

6.4.2.1. Data Collection Network

An AMI data collection network requires all water meter radio transmitters across the utility's service territory to be heard by at least one data collector. There are several approaches to obtaining this network coverage and considerations include whether the City of Thunder Bay or the vendor is responsible for the initial purchase and deployment of data collectors and who is responsible for the monitoring, maintenance, and support of the AMI network.

Establishing the data collection network of an AMI system can be one of the more challenging parts of a deployment effort. Finding and receiving the appropriate approval for locations that meet all the right conditions to allow the AMI network to collect readings for the metered population is often much more difficult than utilities anticipate.

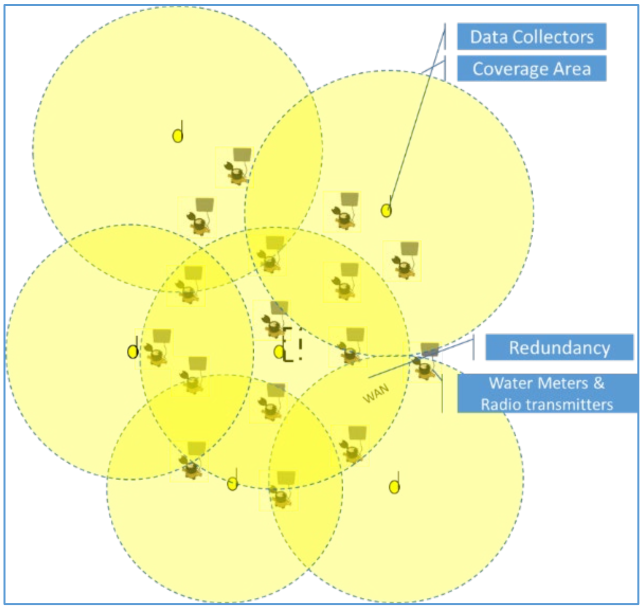
Propagation - Planning the appropriate number and location of data collectors is determined through a propagation study. This "prop" study provides a theoretical performance of the system based on many factors including: the topography of the geographic area being covered, the strength and frequency of transmissions, location of the radio transmitter (inside or outside), foliage, building "clutter", and the number, location, and height of data collectors.

Diameter will provide an initial "prop" study to inform the City of Thunder Bay's decisions on deployment challenges and system budgets.

As part of the procurement process, each vendor will be asked to provide a propagation study for the system that they are offering. This additional propagation study is valuable for two reasons. First, the vendors' study will be designed specifically for their system. Secondly, the vendor-provided propagation study will become a key part of the contractual agreement enabling the City of Thunder Bay to hold the vendor accountable for the cost and performance of their system.

Redundancy - Once a radio transmitter is installed, there are many factors that can disrupt the successful transmission and reception of the meter reading. To mitigate this risk, many AMI systems are designed to include a level of redundancy where any single radio transmitter can be "heard" by multiple collectors, ensuring that if one data collector misses a radio transmission, another is in a position where it can receive it.

Exhibit 47: Overlapping Data Collection Coverage Areas



Data Collector Location - Most utilities prefer to mount the system's data collectors on buildings, pump houses, and water towers that the utility owns. Installing data collectors on the roof of these locations (City-owned buildings, pump houses, water towers, and reservoirs, etc.) often avoids rental fees when installing the devices.

Alternating current (AC) power is also required at these locations and relatively easy to wire to the device. Another advantage to these locations is that the utility's intranet may be available for backhaul eliminating additional data costs. To achieve the level of redundancy required, it is very likely that these locations will not allow for the propagation study to cover the entire area, and more locations will need to be considered.

After considering its own existing buildings, the City of Thunder Bay could identify City-controlled unbuilt land that where poles could be installed specifically for the installation of data collectors. It should be noted that the installation of a new pole or tower infrastructure may be considered unsightly by community members. Irrespective to how unappealing this option is, a certain portion of the network will likely require newly installed poles to achieve the desired coverage.

Engineering Drawings and Approvals - Understanding the complete approval process that must be taken to install data collection equipment is important. Often very specific engineering drawings are required for approval and some municipalities may not have a defined process for approving network locations and installations. Some approval processes require extensive review or public notices and input.

Ensuring the process for approval is clear and well documented, regardless of the type of data collector, is vital for smooth deployment.

Wide Area Network/Backhaul - When planning for an AMI system, backhaul consideration is required to allow the collectors to pass data back to the collection software. Usually, the most cost-efficient WAN process would be to connect the data collector to the utility's intranet. This option would eliminate additional data charges; however, it could also introduce some network security risks. A utility may also have an existing fiber optic network that can allow access to their intranet. If this is the case, then the access points would need to be identified, so preferred locations could be planned around them. Cellular is often the most popular way to backhaul a data collector, especially if the data collector is installed on poles or privately-owned properties.

Shared and/or Third-Party AMI Network

A water utility's willingness to take on the risk and responsibility associated with AMI networks leads utilities to consider both a shared and/or third-party AMI network. Often shared or third-party networks are owned and operated by someone other than the water utility, but the water utility would leverage the network for its AMI deployment. The typical shared and/or third-party AMI network options include:

- *Cellular AMI Network (Shared & Third Party):* where the cellular radio transmitter communicates directly to the cellular provider that has adequate coverage across the service territory.

- *Overlapping Utility AMI Network (Shared & Third Party):* where the local electric or gas utility has already implemented an AMI network, and the water utility chooses the same AMI technology with the same RF frequency. This is not a likely scenario for the City of Thunder Bay as it would likely require cooperation with SynergyNorth and conformation with their technology decisions.

- *Vendor-owned AMI Network (Dedicated & Third Party):* where the AMI vendor proposes to stand-up and own the AMI network for the duration of the system's life and charges the utility a subscription fee.

Some detailed considerations for each type of approach are discussed below.

Cellular AMI Network:

Not all AMI/AMR vendors offer cellular AMI systems for the water market and those that do have different strategies. Some vendors offer cellular as their primary AMI solution while others use cellular transmitters to augment coverage (i.e., gap fill) for their dedicated RF AMI system. There are some benefits to using a cellular network including not having to worry about maintaining a separate network and no additional backhaul costs.

Some AMI vendors do market cellular radio transmitters using a newly released CAT-M chip, but some limit the product warranty and may not support a 20-year product life. Where the cellular product is supported by a 20-year warranty (10 full replacement value + 10 prorated replacement value) and the price of the radio transmitter is market competitive, this technology may compete with other proprietary RF systems. The cost of a cellular system needs to be evaluated over the full 20-year life, because the annual cost to operate this system can be higher than that of a standalone RF system. In recent procurements the cost of both the cellular product and the on-going operational costs have continued to decline making the cellular choice more competitive with proprietary RF systems. Usually, cellular AMI systems are more cost effective for small water utilities (less than 25,000 services).

Another option for deploying cellular radio transmitters could be to install them only in parts of the distribution system where the meters are dispersed or there is no cost-effective data collector location. This approach can benefit the overall system cost by eliminating the need for data collectors for only a few radio transmitters.

A consideration of cellular radio transmitters is on-going compatibility with cellular networks. That is, cellular networks continue to evolve with the purpose of providing more data at greater speeds but ensuring the utility's investment in cellular AMI technology over the expected 20 years is something vendors need to contend with. The last limitation that should be highlighted is regarding latency. A cellular radio transmitter is not always awake, so the latency of a command (remote shut off) could be delayed between 4 and 24 hours depending on the vendor.

Overlapping Utility AMI Network

As water utilities start to contemplate whether to implement AMI, they often look for efficiencies in partnering with the local gas or electric utility. However, if the water utility is a stand-alone utility and is not a multi-commodity utility the reality of cost savings is often smaller than expected. The entire cost of an AMI system consists of radio transmitters (85% of the total cost), AMI network (10% of the total costs), AMI software and implementation (5% of the total cost). If the water utility chooses this approach outside a procurement process, there would be reduced competitiveness for the radio transmitter price as fewer vendors address multi-utility AMI, which could quickly raise the cost of the overall system. Another challenge with this approach is that the parties involved in the partnership will likely have different objectives, budgets, data requirements, and service areas at some points in the expected 20-year life of the system. As a result, one or more of the partners could decide to take an alternate path in their AMI technology, potentially stranding the assets of the other party.

Vendor-owned AMI Network

AMI vendors may provide the option to own and operate the AMI network on behalf of the City of Thunder Bay. Although this option typically comes at a higher cost, it could be incorporated into procurement documents and compared against Utility-owned AMI networks.

Collection Software

An AMI system requires collection or headend software that receives the reading information from the collection network. This software monitors the network devices (collectors and radio transmitters) and can display and report on the different components in the field and their status. This software also passes the daily billable and hourly interval readings required to the MDM application, usually daily. Headend software is also typically used to perform network management (in proprietary networks) such as time synchronization messages to the various components of the network.

Some AMI software vendors limit the number of years hourly consumption data can be stored in this system due to its impact on performance as the database gets larger overtime.

As discussed within the Smart City AMI Network section, where a LoRaWAN technology is chosen, the collection software is replaced with the Network Management Application, and the AMI vendor application server.

6.4.2.2. Optional Capabilities

There are many manufacturers of AMI systems with some providing a unique set of features and functionalities. RFP specifications may reduce the number of systems that could compete during the procurement process. A list of necessary or preferred features would need to be discussed prior to procurement when specification documents are being developed.

Radio Transmitter Alerts and Flags

AMI radio transmitters may have algorithms within the radio transmitters that allow for various flags. Some AMI systems have not added this feature to their radio transmitters as the same functionality can be achieved at the collection/headend or MDM software by analyzing the hourly consumption data. The benefit of performing these functions through the software (collection or MDM) is that the utility can more easily change leak detection thresholds. As an example, if identifying continuous consumption of 1/100th of a cubic foot per hour creates too many events, the utility could easily alter how leaks are determined – i.e., more consumption per hour over a longer time frame. The second advantage of performing customer side leak detection with an AMI system is you do not need to wait for the water bill to identify a leak has occurred, the MDM can be configured to trigger an alarm over a much shorter time frame (say 3 days), so the alert being sent to the customer can better avoid high water bills.

Data Logging

With an AMI system, hourly reading information is delivered to the collection software. Additionally, some systems have designed their radio transmitters to store readings, which can act as another means of data redundancy within the overall system. These radio transmitters will transmit past readings as well as new ones. If a transmission is not heard by a data collector, the headend software can backfill these readings during a future transmission.

Software as a Service (SaaS) versus On-Premises Software

Data Collection, MDM and Customer portal software are all capable of being installed in-house on utility provided server hardware or in a professionally managed / hosted environment referred to as Software as a Service (SaaS). The decision to host or not to host certain pieces of software depend on several factors that include the following considerations:

- Reliability and Security,
- System Support and utility expertise,
- System maintenance,
- Help desk,
- Total life cycle,
- Scalability, and
- Customization.

These considerations and their levels of importance to the utility should be reviewed because hosting can increase the operational cost of the system. This will ensure that the utility gets all the information they require from the vendors to make the correct decision.

Time-Synchronized Readings and Two-way Communication

All currently marketed AMI systems are considered two-way communication systems. The functionality of two-way AMI systems is:

Time Synchronized Top of the Hour Readings – "clocks" in radio transmitters tend to drift and become inaccurate. Synchronization ensures that the timestamping of consumption is accurate, but it requires a two-way radio transmitter to receive the time stamp from the network. Meter readings can be time-synchronized to allow all readings in the utility's network to be read at the same time. An AMI system schedules these readings at the top of the hour (12:00, 1:00, 2:00, etc.) which allows hourly consumption periods to be easily compared.

On-demand Read – Some AMI systems allow a utility to request an on-demand reading. The reading may come from the data collector (in which case the reading may be a "few" hours old) or some systems may allow direct interrogation of the radio transmitter - understanding latency may be a factor in receiving the meter read quickly. That is, due to battery management, AMI radio transmitters are generally not always "listening" because of battery drain. However, when they "wake-up" to transmit data, they can remain "on" for a period to accept commands from the head-end software via the data collector. This might include meter reading for example. Most utilities are looking to obtain readings for final bills and a daily read pulled from the data collector would suffice. Final Bill reading can be accomplished by all AMI vendors in one way or another.

6.4.3. Implications for the City

As noted in chapter 3 Business Drivers (2.2.9), the City of Thunder Bay has a number of financial and non-financial reasons for considering the upgrade of its metering system and automation of its meter reading processes. Some non-financial reasons for considering automation include improvement in customer service and the ability to enhance distribution system monitoring. These business drivers are best achieved using AMI.

6.5. Meter Data Management (MDM) Software

6.5.1. Technology Overview

Meter Data Management software is required in an AMI system due to the large amount of readings and consumption data that needs to be stored, accessed, and reported on. This software can be procured from the AMI vendor as part of the AMI system, as part of a CIS application or can be procured separately as a standalone application. The MDM has several functions:

1. Data Repository – The software is optimized to store years' worth of data that an AMI system produces. For an AMI system that provides hourly readings, the MDM will need to store 8,760 readings and any alerts produced by the radio each year for every customer. Analyzing consumption patterns over a period of months or years necessitates the management of a large

amount of data that needs to be accessed and reported quickly. Most utilities store between three and five years of consumption data upon which time the data is generally aggregated and then deleted.

2. Validations, Editing and Estimation (VEE) – Depending on what the data is being used for, a utility may want the software to identify gaps in data or problem data and display estimates for that period of missing or suspect data. An MDM with VEE functionality can often define the types of data validations that can be performed, whereby a utility is able to create routines on how to handle the different situations. For example, if only 50% of the readings were received for a certain period, the validation will identify what is missing and then create estimates for the missing data. This will ensure when a customer graphs the data, it does not appear like there were large periods of no consumption. This functionality is often employed for electric smart meters. The need for this with a water utility may only be beneficial when displaying data through a customer web portal.
3. Reporting – Another function of an MDM is the ability to produce different types of reports in an efficient manner in comparison to custom SQL queries. Given the amount of data that is accessible, report generation can be problematic and can take up significant IT resources. MDMs provide a standard set of reports, in addition to a custom report builder which allows users to add fields of data or additional criteria and groupings.

   More advanced MDMs have built dashboards within their applications to display the data for the user, minimizing or eliminating reports being generated. More and more water based MDMs are better understanding how to make the data usable and actionable without giving the utility data overload. Water based MDMs continue to see significant development in functionality, which is why most manufacturers are leaning toward Software as a Service (SaaS), to allow for an agile approach to software development.
4. Utility Management – MDMs used for water utilities usually have modules that perform water utility functions such as: district metering, leak detection, misapplied meters, and water consumption program monitoring. Ideally, the MDM will have a Reports and User Interface application that will allow the user to easily use and modify this functionality.

MDM and collection software can also be interfaced with other utility systems such as geographic information system (GIS), supervisory control and data acquisition (SCADA), 311/CIS and works management software. These interfaced connections to other systems need to be well planned to ensure the costs and effort to develop the interface is matched or exceeded by the benefits provided. For example, it may be very critical to be able to open a work order for field personnel to investigate a high-water consumption event that the MDM has identified. In this case an interface from the work management software to the MDM may avoid manual entries and multiple staff engagement steps to resolve the problem in the field.

6.5.2. Enhanced Functionality

Larger utilities often have options beyond an AMI vendor-supplied MDM. For example, many Customer Information Systems (CIS) have an integrated MDM to make data management and implementation easier.

Larger utilities have also decided to procure a best-in-class MDM, which requires them to have a separate procurement for MDM. This allows the utility to choose the MDM that best meets the desired functionality.

The enhanced MDM functionality can include the following elements:

1. Meter and Radio transmitter asset management – the MDM can store all water meter and radio transmitter assets. This link to the account and premise numbers associated with the CIS is used for water billing. Some asset management applications can store maintenance history, RMA, warranty, and testing information.
2. Service orders based on the asset – once an asset has been identified as having a potential issue, the MDM would allow the utility to issue a service order to investigate and repair the asset. Depending on the MDM, this functionality may only issue the work order and may rely on a separate existing utility work order system in the field. This approach varies by vendor.
3. Customer Relationship management: the MDM would hold key customer information that is associated with the account and premises. This would allow communication to be sent to specific or subset group of customers (boil water alert, water outage, water conservation messages)
4. Water Billing and collection: where the MDM is an integrated application with the CIS, some water utilities implement MDM prior to CIS, then build on the functionality later.

6.5.3. Implications for the City of Thunder Bay

Diameter Services recommends the implementation of an AMI system with an integrated Meter Data Management (MDM) capability. The AMI systems on the market today are very well suited to provide the functionality and capacity required by the City of Thunder Bay, without the need for the additional expense of a separate MDM system.

6.6. Customer Engagement Portal (CEP)

6.6.1. Technology Overview

Most water utilities currently allow their customers to log in to view or download their water bill. Customers continue to expect more functionality through their internet and smart phone devices. Public utility operators (electric, gas, water) have been starting to address this expectation through more advanced customer portals.

With AMI, portals give customers access to their data to allow them to better understand their consumption. Portals allow them to set alarms and alerts to avoid unexpectedly large bills. This on-line experience differs depending on the type of customer facing application(s) selected. If the utility wants a seamless experience without the need for the customer to be redirected to different applications for consumption information, billing, and payments, then a third-party application is likely the best approach.

6.6.2. Implications for the City of Thunder Bay

The City of Thunder Bay is currently implementing a new billing system (CIS), transitioning to Infor IPS. This new CIS has an optional Customer Engagement Portal (CEP). As the City of Thunder Bay considers this change, the discussion on business drivers, detailed in Chapter 3 Business Drivers (2.2.9), will help to guide this decision. The City of Thunder Bay has determined that it will be important to provide an interactive experience for its customers, necessitating the portal to provide a range of functionality from bill viewing and payment to interactive usage monitoring and alerts.

6.7. Water Meter Technology

6.7.1. Introduction

Metrology within the water industry has been around for more than 100 years, and some of the original types of measurement technology continue to be used today. This section will explain how each type of measurement works, the history of measurement products, product availability, and key advantages and disadvantages associated with each type of measurement. Lastly, key specifications related to each type of technology will be compared.

6.7.2. AWWA Standards

The American Water Works Association (AWWA) is an industry organization that, among other functions, provides a set of standards for the meters used by water utilities today. With no overarching regulatory bodies in Canada or the United States governing the use of water meters, it is left to the discretion of each utility to determine meter testing, accuracy, and change-out requirements.

Some newer technologies have recently been approved by the AWWA. These standards provide water utilities with a common set of key characteristics (lay length, types of threads, materials of construction, etc.) and performance standards (accuracy at certain flow rates) that can be applied for comparison purposes during competitive procurement.

It is important to note that AWWA does not make recommendations, nor does it state preferences with respect to the type of metering technology, nor does AWWA validate that meter manufacturers adequately comply with the AWWA specifications. The water metering technology selection and validation functions, therefore, remain the responsibility of the water utility.

There are two categories with respect to the types of water metering technology: 1) mechanical measurement, and 2) non-mechanical measurement. The AWWA standards for some of the relevant metering categories are listed below. The relevant AWWA Standards that the City of Thunder Bay would use for the procurements for its AMI project are shown in **bold**.

- AWWA Standards for Mechanical Measurement
  - **C700-20 – Cold-Water Meters – Displacement Type, Metal Alloy Main Case**
  - C701-19 – Cold Water Meters – Turbine Type for Customer Service
  - C702-19 – Cold Water Meters – Compound Type
  - C703-19 – Cold Water Meters – Fire Service Type

    - C704-19 – Cold Water Meters – Propeller-Type Meters for Waterworks Applications
    - C706-96(R05) – Direct Reading, Remote-Registration Systems for Cold Water Meters
    - **C707-10(R16) – Encoder-Type Remote-Registration Systems for Cold Water Meters**
    - C708-19 – Cold-Water Meters – Multi-jet Type
    - C710-20 – Cold-Water Meters – Displacement Type, Plastic Main Case
    - C712-19 – Cold-Water Meters – Single-jet Type
- AWWA Standards for Non-mechanical Measurement
    - C713-19 – Cold-Water Meters – Fluidic Oscillator Type
    - **C715-18 – Cold-Water Meters – Electromagnetic and Ultrasonic Type, for Revenue Applications**
    - C750-19 – Transit-Time Flowmeters in Full Closed Circuits
    - C751-19 – Magnetic Inductive Flowmeters

Water utilities usually opt to use these standards during water meter procurement. Although these standards represent different types of measurement technology, many have similar applications. Some water utilities consider meters from different AWWA standards as comparable, thus different types of technologies (and AWWA standards) would be price comparable. Other water utilities restrict their procurement to a single AWWA standard for a single type of application. Because there are many manufacturers that produce meters that comply with each standard, this has a limited impact on the competitiveness of the procurement.

Although multiple standards may be allowed, the meter's performance and pricing may vary depending on the meter standard being used. Notably, the most common standard used in North America is the C700-20 positive displacement meter. Often water utilities restrict their residential water meter procurement to only allow meters that meet this standard. It is up to the water utility to decide which water meter standards will be allowed based on their experience and the manufacturer's stated product benefits.

6.7.3. Water Meters – Positive Displacement Type, Metal Alloy Main Case

Description of Measurement

Positive displacement type water meters measure the actual volume of water that flows through the measuring chamber. There are two types common in the North American industry: nutating disc and oscillating piston. Both the nutating disc and the oscillating piston measure volumes of water; the method in which they do so, however, differs slightly. Figures 8 and 9 below display how each type works.

Exhibit 48: Nutating Disc Measuring Element

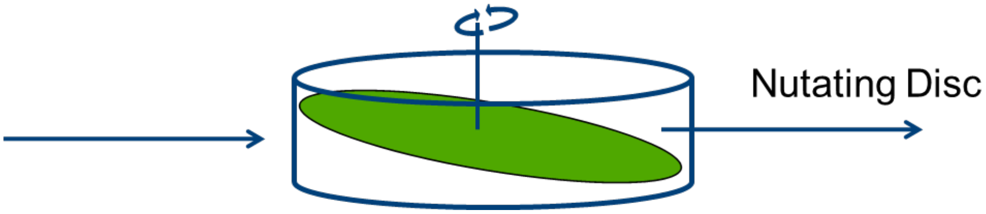
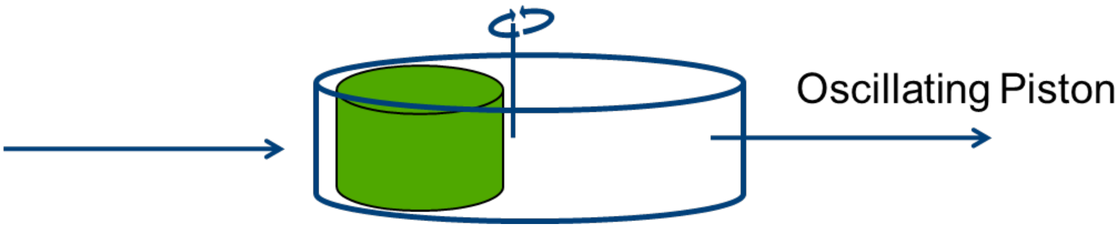


Exhibit 49: Oscillating Piston Measuring Element



As the disc or piston rotates around the axis, it turns a magnet. This movement is detected by a corresponding magnet located in the register head. This "magnetic coupling" allows both the meter body and the register head to be sealed, preventing leakage between the devices. For each manufacturer, a known number of rotations equal a unit of measure.

These meters are typically installed in a horizontal orientation, although manufacturers of piston type meters often also market a warranty for vertical installations. Nutating disc meters have been known to extend their warranty for vertical installation in special situations where this is a mandatory requirement.

History

Positive displacement type of measurement is the oldest (over 100 years in use) and most popular type of water meter used in North America. The patent for the nutating disc meter was filed by James A. Tilden in 1887 and 1888. The oscillating piston meter, patented by Lewis N. Nash in 1884, was adapted from older designs. It has proven to be a resilient and long-lasting water meter, with an expected life of between 15 and 25 years depending on the quality of the water it is measuring.

Market

There are five major domestic manufacturers of the positive displacement type water meters. These manufacturers include Badger Metering, Master Meter, Mueller, Neptune Technology Group, and Sensus Water Meters.

Advantages

Positive displacement type water meters are the most popular type of water meter in North America; most large water utilities rely on these meters for many of their residential applications.

These meters have good accuracy at low flows, with AWWA standards requiring these meters to achieve between 95% to 101.5% accuracy when measuring normal operational flow ranges (0.5 to 25 gpm). Many water meter manufacturers exceed this standard, either by exceeding the accuracy thresholds, or meeting the accuracy standard over a larger flow range. Different manufacturers publish slightly different performance specifications; however, at minimum, all major meter manufacturers meet the published AWWA specification requirements.

The positive displacement water meters do not require a power source to measure flow. The registers for some positive displacement water meters are powered by batteries; however, the measurement of flow is not dependent on this battery power source.

It is very rare for a positive displacement meter to over-register consumption. This provides some confidence to the utility that if a meter is inaccurate, it is to the benefit of the customer. If over-registration occurs, it is usually due to an incorrect water meter register being installed.

Disadvantages

Positive displacement water meter chambers and discs/pistons wear over time. As these meters wear, they become less accurate, allowing more water to pass through the meter undetected. Depending on the quality of the water it measures, the life of a meter is usually between 15 and 25 years. At this point, replacing older meters with new ones is likely to have a reasonable payback of around five years.

Because mechanical water meters have moving parts, they can sometimes make noise as water moves through the meter. Residents may complain of a ticking sound that can vibrate throughout the plumbing of the property.

The tolerances between the disc/piston and the measuring chamber are quite tight. And while most positive displacement meters have a built-in screen on the inlet side to reduce large particles of debris from entering the measuring chamber, debris in the water can jam the meter, stop the disc/piston from turning, and restrict the available flow. When this occurs, the meter stops registering consumption and requires either repair or replacement.

6.7.4. Water Meters – Positive Displacement Type, Plastic Main Case

Description of Measurement

Plastic Main Case meters use the same measuring elements (and registers) as their bronze counterparts and only the meter body material is different.

History

The market was influenced by factors including NSF/ANSI 61 Annex G and Annex F certification, and the Safe Drinking Water Act (NSF 372) that became effective January 4, 2014. Meter manufacturers needed to comply by providing lead-free alloy. As the price of metals continued to rise, some meter manufacturers offered composite materials as a substitute for metal meter construction.

Market

There are two major domestic manufacturers of positive displacement type meters constructed with plastic or composite material bodies. These manufacturers include Badger Meter and Sensus with Mueller discontinuing its plastic-body meter line effective November 2022.

Advantages

Replacing the brass body meter (C700-15) with a plastic/polymer/composite body can reduce the cost of the water meter between 5% and 10%.

Some manufacturers' composite/polymer meters have a burst pressure rating that is higher than the rating for a similar brass meter. Main case strength may have limited benefit to the utility because for both metal and plastic-body meters the burst pressure far exceeds normal utility operating pressure.

Disadvantages

One of the main issues related to plastic main cases is cross-threading. Installation issues are encountered when the plastic meter is threaded with brass meter tailpieces. If the meter is not aligned perfectly, the threads can be cross threaded, which makes the meter unusable until either the threads are repaired, or the meter is replaced. Cross-threading is not typically covered by the product warranty.

A second disadvantage reported by utilities is the inability for plastic/composite/polymer meters to withstand over torquing. Often a brass meter can withstand some torque due to the somewhat malleable nature of brass, whereas plastic/composite/polymer meters may break when subjected to the same conditions. In some cases, installers may tend to under torque the meter to avoid damage which can lead to repeat visits to the meter if it begins leak at the connection point following shifting or temperature changes.

Bronze-body meters are more recyclable than plastic-body meters, and there will likely be a difference in the scrap value/cost of these different designs.

Grounding the home's electrical system is a common practice. Installation of plastic-body meters will break to continuity of the home's internal plumbing and requires the installation of a grounding strap to maintain electrical continuity.

6.7.5. Water Meters – Turbine

Description of Measurement

Turbine meters are a type of velocity meter, where the turbine blades spin about a central shaft proportional to the rate of water flow through the meter.

History

Turbine style water meters are among the oldest metering technologies on the market.

Market

All the major North American water meter companies currently offer turbine meter technology including Badger, Master Meter, Mueller, Neptune, Sensus.

Advantages

Turbine water meters are designed for applications where flow rates are consistently moderate to high. They are less expensive than other meters of comparable size.

Disadvantages

Turbine meters are not well-suited to applications where low flow rates may be encountered due to their lower levels of accuracy at low flows. The accuracy of turbine meters can also be adversely impacted by certain plumbing conditions that cause turbulent or jetting flow. Unlike positive displacement meters, turbine meters can over-register.

6.7.6. Water Meters – Compound

Description of Measurement

Compound meters are designed to provide both low flow accuracy and high flow capacity. They do this by combining the measuring technologies of the positive displacement meter for low flow and turbine meter for high flow. As flow increases, a throttle valve directs an increasing proportion of the flow toward the turbine measuring element.

History

Compound meters have also been available for over 100 years and are the workhorse for the ICI applications for most North American water utilities.

Market

Several of the major North American meter manufacturers offer compound style meters including Badger, Mueller, Master Meter & Neptune. Sensus no longer sells compound style meters, opting to sell its OMNI C2 and F2 (fire flow) meters in those applications.

As non-mechanical meters including ultrasonic meter technologies gain traction in the market, it is expected that these will displace compound meters which are heavier, not as accurate and often more expensive.

Advantages

Wide flow ranges make the compound meter suited to a wide range of applications. The two-register design can be useful to determine meter sizing and maintenance issues.

Disadvantages

The point where the turbine measuring element engages and takes over some measurement from the positive displacement measuring element is called the “cross-over range”. Accuracy of the meter falls, often to as low as 90%-95%, for flows in the cross-over range.

The two-register design of the compound can cause reading and billing errors if the readings for each of the meter’s measuring elements become reversed or the billing multipliers are misapplied.

6.7.7. Water Meters – Fire Service

Description of Measurement

Fire service meters may be either turbine-style or compound-style. The difference between fire service meters and their standard turbine or compound counterparts is that fire service meters are equipped with high-capacity strainers and are rated to withstand higher water pressures. These product differences enable this class of meters to be UL (Underwriters Laboratory) listed and FM (Factory Mutual) approved; designations required to meet the requirements of fire suppression applications.

History

Fire service models of turbine and compound style meters have been sold in North America for over 100 years. They have become the standard meter for a wide range of applications that require measurement of fire-flows.

Market

Like compound meters, it is expected that new non-mechanical metering technologies will displace traditional mechanical fire service designs due to improved accuracy, lower cost, and ease of installation. Currently, mechanical fire service meters are marketed in North America by Badger, Master Meter, Mueller, Neptune, Sensus.

Advantages

Designed for specific applications where low flow accuracy, broad operating range and fire flow capacity make them ideally suited for applications with wide flow ranges that also serve fire suppression lines.

Disadvantages

Fire service meters are designed to meet harsh operating conditions and are therefore bulky and expensive.

6.7.8. Water Meters – Electromagnetic and Ultrasonic Type, for Revenue Applications

Description of Measurement

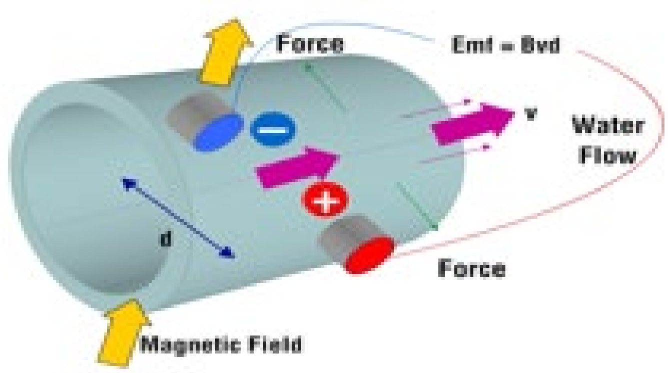
This AWWA standard applies to both Ultrasonic and Electromagnetic meters.

Electromagnetic water meters measure the voltage induced due to movement of water through a magnetic field. The amount of voltage induced is proportional to the velocity of the water. By determining the velocity of the water, and factoring in the cross-sectional area of the pipe, an algorithm then determines consumption for the flowrate. As a result, the sampling rate (i.e., how frequently the flow rate is determined) is important to the accuracy of an electromagnetic meter (i.e., more frequent sampling generally means higher accuracy rates).

Power is required to generate the magnetic field and for the sensors and comes from either battery or from AC depending on the manufacturer and the size of the meter.

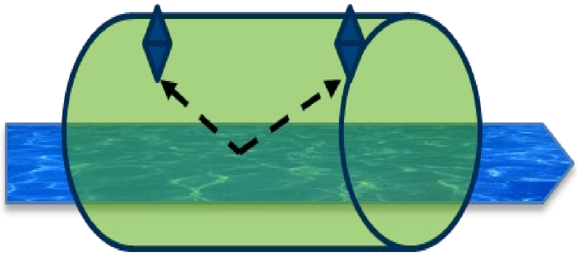
For small meters and some large meters, the power is provided by a battery. The battery generally has a 20-year warranty, typically represented by a “10/10 warranty,” which covers 100% of the replacement value for the first 10 years, and a prorated replacement value for years 11 through 20. This battery is typically “potted” and not replaceable in small meters. Intermediate and large “mag” meters are AC or DC powered and may have replaceable batteries depending on the manufacturer.

Exhibit 50: Electromagnetic Meter



Ultrasonic meters measure the time it takes for a sonic pulse to travel between two transducers. Pulses reflect off particulates in the water.

Exhibit 51: Ultrasonic Meter (Large Size Shown)



Additional features can be incorporated into electromagnetic and ultrasonic meters such as temperature, pressure, alarms, and remote shut-off within the existing meter lay length.

History

Electromagnetic consumption meters have been available in the market for about twenty years. Ultrasonic consumption meters have been readily available in the North America market for approximately five years, in sizes up to 2-inch. In recent years, manufacturers have started introducing this technology in larger meters. Some manufacturers have announced a plan to discontinue large mechanical meters in favour of ultrasonic designs.

Market

Electromagnetic meters: The only major manufacturer of residential electronic magnetic meter is Sensus Water Meters.

Ultrasonic meters: The major manufacturers of ultrasonic meters include Badger Meter, Diehl, Honeywell/Elster, Itron, Kamstrup, Master Meter, and Neptune Technology Group.

Advantages

Key features of non-mechanical meters over positive displacement meters are improved accuracy at very low flows, and very limited deterioration of accuracy over time. Additionally, non-mechanical meters typically have a single-register design making them easier to read and bill, therefore reducing the possibility of reading errors. They are also typically significantly lighter than mechanical meters, making them easier and safer to install.

They may also offer some additional features and functionality, depending on make and model, including:

- Alarm conditions such as: Empty pipe, reverse flow, tamper, low battery, leak detection, etc.
- Temperature reading
- Pressure reading

Although these may not apply to all manufacturer products, the additional functionality described above of these meters has expanded beyond just meter readings.

Non-mechanical meters are essentially an open pipe and unaffected by debris that can impact mechanical meter performance. Large non-mechanical meters are typically installed without strainers which is a requirement of their mechanical counterpart. The accuracy of the meter over time will not show any degradation. In theory, the meter should be as accurate at year 19 as it was on the day of shipment. So, there are no lost revenues over time, and the expected replacement date is defined which aids in capital planning.

Although there is a large discrepancy in pricing of non-mechanical meters among manufacturers, Large (non-mechanical) Meters are generally priced like mechanical meters of the same size. But, as mentioned above, Large non-mechanical meters, do not require strainers which is a cost savings.

Disadvantages

A key consideration is that this technology requires battery power to measure water flow. Typically, manufacturers offer a 20-year warranty. It is important to understand that these meters will have a known and firm product end date. This changes the water utility practice of performing meter accuracy sampling to determine the optimal replacement age. Meters in this class must be replaced prior to the end of their pre-determined (based on battery) meter age. Non-mechanical meters may provide a battery flag to the radio transmitter based on either voltage or meter age warning the utility the meter needs be changed.

Although this meter type is not new to the water industry, this is a new application of this meter type, and hence there is less history of performance and problems. It is not known/field proven if these meters will prove reliable long term.

The market has shown that Small and Intermediate electromagnetic and ultrasonic meters are typically more expensive due to lower manufacturing volumes as well as selling to water utilities based on some of the enhanced functionality. It is expected that these meters will eventually be competitively priced with positive displacement meters, but without a larger purchase volume, presently it is difficult to get the product cost to levels of a positive displacement meter.

With Large Meters, it should be noted that the cost-savings provided by eliminating the strainer may be offset by the requirement of spool pieces because of the different lay lengths of non-mechanical meters. However, most meter manufacturers have mirrored the lay lengths of mechanical meter counterparts. As an example, some 3" ultrasonic meters come in both 12" and 17" lay lengths to address both turbine and compound meter replacements. Furthermore, some non-mechanical meters do not include a test port, so a spool piece with a test port may be required.

Large Water Meter Specification Comparison

The table below shows a comparison of key performance characteristics of each type of meter technology.

Exhibit 52: Comparisons of Each Type of Meter Technology Used for Large Meters

Consideration	Turbine	Compound	Electromagnetic	Ultrasonic
Availability in North American market	>100 years	>100 years	~20 years (battery-powered)	~2 to 5 years
Size Range	1-1/2” to 12”	2” to 8” (10” fire service compound available)	1-1/2” to 24”	5/8” to 12”
Estimated meter life	20 to 30 (soft end-of-life with meter accuracy degrading over time)	20 to 30 (soft end-of-life with meter accuracy degrading over time)	20 (hard end-of-life with meter stopping when the battery dies)	20 (hard end-of-life with meter stopping when the battery dies)
Strainer Required	Yes	Yes	No	No
Power Source	None	None	Battery	Battery
Number of Suppliers	5+	5+	3+	4+
For the specifications below, a 4” meter was chosen as a representative meter size.				
Flow Range (100% +/- 1.5% accuracy)	10 to 1,200 gpm	1 to 1,000 gpm	5 to 1,250 gpm	1.5 to 1,250 gpm
Low flow (minimum 95% accuracy)	10 gpm	0.5 gpm	1.25 gpm	0.75 gpm
Accuracy Drops at Crossover?	No	Yes	No	No
Weight	52 lbs	100 lbs	37.4 lbs	51 lbs

6.7.9. Meter Register Technology

Introduction

The foundation of an AMI system is the water meter and register technology. The register head tracks and displays the total volume of water that has passed through the water meter. Many registers allow remote meter reading. Advances in register technology have enabled the introduction of many other features and benefits since the inception of AMI. Different meter manufacturers present different options. Diameter reviewed the key features of the different technologies and discussed the benefits.

Encoder Registers

Encoder technology is the most common water meter register used as the foundation of an AMI system. The AWWA standard that governs encoder registers is C707-10(R16). This technology allows the meter to be read directly from an AMI radio transmitter opposed to a pulse-type AMI-compatible register; an encoder register ensures that consumption is being recorded and read from a single source – the register.

Older encoder registers were limited by the mechanical nature of their designs and could only provide encoding of the 6-digit odometer. Newer designs that are more reliant on solid-state technology, can encode 8-digits of resolution, making the consumption data much more useful for usage analysis including leak detection. For example, the current 8-digit resolution on a typical residential meter allows remote reading to the nearest 1/100th of a cubic foot.

Encoder registers do have some compatibility limitations. There are two main encoder protocols that are now standard in the North American market: Sensus protocol (all meters except Neptune) and Neptune protocol. Fortunately, compatibility between encoder registers and radio transmitters has been enabled by various licensing agreements between the main players. Today, most radio transmitters are capable of reading both protocols. When procuring any encoder technology, water utilities must fully understand the limitations of what and who is able to read a meter register.

Digital Display

Some encoder registers are available with a digital display instead of a mechanical odometer display. These new registers may also allow for a toggle of the display, so the property owner or service personnel can see the flow rate, in various units, of water passing through the meter while it is being inspected together with any active alarm flags. This is a helpful feature that is often used during meter testing or when property owners want to understand a leak that may be at their building/residence.

One drawback of some digital displays is that they can be difficult to manually read or require a light source (flashlight) to view the display; this problem can be more pronounced in low light areas (meter pits, crawl spaces, etc.) or where dirt and water can impair visibility of the register (meter pits).

Detection Flags

Some advanced encoder meter registers and most AMI radio transmitters have detection flags (i.e., alarms conditions) embedded in the product. They have algorithms that detect certain simply defined conditions; once those conditions are met, a “Yes” flag is transmitted to the radio transmitter and data collector.

Common flags include a continuous consumption flag, a backflow detection flag, and a zero-consumption flag. The majority of meter and AMI manufacturers have designed the radio transmitter to perform the algorithms necessary to produce these flags, however a couple manufacturers perform these functions in the meter register. When flags are produced using the register head, often only that manufacturer’s AMI radio transmitter can access them. As a result, if an encoder register is responsible for performing these algorithms, then the utility may tie itself to a specific radio transmitter and water meter manufacturer if it chooses this kind of solution. On the other hand, when the radio transmitter performs these functions, the utility can continue to competitively procure a wider variety of water meters in the future.

Diameter recommends that the utility seek a solution that allows these flags to be generated and provided by the MDM or the radio transmitter rather than a solution where flags are provided by the encoder register.

High Resolution Encoder Registers

A high-resolution water meter register allows for more precise increments to be recorded (e.g. 1 litre) and communicated through the AMI radio transmitter. Most meter manufacturers have standardized high resolution encoder registers since they best address many of the common business needs of the water market such as leak detection. As a result, this specification will not limit procurement to a single manufacturer and will not impact the cost of the meter.

Exhibit 53: Reading Resolution by Meter Size of High Resolution (8-Digit) Encoders

Registration in cubic metres	Movable Encoded Digits ← Most Significant				Highest Resolution →				Optional Not Encoded
Register Digit →	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
16mm – 25mm	10,000	1,000	100	10	1	0.1	0.01	0.001	0.0001
38mm – 100mm	100,000	10,000	1,000	100	10	1	0.1	0.01	0.001
150mm and up	1,000,000	100,000	10,000	1,000	100	10	1	0.1	0.01

As an example, to demonstrate the difference between high- and low-resolution registers, a typical residential sized (i.e., 5/8" to 1") meter with a low-resolution register would provide a remote reading to the nearest 500 litres (depending on the age and design of the register). A high-resolution register provides resolution to the nearest 1 litre. See the comparison of relative register resolutions in Exhibit 54: Comparison of Low and Encoder Registers.

Exhibit 54: Comparison of Low- and High-Resolution Encoder Registers

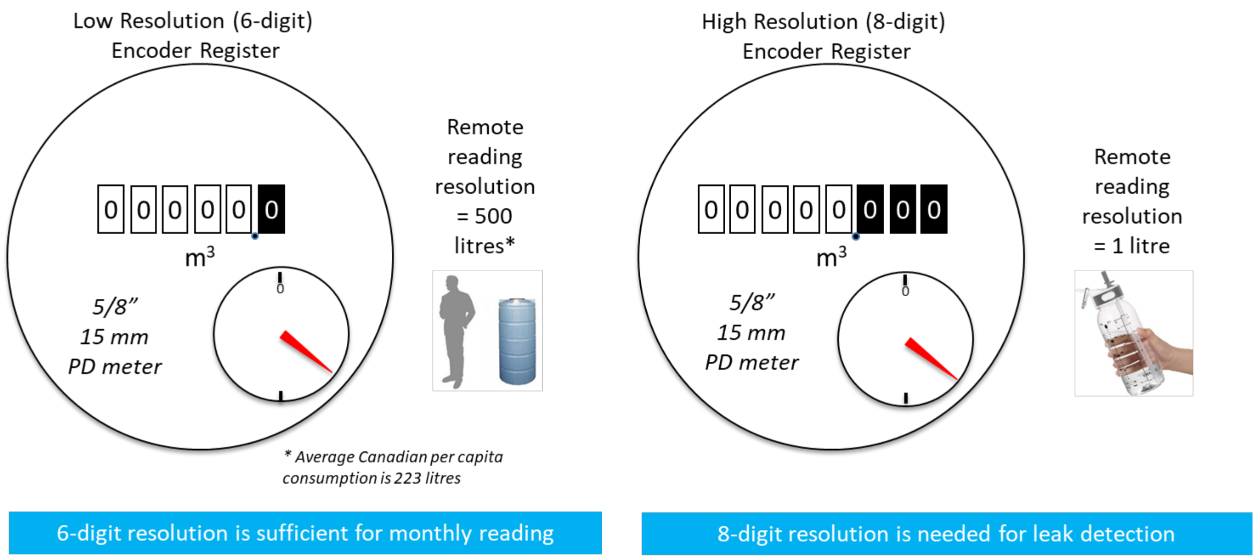
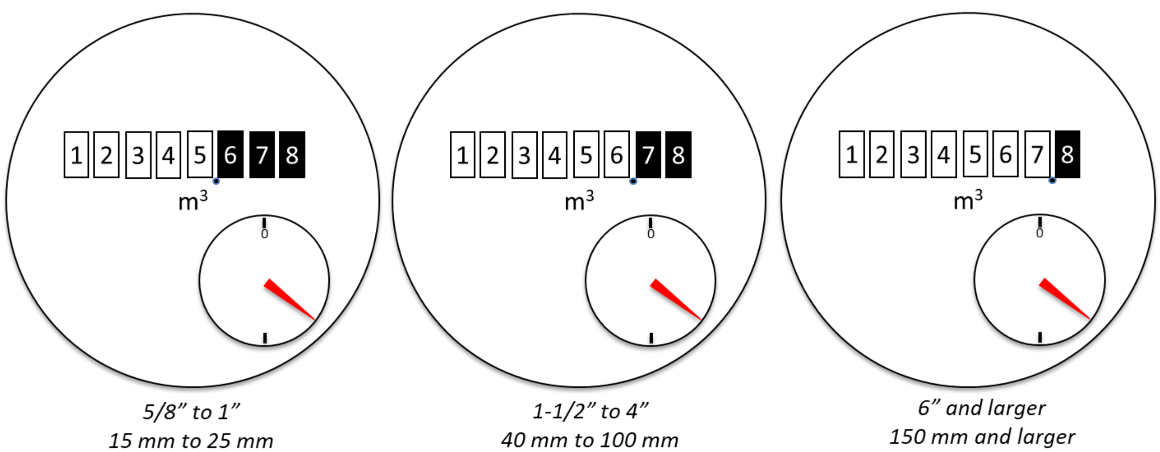


Exhibit 55: High Resolution Encoder Registers by Size shows the register resolution for various meter sizes.

Exhibit 55: High Resolution Encoder Registers by Size



Billing read:	12345 m^3	123456 m^3	1234567 m^3
Remote resolution:	1 litre	10 litres	100 litres

In Exhibit 56: Continuous Flow Condition - High vs Low Resolution Encoder Registers, data from an actual AMI system on the left (8-Digit Encoder) is compared to how that same scenario would have been graphed if the water meter was equipped with a 6-Digit Encoder (right). The high-resolution encoder allows the user to clearly identify that consumption on an hourly basis never reaches zero – a key indicator of a continuous flow conditions such as a customer-side leak.

Exhibit 56: Continuous Flow Condition - High vs Low Resolution Encoder Registers

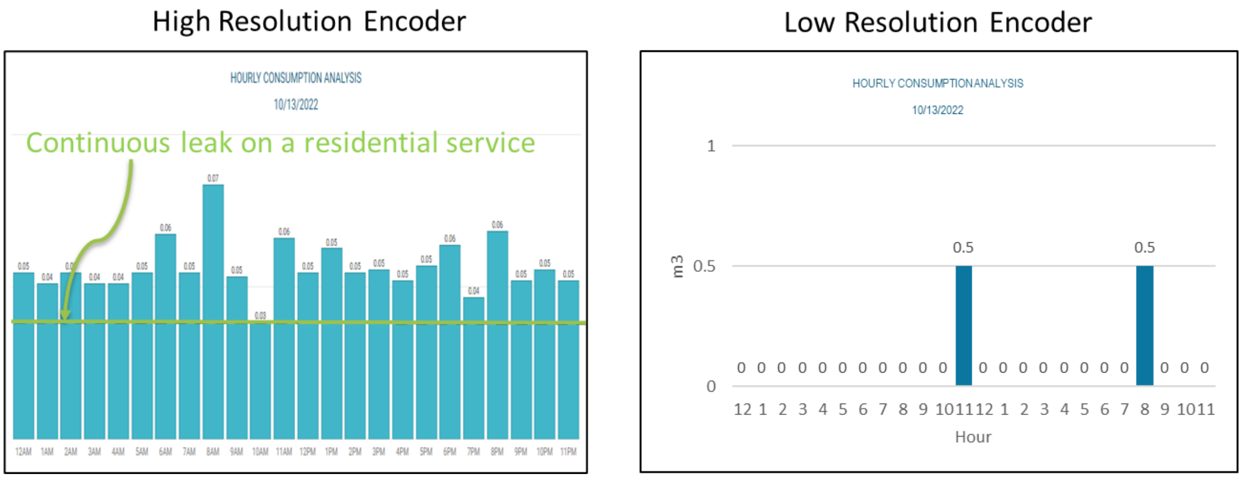
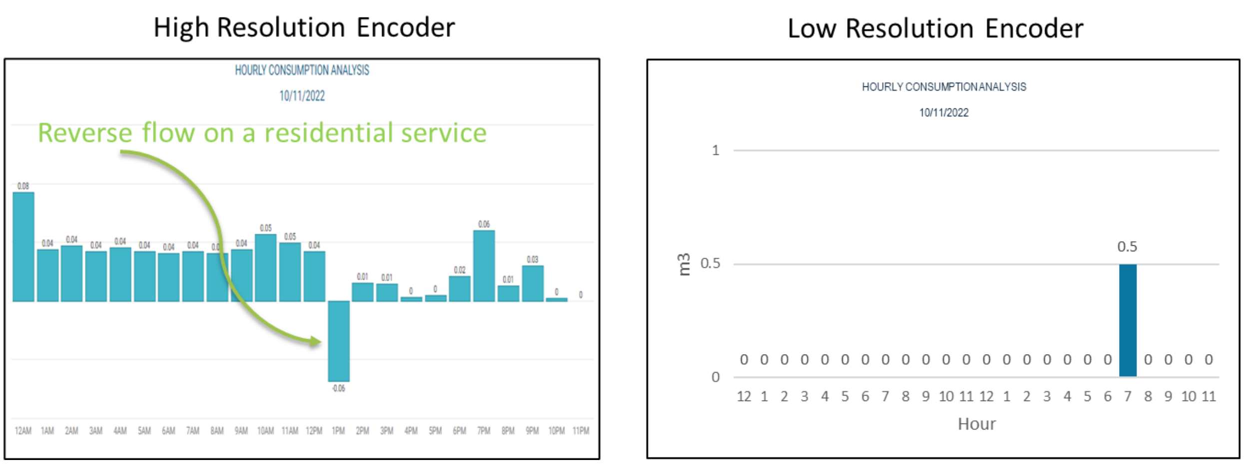


Exhibit 57: Reverse Flow - High vs Low Resolution Encoder Registers illustrates the comparison of high versus low resolution encoder registers and their ability to identify a reverse flow condition. The high-resolution encoder on the right clearly catches the reverse flow condition while the low-resolution encoder does not.

Exhibit 57: Reverse Flow - High vs Low Resolution Encoder Registers



Integrated Radio with Register

Some meter manufacturers offer integrated encoder registers with a built-in radio transmitter (often referred to as “radio under the glass”). The single product comes shipped attached to a water meter and requires no installation of the radio transmitter itself. Some manufacturers require the installer to activate the radio transmitters by sweeping a magnet across a location on the register, while others detect water moving through the meter which activates the radio transmitter.

The main benefit of this type of product is ease of installation. The installer does not have to run a wire, connect the wire to the meter encoder, and at times program the radio transmitter. An integrated radio transmitter and encoder register does not require these additional installation steps and there is no future maintenance required for the wiring.

A disadvantage to an AMI solution that is built on an integrated radio transmitter and encoder register is that this type of product eliminates competitive water meter purchases for the entire life of the system (typically 15 to 20 years). An AMI system already has restrictive RF protocols that prevent a utility from using radio transmitters from a different supplier. Combining a radio transmitter with the integrated water meter register puts the same procurement restriction on the water meter purchase. In the future, if issues develop relating to product quality or pricing the utility will have limited options for alternatives.

Another disadvantage of the integrated radio transmitter and encoder register is that the radio is located in the same environment as the water meter, i.e., in a basement or under a meter box lid. In order to not reduce the range of the radio's communication, these devices should offer the ability to connect to a remote antenna that can be installed on the exterior surface of the building or meter box lid.

Some ultrasonic meters have an integrated radio transmitter with the meter register, allowing a single battery to perform the reading and transmission functions. These should be evaluated with the additional risk discussed above.

For these reasons, Diameter recommends caution in considering a solution that requires an integrated radio transmitter and encoder register. The short-term benefits (ease of installation) may expose a utility to long-term risk.

Manufacturers who market an integrated radio transmitter with the register are:

- Neptune R900i product
- Sensus Ally electro-magnetic meter
- Kamstrup MULTICAL 21 / FlowIQ 21xx water meter
- Diehl
- Master Meter

Registers that Adapt / Program to Different Meter Manufacturers

Some companies offer encoder registers that can be installed on other manufacturers' water meters. These registers can be programmed to specific gear ratios (number of rotations / units of measure) and record the water moving through the meter. The programming depends on the installer selecting the correct meter manufacturer, meter model, and size. Any issues with this programming can lead to high or low registration. Some manufacturers also include the AMI radio transmitter integrated into this register.

While the flexibility of this register design is attractive on the surface, there are significant disadvantages to this type of product:

- Programming can be problematic, and any type of installation error could lead to significant billing issues. If the public loses confidence in the water meter used by the utility, it could force a 100% inspection to ensure that programming is correct on all meters.
- Neither the meter manufacturer nor the retrofit register manufacturer will cover warranty coverage the combined product as installed, meaning that any issue with meter accuracy or readings are the problem of the water utility.

Manufacturers of these types of products include:

- Master Meter 3G Interpreter, Elinx Interpreter
- Metron-Farnier i8

Due to the high impact of installation programming errors, and the loss of warranty coverage, this category of product is not recommended by Diameter.

6.7.10. Implications for the City of Thunder Bay

Diameter Services recommends that high resolution encoder registers be the standard for all future meter purchases. The higher resolution along with the frequent reading capability of AMI, offer a range of benefits including continuous flow, reverse flow, and leak detection indications that are extremely helpful in troubleshooting various water usage situations.

For meters that are being retrofitted with new registers, those registers should be provided by the same manufacturer as the meter. Any other combination of meter and register can lead to errors and loss of product warranty.

6.8. Other Field Sensor Technology

6.8.1. Remote Shut-off Valves

Using their two-way communications capabilities, some AMI systems enable the use of remote shut off valves. These valves would be able to reduce flow to a site or turn off completely without the need for someone to visit the property.

Due to the challenges and expense of manual disconnection and reconnection of service, some utilities find this an attractive option. There are drawbacks, however. These devices are expensive, adding significant cost to each installation. There are also social ramifications and if these devices are not installed on all water services, the utility may be perceived as targeting customers who are economically disadvantaged.

Installation of these devices can also be more challenging, as they will likely require changes to the meter setting or installing a specific manufacturer water meter that includes a remote shut off device within the meter itself.

Some water meters have recently been introduced with remote shut off capability within the standard water meter lay length, which would address some of the increased cost of installing this feature.

Some good applications for these products would include:

- Tenant properties with high tenant turn over. Some university or college areas may have many new customers every year and it could be challenging and costly to utilize collection agencies and transfer charges to Tax Roll.
- Parent and child meters, some utilities have properties with a single curb stop but multiple customers, so if a single customer does not pay their bill there is no means for the utility to shut them off.
- Seasonal services – where the water is shut off and turned on twice or more each year, having a remote shut off meter may help reduce truck rolls.

6.8.2. Acoustic Leak Detection

An optional addition to an AMI/AMR system is the installation of acoustic leak detection (ALD) devices across part or all the utility's water system. These devices could be permanent or temporary installations where the devices are picked up and relocated on a regular basis. These devices measure the noise of the water flowing in the system and send these acoustic readings through several radio transmitters in the network. It will then make its way back to a leak detection software that will place each device on a GIS map. Leaks in the system are detected by the pitch and change in acoustic readings from each reporting device. Typically, depending on the density of the devices and the type of material used for the water mains, an ALD device would be installed for every 10 water meters in the system.

6.8.3. Temperature and Pressure Monitoring

Temperature: A water utility whose temperature can drop below freezing may benefit from the ability to monitor water temperature for meters situated in meter pits, crawl spaces, or other exposed environments. Early warning of potential freezing conditions could prompt a "run your water" alert that avoids possible burst pipes and property damage.

Among other factors, residual chlorine levels in water supply are affected by temperatures: the higher the temperature, the faster the chlorine degrades. The ability to monitor temperatures can be an indicator of potential water quality issues.

Pressure: Water utilities with numerous pressure zones or limited SCADA points find it expensive to collect pressure readings. Pressure reading collected in more locations of a water system provide several benefits:

- Ensure adequate pressure to avoid water quality issues and customer complaints.
- Drop in pressure as an indicator of main or water service breaks.
- Provide pressure inputs to the hydraulic model to better understand the distribution system.
- Reduce pressure within a specific pressure zone to reduce the leakage within the system while still maintaining minimum fire pressure levels.

Many vendors offer non-mechanical meters with integrated pressure and temperature monitoring that can be communicated through the AMI system. In other cases, pressure sensors are available that are compatible with AMI systems

It should be noted that not all meters and AMI systems are fully compatible when in the case of pressure sensing, so the need for this compatibility should be clearly stated in the AMI system and meter procurements.

6.8.4. Implications for The City of Thunder Bay

The City of Thunder Bay typically experiences about 100 frozen services per year. Monitoring temperature in an effort to provide alerts to customers at risk of freezing could prove to be a valuable customer service initiative that could be addressed with AMI and strategic installation of meters capable of sensing temperature. A customer engagement portal with the ability to manage customer outreach could be used to proactively alerts customers whose service is at risk of freezing.

7. SYSTEM INTERFACE AND INTEGRATION REQUIREMENTS

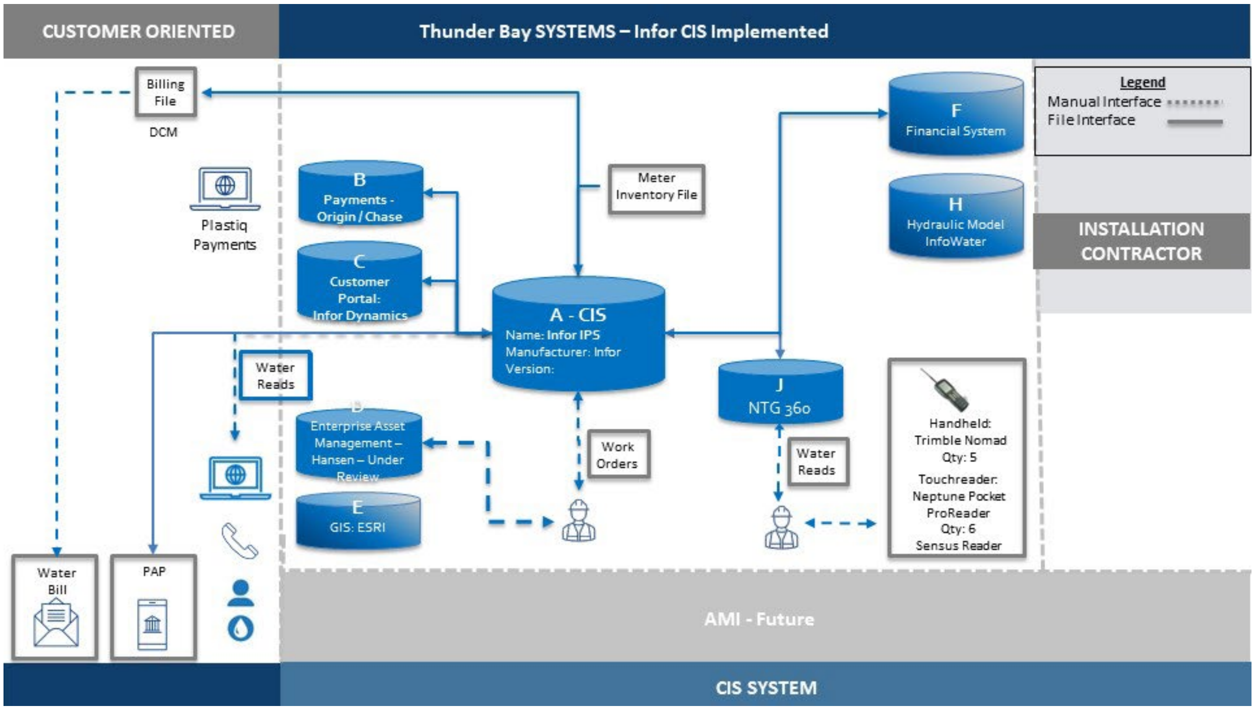
7.1. System Assessment – Existing

7.1.1. System Assessment – Existing Description

Through workshop activities, Diameter performed a system review with the City of Thunder Bay's project team. The purpose of this assessment was to identify the systems currently in use and those systems that may be impacted with the implementation of AMR or AMI technology. In addition, risks and challenges were identified as well as opportunities to improve the customer's experience. This current system diagram is augmented with Transition and Future system design diagrams. These diagrams are not intended to be the final solution as different vendors may propose different types of system architecture. It is intended to give the City of Thunder Bay a good idea of the scale of the impact this project may have on their systems. This document is an initial step in understanding the level of integrations the City of Thunder Bay should anticipate supporting this organizational change.

The City of Thunder Bay is currently undergoing the implementation of a new CIS system called Infor IPS. It is anticipated that Infor IPS will be in production within the next 6-12 months at the time of this report. For the purposes of the workshops and this report, it was assumed Infor IPS was the active CIS system for the City of Thunder Bay. Figure 13 below represents the system diagram of the City of Thunder Bay's existing state and serves as the starting point for both the AMR and AMI transition and future diagrams.

Exhibit 58: Existing State System Diagram



7.1.2. CIS Systems

The main purpose of the Infor IPS system is to support the meter to cash process including water, sewer billing and collections, perform Customer Relationship Management (CRM) and service order management activities. Infor IPS will be considered the system of record for water meter and radio transmitter information. The current service order process relies on a combination of the City of Thunder Bay's CIS and the Hansen work order system and is a paper-based process.

The City of Thunder Bay currently obtains meter readings by utility staff manual readings by handheld device, or customer provided readings. The remaining reads are estimates that are used for billing purposes. The current meter reading process will need to be maintained long term until more than 95% of meters have been converted to an AMR or AMI system. The software and related handheld meter reading equipment will need to be maintained through the transition, which could last up to 3 years. The City of Thunder Bay is upgrading the current Neptune N_Sight data management system used for meter reads, which is no longer supported, to the Neptune 360 platform to process manual handheld reads. Diameter has reviewed the handheld devices that are being considered as replacement and verified that for some AMI systems, a portion can be repurposed for an installation tool once AMI is fully deployed. It is still recommended for the City of Thunder Bay includes the replacement of handheld devices in the capital costs of the AMR or AMI financial model.

7.1.2.1. Challenges and Recommendations

Infor IPS is a commonly used system for a water utility the size of the City of Thunder Bay. The integration effort will require some business requirements definition and adjustments to some processes the system currently supports (e.g. the meter reading process, customer-facing applications).

The City of Thunder Bay does plan on the adoption of Infor IPS to allow for more automated interfacing processes. Although this will open the door for improvements in some of the manual interfaces identified above, it should not be seen as a silver bullet. It will take significant effort to learn, develop, configure and test all automated interfaces.

Challenges identified:

1. **New CIS software:** At the time of this report, Infor CIS is planned to be in production by the end of Q2 2025. As opposed to a major system upgrade from the same vendor, the City of Thunder Bay has adopted a different CIS vendor which will involve new interfaces, new business processes, and a full database import from the current Vailtech CIS.

2. **Manual paperwork order process:** As the City of Thunder Bay moves toward AMR/AMI, data integrity and consistency become critically important. Changes to water meters, registers or radio transmitters using a manual paperwork process can be problematic. With monthly or hourly consumption data, updating changes to equipment in the field is very time sensitive. It is recommended to implement an automated interface between current and future installation contractors. This can be done during the startup phase of the AMR/AMI project; future contracts will then need to conform to this standard.

3. **CIS period of stabilization:** Implementing Infor IPS will be a significant change the City of Thunder Bay's water billing processes and customer service activities. Given the level of integration required with either an AMR or AMI system during both implementation and post-implementation, it is recommended that the City of Thunder Bay undergo a 6-month period of stabilization with Infor IPS prior to embarking on an AMR/AMI project. This will ensure all processes and activities are understood and performed as expected by the City of Thunder Bay's team and ultimately its water customers.

7.1.3. Customer Facing Applications

The City of Thunder Bay does not currently offer a customer-facing application or portal to access their water billing information. However, with the transition to Infor IPS the City of Thunder Bay is implementing the Infor Dynamics customer portal. This application is inherently interfaced to Infor IPS and provides some functionalities allowing customers to view and pay their current water bill and view their historical water bills. At the time of this report, the Dynamics portal does not offer the capability of storing, displaying, and analyzing hourly water consumption data.

7.1.3.1. Challenges and Recommendations

The City of Thunder Bay's project team identified several customer service business drivers as important and/or critical to the success of the project (see Section 3 Business Drivers). Functionality from an enhanced customer portal, such abnormal consumption alarms, would allow the City of Thunder Bay to reach a progressive level of customer service and engagement.

Several AMI vendors offer customer portals that offer enhanced water consumption presentment and are inherently integrated with their MDM software. Alternatively, there are 3rd party customer portals that offer best in class functionality but would require more effort and budget for integrating with the City of Thunder Bay's CIS. Should the City of Thunder Bay proceed with an AMI system, it is recommended the City investigate AMI capable customer portal in order to realize the enhanced customer service abilities identified.

7.2. System Assessment - Transition

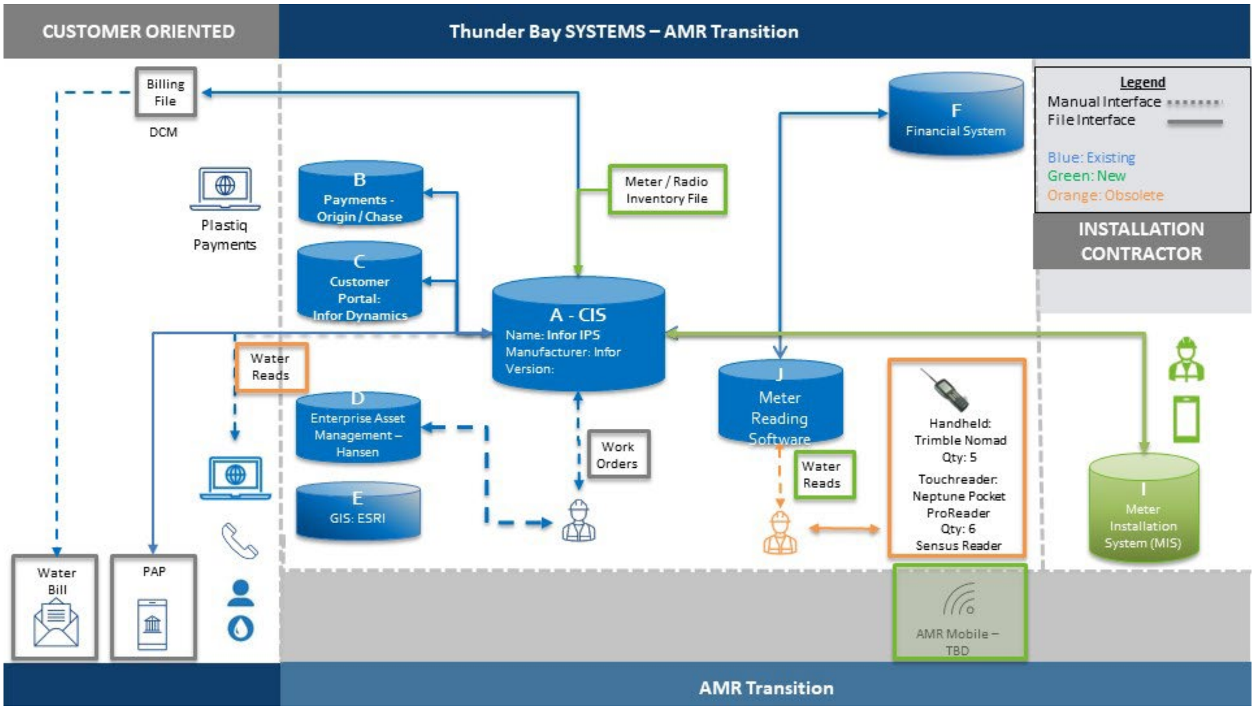
The diagrams below provide an overview of the systems and interfaces that will be impacted by movement to an automated meter reading system or an advanced metering system.

The blue systems and interfaces represent existing architecture, orange will represent transitionary systems or interfaces that will go away after the project is completed, and green represents new systems or interfaces contemplated. The solid lines represent automated interfaces that require no people interaction, the dashed lines represent a manual process that relies on manual intervention.

7.2.1. AMR Transition Description

The diagram below provides an overview of the systems and interfaces that will be impacted by movement to an AMR system.

Exhibit 59: Transition Systems Diagram



7.2.1.1. AMR System Changes

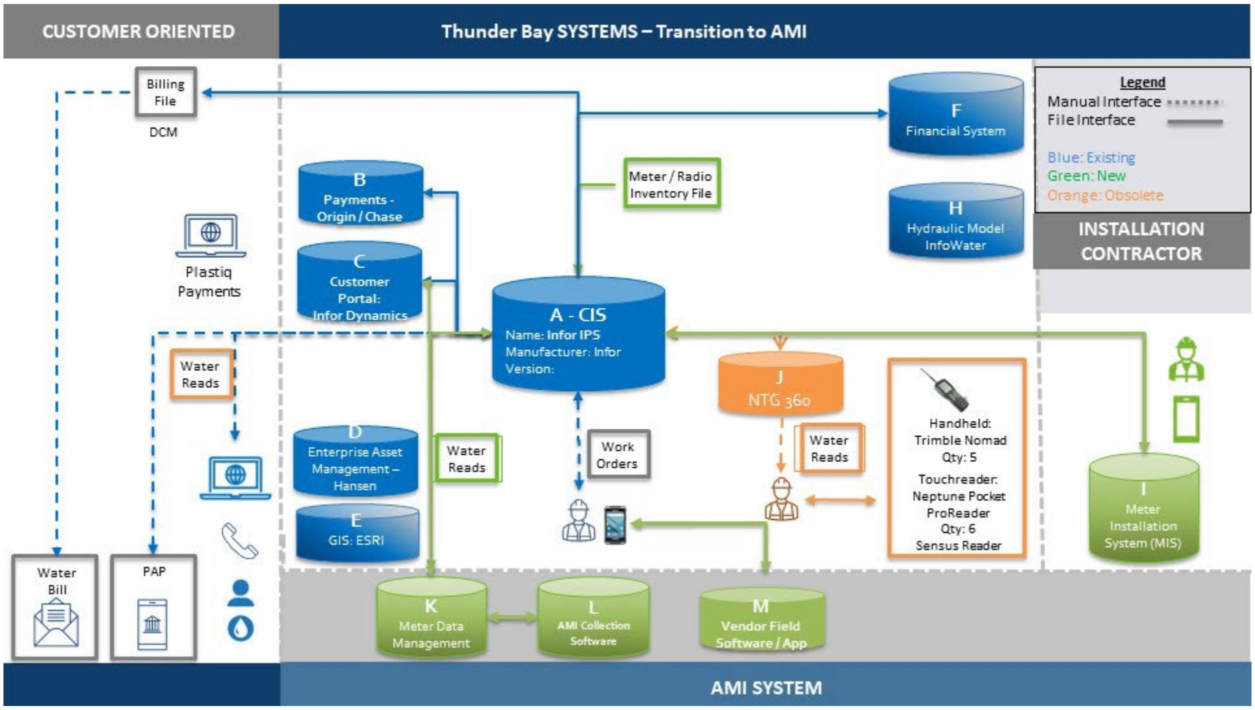
With the adoption of an automated meter reading system, the current process of obtaining water readings through customer provided readings and manual handheld device readings will become obsolete. The application which may start to go away, depending on the successful AMR vendor, would be the Neptune 360 system (being replaced with the future AMR mobile application).

It is recommended to interface Infor IPS system and the AMR Installation contractor Meter installation system (MIS) during the start-up phase.

7.2.2. AMI Transition Description

The diagram below provides an overview of the systems and interfaces that will be impacted by movement to an AMI system.

Exhibit 60: Transition State to AMI



7.2.2.1. AMI System Changes

Similar to the AMR system change, the adoption of an advanced metering information system will see the current process of obtaining water reads through customer provided reads and manual handheld device reads will become obsolete.

The existing Neptune 360 software will become obsolete once the meters read by manual handheld devices have been equipped with a radio transmitter.

It is recommended to interface the Infor IPS system and the AMI Installation contractor Meter installation system (MIS) during the start-up phase.

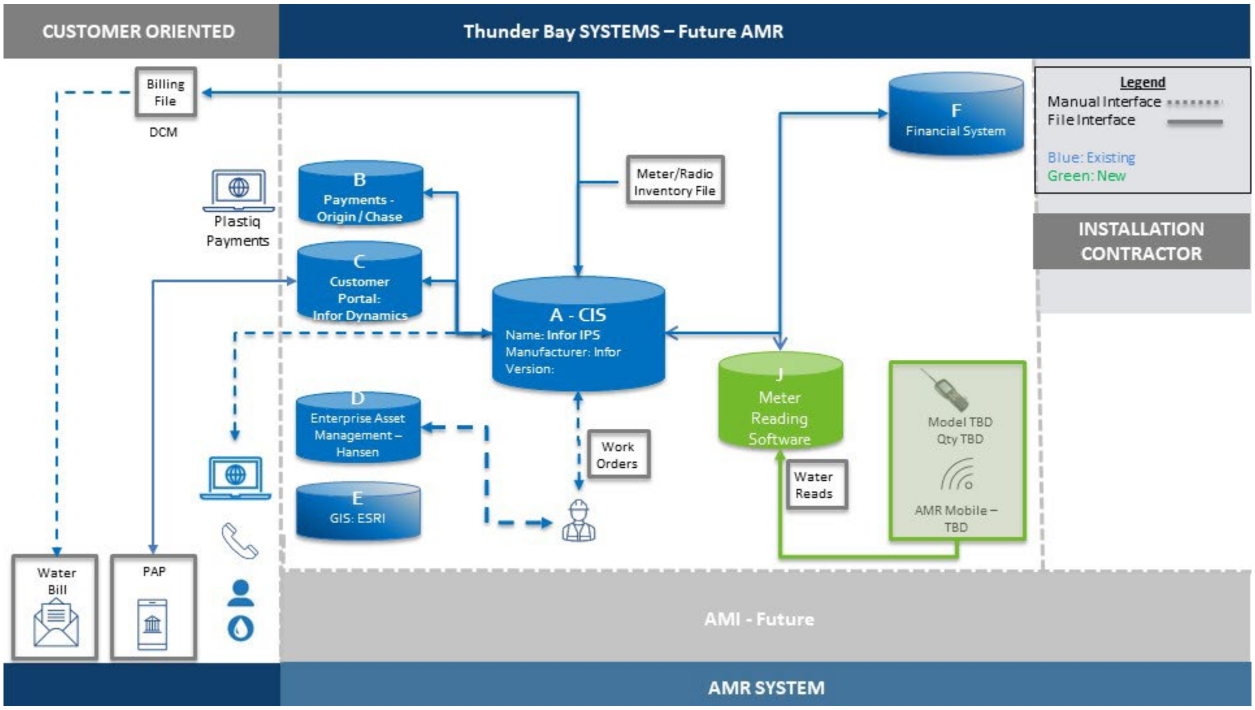
The AMI system software components (K, L, M) will be implemented and integrated with Infor IPS upon project start up.

7.3. System Assessment - Future

7.3.1. AMR Future Description

The diagram below provides an overview of the City of Thunder Bay's future AMR system architecture. Should the City of Thunder Bay choose to proceed with an AMR system, this should act as a guide or reference point as the City moves forward with some of the recommendations made in this report.

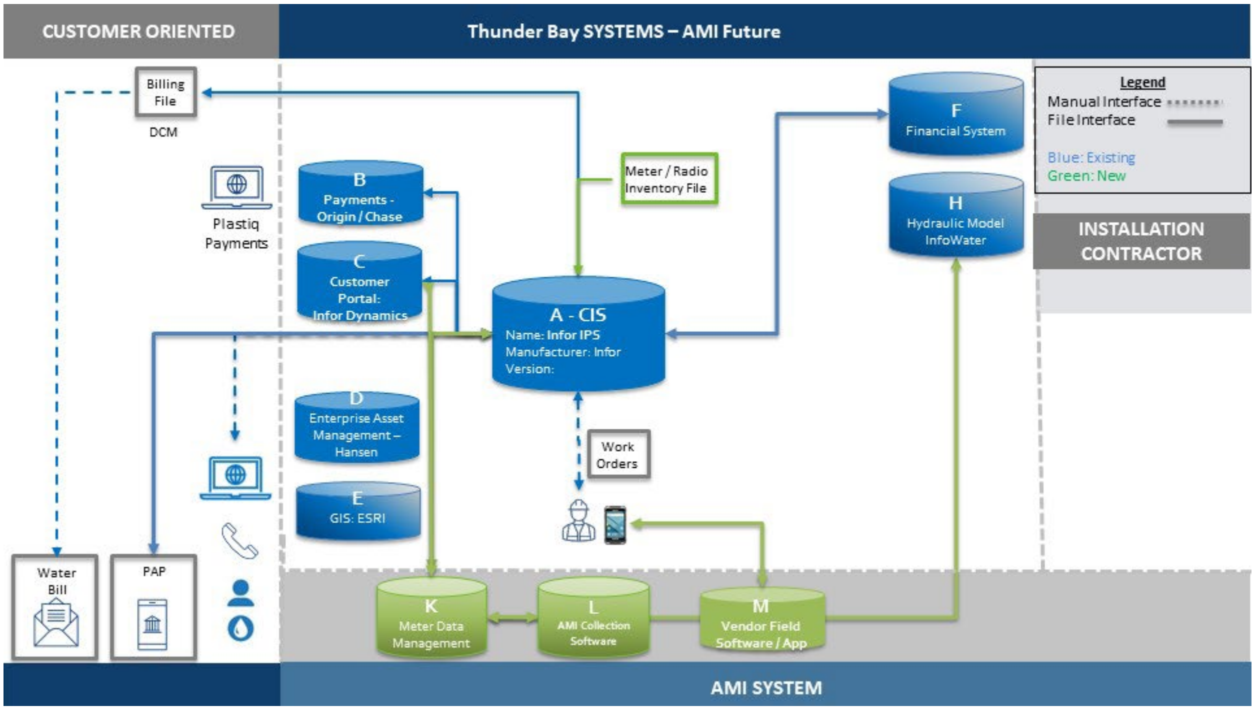
Exhibit 61: Future AMR System Diagram



7.3.2. AMI Future Description

The diagram below provides an overview of the City of Thunder Bay's future AMI system architecture. Should the City of Thunder Bay choose to proceed with an AMI system, this should act as a guide or reference point as the City moves forward with some of the recommendations made in this report.

Exhibit 62: Future AMI Systems Diagram



8. PARTNERING OPPORTUNITIES

8.1. Introduction

The focus of this task is to determine if there are efficiencies to be gained by partnering with other local utilities in the sharing of infrastructure to improve system performance or reduce costs. Tbaytel and Synergy North were considered as possible partnering opportunities.

8.2. Tbaytel

Cellular AMI systems leverage certain existing cellular networks to provide communications between the meters and the utility. The City of Thunder Bay requested an investigation into the potential to work with Tbaytel to reduce deployment and operational costs.

The two primary providers of cellular AMI systems for water meter reading are Badger Meter and Neptune Technology Group. Diameter Services contacted both companies to determine their ability to support communications via the Tbaytel network. Both providers stated that they operate on the major Canadian and American cellular carriers. Both also felt that a special product would need to be developed that would allow their AMI devices to operate over other carriers.

Currently, the predominant cellular AMI systems use Cat-M (aka LTE-M) chips that are compatible with 4G LTE cellular networks.

8.3. Synergy North

Synergy North provides electricity service to the communities of Thunder Bay and Kenora, serving a total of 50,000 residential and 6,000 commercial customers. Synergy North implemented an AMI system in 2011 and the possibility of piggybacking on that system was evaluated.

The Synergy North AMI deployment was completed in 2011 using a system known as EnergyAxis supplied by Elster. The EnergyAxis system was designed to address the AMI needs of both electric, gas, and water meters.

Diameter Services does not recommend piggybacking on the Synergy North AMI network for the following reasons:

First, AMI systems have a typical life expectancy of about 20 years. Since the Synergy North implementation is already 14 years old, the City of Thunder Bay would run the risk of piggybacking on a technology that may be due for replacement before the City has recovered its investment. Should Synergy North opt to change AMI providers, the City of Thunder Bay's communication network would be removed leaving no means for the City to retrieve water meter consumption data.

Secondly, the decision to use the existing AMI system would put the City of Thunder Bay in a sole-source situation where the only viable provider of AMI radio transmitters and software would be Honeywell, the current owner of the Elster technology[13].

[13] Honeywell Financial Release, July 28, 2015, https://investor.honeywell.com/static-files/e4d02862-b636-4e73-bbdb-53596575d8a3, accessed on September 14, 2024.

9. CAPITAL ASSET MANAGEMENT PLAN

9.1. Introduction

AMR / AMI systems include several components that will need to be maintained and eventually replaced. The new water meters, radio transmitters and data collection equipment all have different life cycles. PSAB 3150, introduced in 2009, provides accounting standards for municipalities to track and report on their Tangible Capital Assets (TCAs), with Water Utility Equipment listed as an asset class that needs to be included.

It is recommended that the City of Thunder Bay include AMR / AMI components in the drinking water section of their Capital Asset Management Plan.

9.2. AMR/AMI Asset Class

The City of Thunder Bay's 2024 Asset Management Plan Phase 2 provides a long-term integrated approach to managing assets. Section 4.0 identifies Drinking Water as its own category of asset classes, which are placed into two groups:

- Watermains, Hydrants, and Valves
- Water Treatment & Distribution Facilities

Each asset class presents the replacement value, the asset totals, average age, and overall condition ranking. An AMR / AMI system should be considered a separate asset class, with the different components broken into several asset totals, as provided in the table below.

Exhibit 63: Dedicated AMR/AMI Asset Class

Asset Class	Replacement Value	Asset Totals	Average Age	Average Condition
All Drinking Water Assets	887,672,000	See below	55 years	Fair
Drinking Water Assets*				
Watermains, hydrants and valves	$729,241,000	726 km watermains 9,559 valves 2,595 hydrants 37,877 service connections	55 years	Fair
Water Treatment & Distribution Facilities	$158,431,000	1 Water Treatment Plant 7 Pumping stations 4 Reservoirs 1 Standpipe 3 Water Fill Stations	37 years	Good
AMR/AMI - Meters, Radios, Reading equipment	**$11,260,417**	**37,990 Water Meters 37,990 Radio Transmitters 6 Hand held equipment devices**	**~1.5 years**	**Very Good**

Note that the replacement value of the AMR/AMI asset class was derived from the capital cost section of the financial model. The condition rating would be based on a citywide 2-year implementation program.

9.3. Asset Lifecycle

Each component in an AMR/AMI system has a unique lifecycle that is dependent on key attributes and characteristics of the asset, such as make, model, age, warranty, etc.

9.3.1. Water Meters

To establish the lifecycle and replacement costs of water meters, it is important to distinguish between different meter types (mechanical or non-mechanical) as described in section 6.7 Water Meter Technology. It should be noted that at the time of this report, the preferred meter type has yet to be determined.

Mechanical water meters

- Utilize nutating disc or oscillating piston technology to measure water consumption
- Do not require batteries

- Primary consideration is with accuracy decline and revenue loss
- Mechanical meters are commonly replaced on a 20–25-year cycle
- Replacement value is consistent throughout the asset's life (notwithstanding inflation)

Non-mechanical water meters

- Utilize ultrasonic or magnetic technology to measure water consumption.
- Requires batteries and have a finite lifecycle.
- Maintains accurate consumption throughout the meter's life.
- Most vendors claim a 20-year lifecycle which typically includes a prorated warranty that impacts replacement value. See Appendix B: Sample Warranty Proration Table.

Regardless of the technology chosen (AMR or AMI), the water meter lifecycle and replacement costs will be determined by the meter type.

9.3.2. Radio Transmitters

Radio transmitters are typically mounted on the outside of a home or business and connected to the water meter by a wire.

- Require batteries and have a fairly predictable battery life – based on programmed activation.
- Most vendors claim a 20-year lifecycle which typically includes a prorated warranty that impacts replacement value. See Appendix B: Sample Warranty Proration Table.
- Two-way communication, and additional activation can impact the estimated lifecycle.
- Following installation best-practices can minimize premature failure.

The City of Thunder Bay can assume that radio transmitters, regardless of the technology, will last 20 years on average, with the replacement cost of the radios derived from the successful vendor's proration warranty.

9.3.3. Handheld reading devices

Both AMR and AMI systems will require handheld reading devices, and the financial model has included the devices for both scenarios. The financial model has an estimated total handheld cost of $16,600 for the AMR scenario and $10,800 for the two AMI scenarios. For the purposes of the capital asset plan it can be assumed that handheld devices will last between 5 and 7 years.

9.4. System of Record

Municipalities are required to report on their TCAs as a statement of their financial position. As such, it is important to identify and utilize the system of record for any given asset class. It is recommended that the City of Thunder Bay utilize Infor IPS (CIS) as the meter and radio system of record. Infor IPS will maintain critical asset related information such as:

- Meter make, type, size, age (meter install date)

- Radio make, model, age (radio install date)
- Failures / replacements (replacement date)

A well-maintained system-of-record will provide the ability to meet the City of Thunder Bay's asset management plan reporting and auditing requirements.

10. PROCUREMENT STRATEGY

10.1. Scope and Groupings

The framework for the procurement strategy is established by decisions related to what to include in the procurement scope and how to group the different procurement elements. This process begins by defining the products and services required for procurement and determining who should perform the work (City of Thunder Bay resources or outsourced resources). In the case of the City of Thunder Bay, the following elements and support structures for the AMR/AMI system, water meters and installation were discussed in a procurement workshop with Diameter to provide a broader understanding of all of the procurement elements and how they pertain to the City.

Exhibit 64: Project Scope

With an understanding of what products and services are required as part of the procurement strategy, the City of Thunder Bay's decisions shifted to determine what elements should be grouped during procurement and in which order should the various components be procured.

The primary procurement groupings include:

A. AMI/AMR technology (which may include the MDM software),
B. Installation and deployment, and
C. Water meter supply.

The customer portal may also be procured as a component of the AMI technology if the AMI vendor's features and functionality meet the City of Thunder Bay's needs; alternatively, a fully functional (best=in-class) customer portal can be procured separately.

Based on the primary procurement groupings depicted above, there are four procurement options for the City of Thunder Bay's consideration:

Exhibit 65: Procurement Options

Options	Description
Option 1	**Turnkey** Single Procurement (A+B+C).
Option 2	Combine A (AMI/AMR Technology) + B (Installation & Deployment), and **C (Meter Supply) as a separate procurement.**
Option 3	A **(AMI Technology) as a separate procurement** and Combine B (Installation & Deployment) + C (Meter Supply)
Option 4	**All Separate** Procurements: A (AMI/AMR Technology), B (Installation & Deployment), and C (Meter Supply).

Exhibit 66: Procurement Strategy Diagram

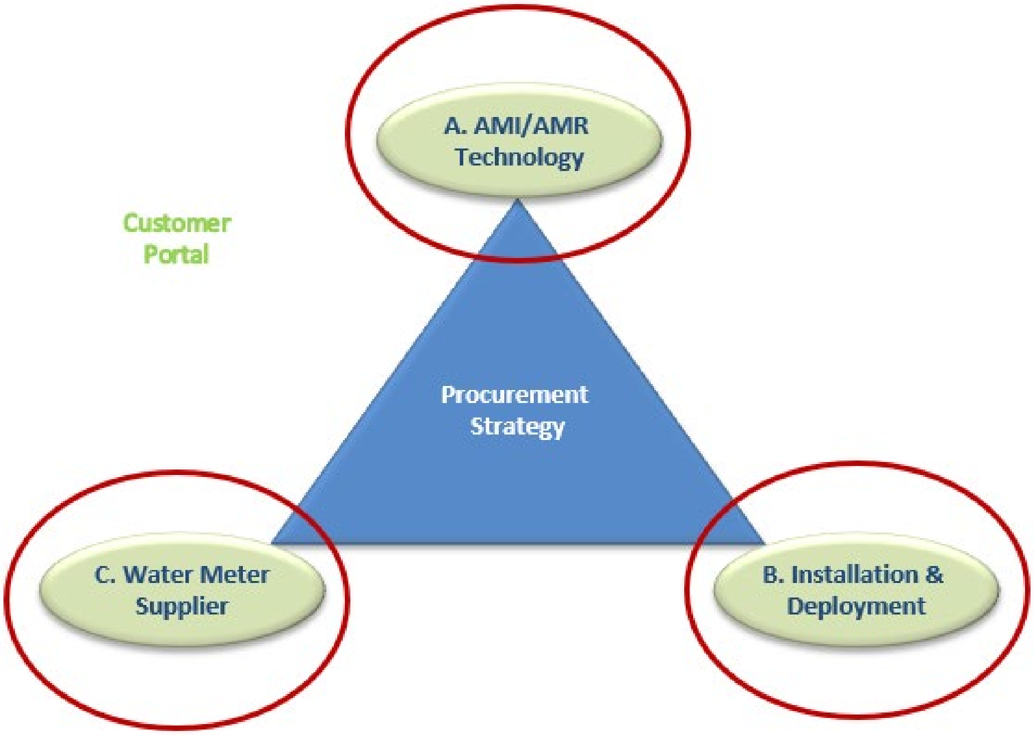
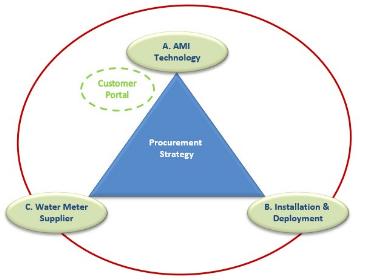
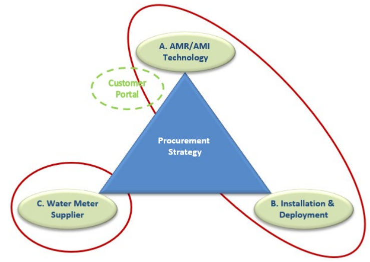
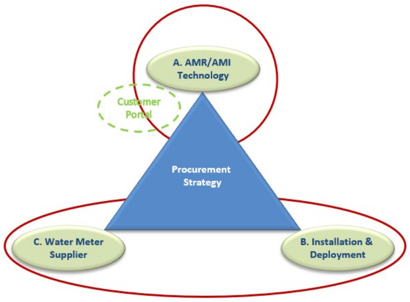


Exhibit 67: Procurement Advantages and Disadvantages

Option 1 **Single Procurement** Turnkey (A+B+C)	**Option 2** **Two Procurements** AMI + Installation (A+B) Meter Supply Separate (C)	**Option 3** **Two Procurements** AMI Separate (A) Installation + Meter Supply (B+C)
		

Option 1 **Single Procurement** Turnkey (A+B+C)	Option 2 **Two Procurements** AMI + Installation (A+B) Meter Supply Separate (C)	Option 3 **Two Procurements** AMI Separate (A) Installation + Meter Supply (B+C)
Advantages (Benefits) • Responsibility for all components in a single vendor. • Product warranty can include in/out costs for the first year. • Product payment is tied to installation.	**Advantages (Benefits)** • Responsibility for AMI performance is in a single contract. • Installation remains with AMI vendor who then has complete responsibility for successful communication to collection equipment. Since Installation issues create the most risk of poor AMI performance coupling Installation with AMI is advantageous for the City of Thunder Bay. • Allows for multiple meter manufacturers and components.	**Advantages (Benefits)** • Medium cost scenario. • Provides the best selection of AMI systems.
Disadvantages (Risks) • May be higher costs due to some vendors having to put margin on margin for products. • Prime contract performance bond requirements may limit vendors (smaller companies will not be able to bid).	**Disadvantages (Risks)** • Issues with faulty meters will be a City of Thunder Bay responsibility. • Bad wiring to encoder could be blamed on meter (City of Thunder Bay responsibility). • Potential loss of some meter features	**Disadvantages (Risks)** • City of Thunder Bay will bear liability: Supplying meters • Install and AMI system working together has the most liability. • Non-mechanicals meters - AMI and meter supply need to be procured together to ensure you get all the functionality

A fourth option was also discussed whereby all elements would be separately procured however this option requires the most support and coordination between components. With this type of strategy, it can be difficult to determine responsibility should issues arise and potentially vendor finger-pointing.

There are advantages and disadvantages to options 1 to 3 and some options are more prevalent than others in the marketplace. It is important to know that the groupings can also influence the competitiveness of the marketplace and impact overall project costs and resource demands for the City of Thunder Bay. Based on recent experience with similar sized municipalities the expected market landscape follows:

Exhibit 68: Procurement Competitive Landscape

Prime Contractor	AMI Supply	Meter Supply	Installation Contractor
KTI	Sensus	Sensus	KTI
Neptune	Neptune	Neptune	Neptune
Metercor	Kamstrup Itron	Kamstrup Zenner	Metercor
Wolseley	Badger Itron	Badger Honeywell	Metercor Wolseley
Aclara	Aclara	TBD	TBD
MasterMeter	MasterMeter	MasterMeter	TBD

Recommendations: Diameter recommends **Option 1, Single Procurement**. This aligns with the City of Thunder Bay's preference for a wholistic approach to the project with all elements accounted for under a single prime contractor who is ultimately responsible. This approach also mitigates the administrative burden of managing and aligning multiple vendors. From a competitive perspective, with a turnkey procurement strategy (option 1), it is expected the City of Thunder Bay would receive 3 to 4 submissions including the major market players.

10.2.Procurement Type

Diameter presented the City of Thunder Bay with several competitive procurement methods for consideration. It is important to mention AMR/AMI projects typically do not fall neatly into normal procurement rules. Through workshop discussions, Diameter reviewed the advantages and disadvantages of pursuing an RFP versus a tender process; notably the tender process primarily focuses on price solicitation for specific goods and services (generally commodity items), is highly structured, and leaves little room for deviation from what has been requested.

Exhibit 69: RFP Versus Tender Advantages and Disadvantages

RFP Process	Tender or Bid Process
Advantages • Allows for apples to oranges comparison • Allows for alternatives • Procurement includes strong specifications but allows for variation in the offering • Software can be difficult to compare • Most common type of AMI/AMR procurement	**Advantages** • Likely lowest price • Save time on evaluation • Could work for just water meters
Disadvantages	**Disadvantages**

RFP Process	Tender or Bid Process
• The awarded solution may not be the lowest cost solution • Can be difficult to convince politicians as to why a higher cost solution is better	• No consideration for innovative solutions • Easy to have bidders disqualified due to a small non-compliance • Price is not the only factor with these types of projects • Quality of team and proven products need to be evaluated

Diameter does not recommend a tender process for the AMI/AMR or the installation procurement as the market offers too much variability in experience and product functionality for a tender process.

An RFP for the water meter supply allows the City of Thunder Bay to score product support and customer service levels offered post project. It could also allow the City of Thunder Bay to place value on a local presence. This approach also allows the City of Thunder Bay to evaluate product options as some manufacturers have unique features that should be given qualitative points should they align with the City of Thunder Bay's business drivers.

Recommendations: The City of Thunder Bay's Project Team expressed preference for an RFP process and the evaluation would ensure that the City would be moving forward with vendor(s) that were proven in the market.

10.3. Network Expansion / Procurement Beyond the Project

Should the City of Thunder Bay adopt AMI technology it is important to understand that AMI technologies are proprietary, and that the AMI vendor they choose for their initial roll-out will be the only vendor it can purchase AMI equipment for the next 20 years or so (assuming no seismic shift in the industry). The reality is vendors create "stickiness" whereby only they can provide radio transmitters, network infrastructure (collectors, repeaters, towers) and the head-end software for their network. This limits price competition following the project, however, that is not to say vendors can charge higher prices for their technology once a utility is "captive".

As part of the Procurement / Contract process, it is common to establish product supply pricing for equipment beyond the project scope (e.g. radio transmitters, meters, network equipment) with allowable increases based on an agreed-to index such as the Consumer Price Index. It is understood that the City of Thunder Bay may be headed for a new period of growth which may lead to the expansion of the City's water service area. Understanding the infrastructure requirements for this area should be included as part of the RFP process.

In general, network expansion is a consideration for utilities when choosing its AMI vendor. Understanding each vendor's infrastructure implications and the options they provide (i.e. cellular) for network expansion will be included in the RFP document.

Some actions the City of Thunder Bay can take to allow for both known and unknown new development:

1. City of Thunder Bay should increase the new water meter costs that gets charged to the developer / property owner to include the AMR/AMI radio transmitter in addition to the water meter.
2. For larger scale developments over 1KM in geographic area, the City of Thunder Bay should pass on the cost of the vendor's RF propagation study and the cost of additional data collectors required to service the territory (i.e. supply and install costs). Depending on the proximity of the new development to the existing service area there may be some or no additional equipment required.
3. For new areas, we would suggest including AMI coverage as a provisional item within the original RFP.

These policy changes will help the City of Thunder Bay expand the network, including the additional equipment and ensure the cost of the AMI system is covered by Developers.

11. IMPLEMENTATION SCHEDULE

11.1. Introduction

An AMR/AMI system implementation project is not your typical engineering project. The combination of products being supplied (often from different vendors), installation services, software applications and software integration into existing and new applications presents unique challenges. Complicating this further, the products and software application all need to be compatible with one another and provide the right data, in the right way, to the right systems, at the right time in the business process. In fact, AMR/AMI projects often more closely mirror technology projects rather than installation projects. Finally, the work needs to be done while engaging the City of Thunder Bay's customers.

These challenges support a single, dedicated and focused implementation approach. To create this focus, Diameter recommends establishing distinct project phases that, once complete, represent the progress of certain key elements of the overall project.

11.2. Project Phases

Below is a description of the project's unique phases and some key activities the City of Thunder Bay should expect within each phase. Often resource requirements may change depending on the nature of the project phase, some requiring a heavier legal, procurement or IT element.

Phase 1 – Business Case: Diameter's current assignment would represent phase 1 of the project. This phase provides the framework and foundation that will guide future phases. The completed deliverables of this engagement are the key activities required.

Phase 2 – Procurement: The procurement phase is more complicated than most. As detailed in Chapter 11 Procurement Strategy, it is recommended the City of Thunder Bay proceed with a single turnkey procurement if the City opts to proceed with a "go-fast" implementation strategy. If the City of Thunder Bay opts for a slower implementation (such 5 years), the City of Thunder Bay should consider procuring the AMI system separately.

These procurements are:

"Go-fast" Accelerated Implementation

- Procurement 1 - Turnkey Request for Proposal: AMR/AMI System, Meter Supply and Installation Services. This procurement would include the AMR/AMI radio transmitter supply, data collector supply and installation (AMI only), Headend and Meter Data Management (MDM) software (AMI only), software integration services, project management, water meter installation services, meter installation system (MIS), project call center, and material coordination activities. It would also include the supply of water meters that will be replaced as part of the project, including meters necessary for newly constructed homes and buildings necessary for maintenance that arise as a matter of course.
- Full Functionality Customer Portal application – TBD.

- Infor IPS CIS – Integrations – the likely sole source procurement with the Infor IPS interface and testing subject matter experts to support development of the City of Thunder Bay side of the AMR/AMI, MIS and potentially customer portal interfaces.

"Go-slow" Extended Implementation

- Procurement 1 – Request for Proposal: AMR/AMI System - This procurement would include the AMR/AMI radio transmitter supply, data collector supply and installation, Headend and Meter Data Management (MDM) software, software integration services.
- Procurement 2 – Request for Proposal: Supply of Water Meters and components and Installation Services. This procurement would include project management, water meter installation services, meter installation system (MIS), project call center, and material coordination activities. It would also include the supply of residential water meters that will be replaced as part of the project.
- Full Functionality Customer Portal application – TBD.
- Infor IPS CIS – Integrations - the likely sole source procurement with the Infor IPS interface and testing subject matter experts to support development of the City of Thunder Bay side of the AMI, MIS and potentially customer portal interfaces.

Phase 3 – Start Up: This phase includes engaging Consultants and the City of Thunder Bay's internal resources as the AMR/AMI, meter and installation vendor(s) set up the facilities, software, integration services and user acceptance testing. The detailed activities of the City of Thunder Bay should expect to include:

- Setup of the local project office and warehouse to support project Phase 4.
- Development and approval of the public outreach program and materials.
- Integration development between the various new and existing systems.
- The contractor's development and internal testing of the Meter Installation System (MIS) to manage the installation work orders.
- Configuration and training on all proposed software applications.
- Inspection, planning, deployment, and configuration (as required) of the AMI collector network.
- Development of installer training policies, procedures, and training.
- Set up and training of the contractor's call center personnel in project specific protocols.
- Material planning, approval and forecasting of all water meter, radio transmitter and other required installation materials.
- Perform Initial User Acceptance Testing (IUAT) to ensure all systems are ready for installation and continued water billing. Approval of the IUAT is the milestone to ensure the new systems support the billing process and will allow the Contractor to move into Phase 4a – Proof of Concept.

Phase 4a – Installation and Deployment, Proof of Concept (POC): The project will go through a limited proof of concept where the software applications are fully integrated, and the contractor installs a limited number of water meters and AMR/AMI equipment. This is an important project phase to ensure the Contractor is ready to ramp up production in a controlled manner. The detailed activities that the City of Thunder Bay should expect to include:

- Perform water meter replacement, retrofit and/or upgrade activities within the pre-defined POC area. The POC area will be agreed upon with the chosen vendor with the intended purpose of testing installation processes and information tracking, integrations and data flow to ensure a continued successful billing process. As such, the POC would typically include a combination of ICI and residential customers. The POC is less about testing the technology and more about testing installation/implementation processes to ensure a successful project. The reason POCs focus on integrations and data flow is that generally speaking, AMI technologies are proven, and the system capabilities are widely understood. However, one of the major potential differences from deployment to deployment is the amount infrastructure required to ensure data is received regularly from every endpoint. As part of the RFP and contractual process, the infrastructure requirement is the vendor's responsibility and not the risk of the City of Thunder Bay.
- Once the POC has been completed, deploy and configure (as required) the AMI collector network for the entire service territory.
- The Contractor will perform quality assurance on installations performed.
- The consultant and owner's representative will perform quality inspections on up to 5% of the Contractor's installation work. Where the quality program shows issues, additional effort may be required to increase the inspection percentage.
- Implementation of the public outreach program.
- Operate a project call center to receive customer inquiries, appointment requests, and receive and manage any customer complaints.
- Planning and implementation of the Final User Acceptance Testing (FUAT) to ensure all identified AMI business drivers as well as Contractor committed functionality are achieved. Approval of the FUAT is the milestone to allow the Contractor to move into Phase 4b – Installation and Deployment.

Phase 4b – Installation and Deployment: Once the contractor has passed the Final User Acceptance test, the City of Thunder Bay and project Consultant will validate the system and contractor are meeting the specifications of the procurement. Similar to the activities of the proof of concept, this phase includes the following:

- Perform water meter replacement, retrofit and/or upgrade activities on an area-by-area basis.
- The Contractor to perform quality assurance on installations performed.
- Diameter to perform quality inspections on the Contractor's installation work.
- Implementation of the public outreach program.
- Operate a project call center to receive customer inquiries, appointment requests, and receive and manage any customer complaints.
- Achieve completion of the Project Milestones within the agreed-upon timeline.

Phase 5 – Close out: Effective management of the close out activities is an important phase in the overall project as it ensures proper closure and hand off as the system transitions from the implementation to the on-going ownership, operation and maintenance by the City of Thunder Bay. Effective management of close out activities should be planned and monitored prior to entering Phase 5. The activities that the City of Thunder Bay should expect to include:

- System acceptance based on the City of Thunder Bay's specifications and metrics to define contractual compliance requirements for project completion related to system acceptance.
- Project close out activities and reporting.
- Review of lessons learned.
- Transition programs to operations.

11.3. Project Phases Accelerated Duration

Diameter recommends an accelerated project duration. Converting all customers to the AMR or AMI system as quickly as possible allows the City of Thunder Bay to realize benefits sooner. The table below provides an expected duration of the above project phases considering the City of Thunder Bay's internal review and approval processes.

Exhibit 70: Project Duration by Phase

Phase	Duration (months)
Phase 2: Procurement	8 months
Phase 3: Startup Phase	6 months
Phase 4a: Proof of Concept	3 months
Phase 4b: Installation and Deployment	22 months
Phase 5: Close Out	2 months
Total	**41 months**

Phase 4b holds the biggest risk to schedule, average installations would likely need to exceed 500 per week or approximately 13 installers performing work. Refer to Appendix C for a more detailed project schedule.

Diameter recommends performing the project over a 41-month schedule due to a number of expected benefits, namely:

- Economies of Scale: If the project were to be performed over a longer period of time, the cost of the project is expected to be 10% to 15% higher. The installation services require facilities, project management and supervision to manage the project – costs that are directly linked to the project's duration. The shorter the project's duration, the lower the overhead costs.

- Proprietary AMI Systems require a single procurement. Because the AMI system is proprietary, the City of Thunder Bay will need to purchase AMI radio transmitters from a single vendor. The City of Thunder Bay has the best opportunity for cost competitive procurement prior to selecting a vendor. If the project is done over a longer period, it is likely more than one procurement will be necessary. Any future procurement would be limited to the previously selected AMI system, eliminating any pressure on the price of the AMI radio transmitter.

- Technology Changes: AMI technology development for water utilities has come a long way in the last five years and vendors continue to develop their products and software applications to provide more functionality. Implementing the project over a longer period than recommended leads to the risk of new products being developed with different functionality, which may lead to differing customer service levels.

- Unequal service levels: The City of Thunder Bay considers customer service enhancements to be a priority in this project. Many of the business drivers of customer service-related enhancements provide customers with new features through a fully functional customer portal. These include hourly consumption graphs, continuous leak detections, high consumption alerts, meter problem alerts, and reverse flow alarms. If the project is done over a longer period of time, certain customers will have these features while others will not. Some customers will have access to the benefits of consumption alerts which may avoid high water bills, while others will be required to pay the high-water bill because they did not have this advantage.

- Business drivers assume consistent data across all customers. Many of the business drivers require hourly consumption data from all customers, which in large part impacts whether the City of Thunder Bay can leverage its investment. When only a small percentage of the customers have this data, it provides an incomplete picture of the total system, total system demand and the ability to assess and enforce conservation initiatives. If the City of Thunder Bay decides to implement AMI over a longer period, the business drivers would need to be revisited. The technology fit assessment that was performed as part of this analysis likely may not apply and some of the functional benefits would be pushed until all meters are converted to AMR / AMI.

To conclude, an accelerated implementation of approximately 41 months is strongly recommended to realize the identified benefits and support the City of Thunder Bay's objectives for this project. Implementation schedule, procurement strategy, capital costs, and resourcing all are impacted by extending the project duration.

12. RECOMMENDATIONS

12.1. Introduction

The recommendations within this chapter are derived from analysis and the City of Thunder Bay staff's feedback on potential direction and alternatives. The recommendations should guide the City of Thunder Bay's decisions relating to the implementation of the recommended technology.

Recommendations are grouped into the following categories:

- Technology decisions
- Deployment choices
- Procurement recommendations
- Project support
- Optimization

Recommendations are numbered and identified R01 through R13 for reference.

12.2. Recommendations

R01: Deploy AMI instead of AMR or manual reading

Diameter recommends the City of Thunder Bay implement AMI Technology to achieve both non-financial and financial benefits associated with the business drivers.

Diameter recommends the City of Thunder Bay implement AMI since only AMI will satisfy the Business Drivers and the AMR alternative, for the most part, will not. As outlined above, the City of Thunder Bay identified 20 Business Drivers that were deemed Important or Critical to the Project and all 20 were fully (14) or partially (5) satisfied by AMI whereas only 10 were partially supported by AMR.

The City of Thunder Bay identified multiple opportunities to improve the meter-to-cash process, water operations and customer service levels with water customers. Examples of improvement opportunities include increasing meter reading reliability, performing same-day final reads, improving meter reading safety, customer leak detection, distribution system pressure monitoring, better information for hydraulic modelling and conservation program support. These examples are all readily achievable with AMI.

The additional Customer functionality will provide new ways for the City of Thunder Bay to engage their water customers, reduce complaints or concerns about their water bills, and fuel a digitally powered customer service tool.

R02: Install radio transmitters on the exterior wall

Diameter recommends that, wherever possible, the radio transmitter be installed on the exterior wall of the building. Exceptions can be made where interior finish work would make this overly costly or disruptive for the customer. While installing radio transmitters externally is a more difficult installation process, improved read success, reduced data collector count, and improved access for maintenance provide lasting benefits to the City of Thunder Bay. Refer to 6.2.3, Radio Transmitter Installation for details

R03: Implement an AMI system that is independent of other local utilities

Through the design phase of the project, the team investigated the opportunity to partner with local utilities Synergy North and Tbaytel to determine if partnering could benefit any of the parties.

The Synergy North AMI system installation was completed in 2011, meaning that it is already at least halfway through its expected service life. Piggybacking on this AMI system would also require a decision by the City of Thunder Bay to sole-source key elements of its system from the incumbent vendor. As a result, it would not be to the City of Thunder Bay's benefit to leverage Synergy North's AMI network.

Tbaytel provides cellular phone service to the City of Thunder Bay's service area. While there exists a possibility that a cellular AMI system could use the Tbaytel communications network, there remain some challenges including the cost-effectiveness of developing, testing, and supporting a specialized cellular radio transmitter for the City of Thunder Bay's use. Furthermore, cellular AMI providers use Cat-M (also referred to as LTE-M) technology that are best suited for 4G networks.

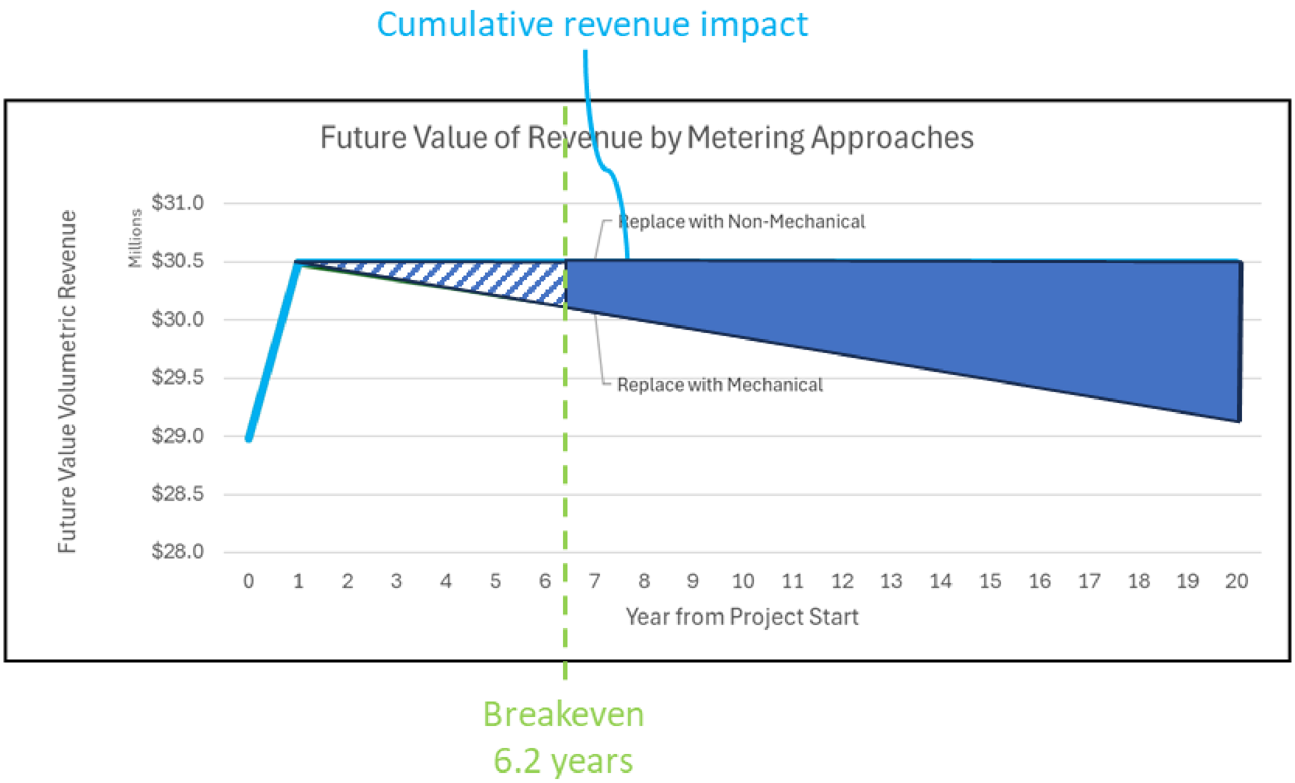
It is recommended that the City of Thunder Bay proceed with a stand-alone AMI technology.

See Chapter 8, Partnering Opportunities (2.2.16) for further discussion.

R04: Deploy non-mechanical meters

An analysis of the City of Thunder Bay's meter population reveals expected revenue gains from the installation of non-mechanical meters, such as ultrasonic or magnetic flow meters, over traditional mechanical meters. Exhibit 71 below illustrates the revenue benefit over time of non-mechanical meters.

Exhibit 71: Comparison of Mechanical and Non-mechanical Meters on Revenue



While non-mechanical meters are more expensive than their non-mechanical counterparts, the additional investment in technology is expected to provide a simple payback within 6.2 years and a net present value of $5.6 million over the life of the technology.

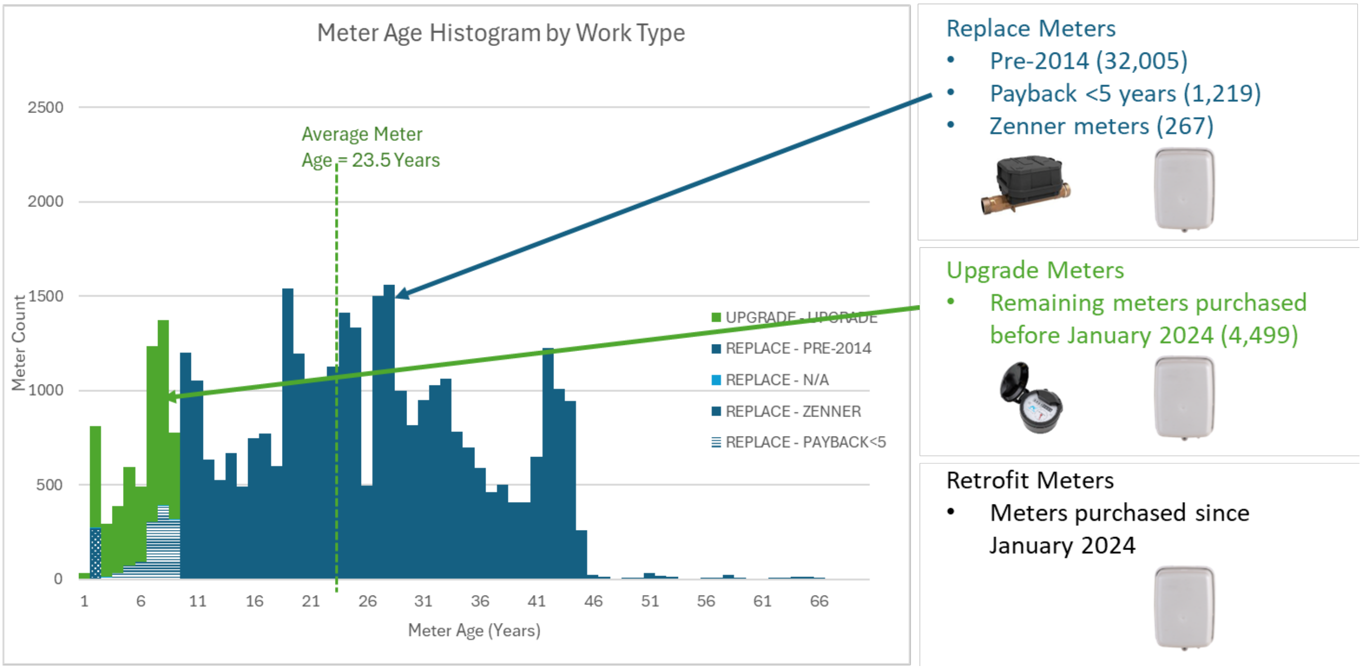
In addition to the financial benefits, the market is increasingly moving toward non-mechanical meters as they offer a range of enhanced features which may (specific features vary by manufacturer) include pressure, temperature, reverse flow, and empty pipe information.

R05: Follow work type approach

Chapter 4.4, Work Type Recommendations, outlined the optimal approach to updating the City of Thunder Bay's metered services. See Exhibit 72: Work Types for a breakdown of meters by age.

- Replace 33,491 meters
- Upgrade 4,499 existing meters with AMI-compatible registers
- Retrofit any new meters purchased since January 2024 with a radio transmitter since these meters are already AMI-compatible.

Exhibit 72: Work Types



The work types and expected quantities shown above are based on the general assumption that water meter registers cost about 60% of the cost of a completely new meter. When competitive pricing is obtained through the procurement process, if the cost of registers is higher relative to the new meter cost, the City of Thunder Bay can opt to replace more meters.

R06: Implement system quickly, not over 20 years

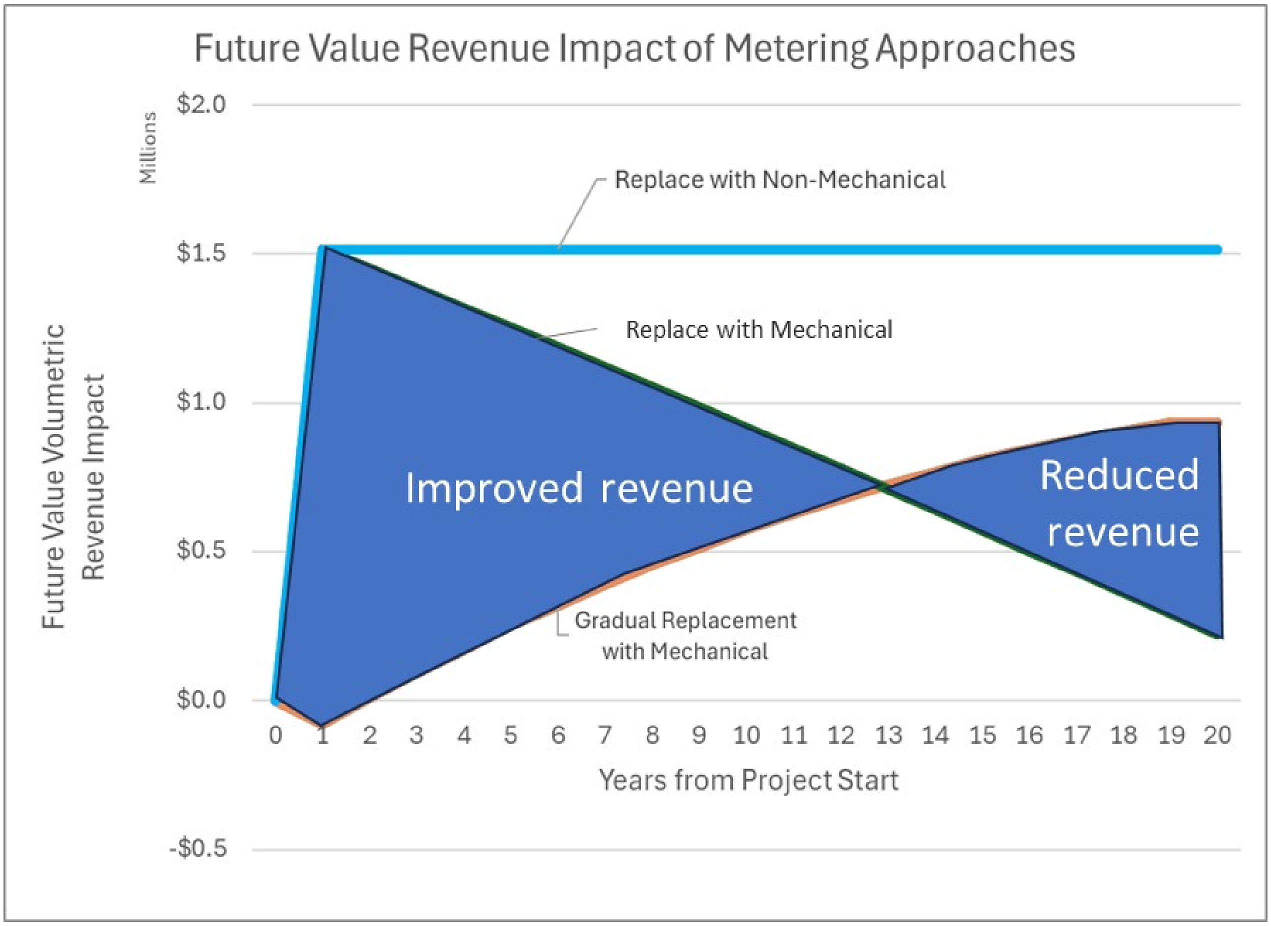
While a gradual deployment of the AMI system over an extended period, such as 20 years, is possible, it is not recommended. Diameter Services recommends the following deployment schedule to maximize the value of the City of Thunder Bay's investment.

Exhibit 73: Project Duration by Phase

Phase	Duration (months)
Phase 2: Procurement	8 months
Phase 3: Startup Phase	6 months
Phase 4a: Proof of Concept	3 months
Phase 4b: Installation and Deployment	22 months
Phase 5: Close Out	2 months
Total	**41 months**

Exhibit 74: Revenue Impact of Accelerated Meter Deployment, below, illustrates the benefit of improvement in meter accuracy and how an accelerated approach is more beneficial than a gradual (20 year) meter replacement program, yielding a net revenue improvement of $6.8 million.

Exhibit 74: Revenue Impact of Accelerated Meter Deployment



In addition to the revenue improvement, a range of non-financial benefits will be gained from an accelerated deployment, including lower project costs due to economies of scale, reduced impact of technology changes, and more equitable service levels for the City of Thunder Bay's customers. For a more detailed discussion of these non-financial benefits, see Section 11.3, Project Phases Accelerated Duration.

R07: Procure via a Request For Proposals, not a bid or tender

The procurement of an AMI system is a complex combination of hardware, network services, installations, and software. In addition, the various providers in the market have different approaches and strengths. As a result, the decision on the best AMI system to meet the City of Thunder Bay's needs is much more complicated than determining the lowest price offering.

Diameter Services recommends that the system be procured using a structured and comprehensive Request for Proposals (RFP) approach that will allow the City of Thunder Bay to evaluate how well each competitive offering addresses the City's needs.

R08: Procure using a turnkey approach

Diameter Services recommends that the City of Thunder Bay issue a single RFP that includes all of the key components of the AMI system including meters, radio transmitters, AMI network, system deployment, and system software. In addition, we recommend the inclusion of an optional customer portal software that will work with Thunder Bay's CIS bill payment capabilities that the City of Thunder Bay plans to deploy in 2025 (see R13: Deploy customer portal that supports full AMI functionality).

Packaging all of the key project elements into a single RFP provides the best assurance of end-to-end compatibility and enables the City of Thunder Bay to hold a single entity responsible for the overall system success.

R09: Redeploy meter readers for other activities

A common approach for utilities implementing AMI systems is to retain, retrain, and redeploy meter reading personnel rather than eliminate these positions. Employees can often be trained on value-added functions that support the AMI system including proactive customer service activities, radio transmitter installation and troubleshooting, and support of other operational programs including valve turning, hydrant inspections, line flushing, and water sampling.

R10: Meter shop to be responsible for intermediate & large meters, contractors for small meters

The City of Thunder Bay has considerable expertise among its meter shop staff. Diameter Services recommends that while the small meter work will be contracted out, that the intermediate and large meter work should be managed by the City of Thunder Bay's crews. Intermediate and large meter work can be challenging and requires greater distribution system understanding and experience. Allowing this work to be performed by City of Thunder Bay staff ensures that this skillset is retained and enhanced.

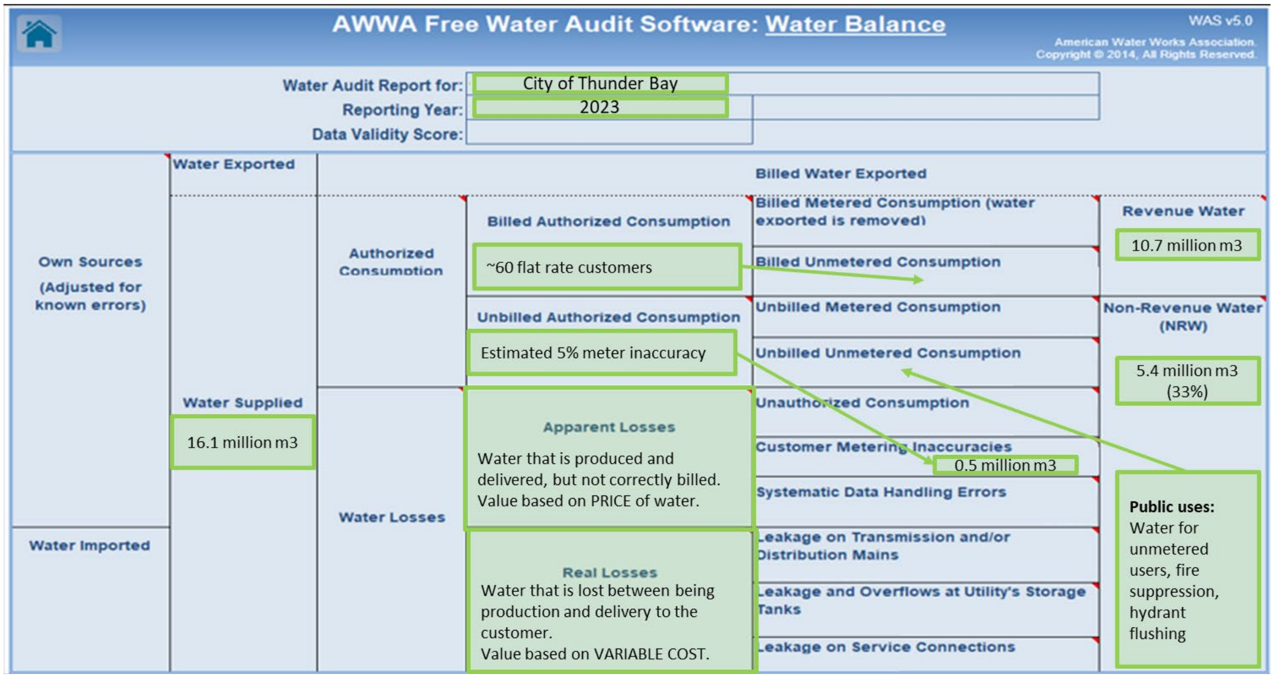
R11: Amend City of Thunder Bay's Waterworks Bylaw so the builder is responsible for wire run

Another common approach is to update the Waterworks Bylaw to include running a wire to the outside of the building. It is much easier for the builder to do this work than to have City of Thunder Bay crews install the wire after the building's finish work is complete. City of Thunder Bay crews would then be able to install the radio transmitter on the exterior wall of the building without the need to enter the premises.

R12: Continue to expand the use of the AWWA water audit software

The American Water Works Association (AWWA) introduced an MS Excel-based water audit software that it offers for free to the market. Diameter Services sees the value in this tool as a way to identify Non-Revenue Water (NRW) volumes and isolate sources of loss. It is recommended that the City of Thunder Bay continue to use this tool to build a baseline of water usage that will improve as the City implements AMI.

Exhibit 75: Mock-up of City of Thunder Bay Water Audit



In addition, Diameter recommends the following steps to identify some known sources of non-revenue water:

- Meter supply lines to unknown locations.
- Estimate water used in hydrant flushing, firefighting usage, and other authorized uses.
- Issue hydrant meters for contractors to track consumption.

By building a better understanding of the City of Thunder Bay's water uses, it will be easier to identify and address causes of water loss. Furthermore, a reduction in water loss offers the opportunity to reduce the energy consumed to produce and pump water that is never delivered as well as the greenhouse gases (GHG) produced in the generation of that energy.

R13: Deploy customer portal that supports full AMI functionality

The City of Thunder Bay has undertaken an upgrade of its CIS / billing system to Infor IPS. The Infor IPS system provides an add-on customer portal that allows customers to see billing information and make payments.

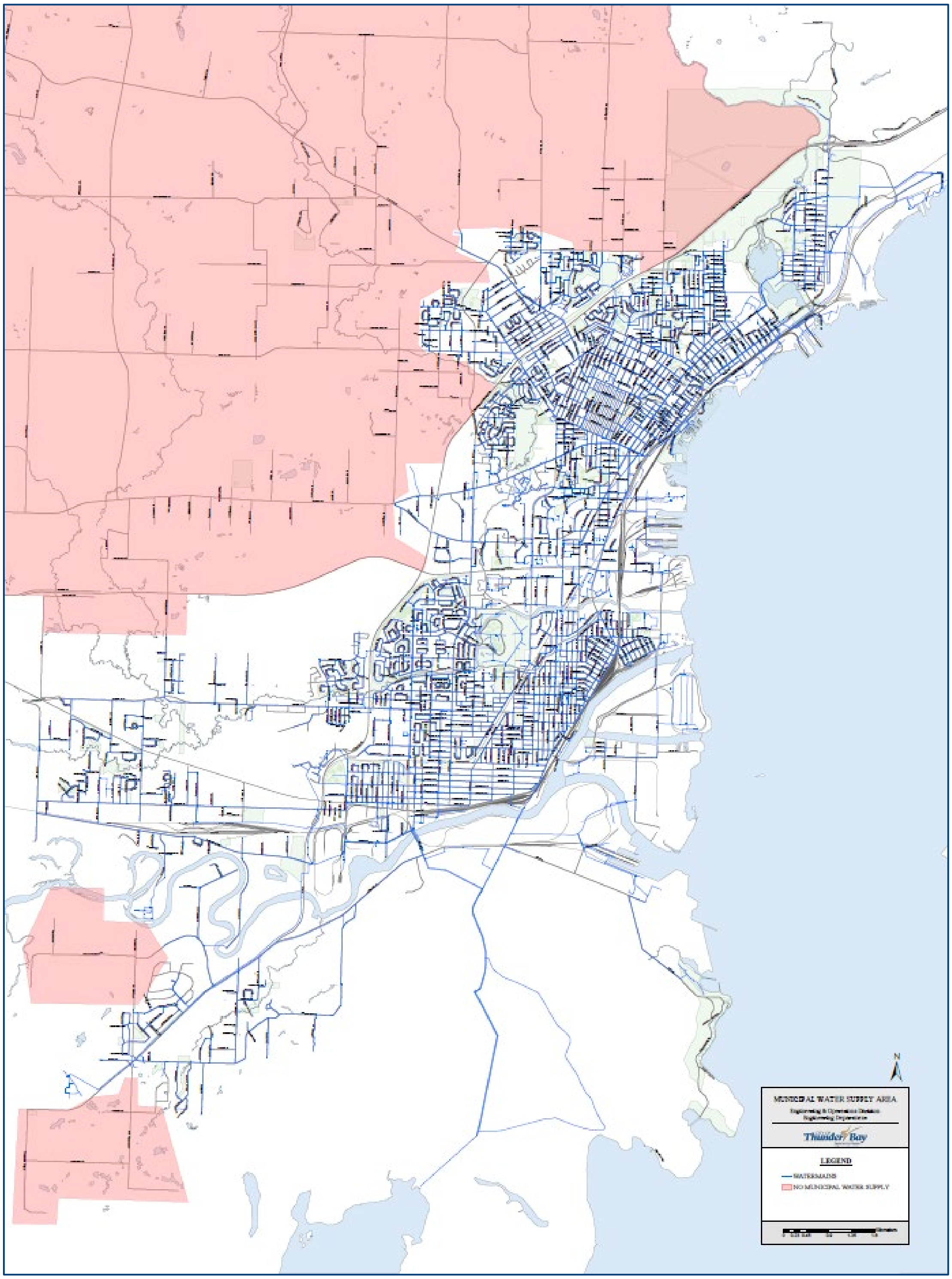
In addition to this customer portal, Diameter Services recommends the introduction of a customer portal that supports the additional data and functionality provided by AMI. For example, a homeowner would be able to see their daily or hourly consumption, helping to provide early warning of water leaks or other unexpected consumption that would otherwise lead to a high bill. Adding a second customer portal that supports AMI systems can be linked to the payments portal to create a seamless customer experience.

This customer portal functionality can be included as an optional element of the AMI request for proposals as noted above in section R08: Procure using a turnkey approach.

13. APPENDICES

Appendix A: Map of Thunder Bay's Drinking Water Service Territory

Exhibit 76: Thunder Bay Drinking Water Service Territory



Appendix B: Sample Warranty Proration Table

Exhibit 77: Sample Warranty Proration Table

Year	Proration Rate (Percentage of Average Radio Transmitter Warranty Costs to be covered by Vendor)
1	100%
2	100%
3	100%
4	100%
5	100%
6	100%
7	100%
8	100%
9	100%
10	100%
11	70%
12	70%
13	60%
14	60%
15	50%
16	45%
17	35%
18	30%
19	25%
20	25%

Note that vendor warranties may vary, and care should be taken to understand the exclusions and conditions that a vendor may include in their warranty's fine print.

Appendix C: Recommended Project Schedule

Exhibit 78: Recommended Project Schedule

Task Name	Duration	Start	Finish
Thunder Bay - AMI / AMR Implementation	**1196 days**	**Thu 24-03-14**	**Thu 28-10-12**
Design Stage - Phase 1: Project Planning / Detailed Design	**233 days**	**Thu 24-03-14**	**Mon 25-02-03**
RFP / Negotiate Consulting Support for Procure and Manage	**45 days**	**Tue 25-02-04**	**Mon 25-04-07**
Procurement Stage - Phase 2: Procurement	**164 days**	**Mon 25-04-14**	**Thu 25-11-27**
Project Management	**164 days**	**Mon 25-04-14**	**Thu 25-11-27**
Progress Meetings (1 hour remote meeting every 2 weeks)	164 days	Mon 25-04-14	Thu 25-11-27
Procurement Stage Kickoff Meeting	**2 days**	**Mon 25-04-14**	**Tue 25-04-15**
Risk Management Monitoring	**164 days**	**Mon 25-04-14**	**Thu 25-11-27**
Specification Development	**48 days**	**Wed 25-04-16**	**Fri 25-06-20**
AMI / AMR and Installation Specification, Water Meter Specification & RFP Development	**48 days**	**Wed 25-04-16**	**Fri 25-06-20**
Prepare 1st Draft of RFP	15 days	Wed 25-04-16	Tue 25-05-06
Submit first 1st Draft RFP	**7 days**	**Wed 25-05-07**	**Thu 25-05-15**
Prepare 2nd Draft of RFP	10 days	Fri 25-05-16	Thu 25-05-29
Submit first 2nd Draft RFP	**16 days**	**Fri 25-05-30**	**Fri 25-06-20**
Procurement	**100 days**	**Fri 25-07-04**	**Fri 25-11-21**
Manage Stage - Phase 3, 4, 5	**753 days**	**Tue 25-11-25**	**Thu 28-10-12**
Program Management	**753 days**	**Tue 25-11-25**	**Thu 28-10-12**
Communication and Project Coordination	753 days	Tue 25-11-25	Thu 28-10-12
Document Control	753 days	Tue 25-11-25	Thu 28-10-12
Diameter's Project Playbook	753 days	Tue 25-11-25	Thu 28-10-12

Draft Meeting Agenda, Attendance and Minutes	753 days	Tue 25-11-25	Thu 28-10-12
Progress Meetings	753 days	Tue 25-11-25	Thu 28-10-12
Manage Action Log, Change Orders, Tasks and follow up	753 days	Tue 25-11-25	Thu 28-10-12
Contract Management	753 days	Tue 25-11-25	Thu 28-10-12
Project Scope Management and Contractor Change Orders	753 days	Tue 25-11-25	Thu 28-10-12
Project Budget Management	753 days	Tue 25-11-25	Thu 28-10-12
Contract Schedule Management	753 days	Tue 25-11-25	Thu 28-10-12
Monitor and Report Quality of Inspection Program	753 days	Tue 25-11-25	Thu 28-10-12
Review Installation Data Quality	753 days	Tue 25-11-25	Thu 28-10-12
QA Post Installation Approvals	753 days	Tue 25-11-25	Thu 28-10-12
QA Field Inspections	753 days	Tue 25-11-25	Thu 28-10-12
Support Complaints Process (Liaison to Installation Vendor)	753 days	Tue 25-11-25	Thu 28-10-12
Direct Contractor	753 days	Tue 25-11-25	Thu 28-10-12
Review and Approval of Invoices	753 days	Tue 25-11-25	Thu 28-10-12
Coordinate, Inspect and Approve Data Collector Installations	753 days	Tue 25-11-25	Thu 28-10-12
Validation of Future Process and Metrics	753 days	Tue 25-11-25	Thu 28-10-12
Assist with Implementation of Future Business Processes	753 days	Tue 25-11-25	Thu 28-10-12
Assist with Execution of Organizational Change Management Plan	753 days	Tue 25-11-25	Thu 28-10-12
Risk Management Monitoring	753 days	Tue 25-11-25	Thu 28-10-12
Materials Handling (Optional)	753 days	Tue 25-11-25	Thu 28-10-12
Steering Committee Support	753 days	Tue 25-11-25	Thu 28-10-12
Phase 3: Start-up	**160 days**	**Mon 25-12-08**	**Fri 26-07-17**
Diameter - Kickoff Meeting	1 day	Mon 25-12-08	Mon 25-12-08

Project Kickoff Meeting (Vendor, Thunder Bay, Diameter)	2 days	Mon 25-12-15	Tue 25-12-16
Project Start-up Meetings	5 days	Wed 25-12-17	Tue 25-12-23
Progress Meetings (Weekly)	146 days	Tue 25-12-23	Tue 26-07-14
Steering Committee Meetings	**148 days**	**Wed 25-12-24**	**Fri 26-07-17**
System Integrations Workstream	**125 days**	**Fri 25-12-26**	**Thu 26-06-18**
Network and Software Deployment Workstream	**127 days**	**Wed 25-12-24**	**Thu 26-06-18**
Public Outreach Workstream	**96 days**	**Wed 25-12-24**	**Wed 26-05-06**
Installation Readiness Workstream	**80 days**	**Wed 26-01-21**	**Tue 26-05-12**
Testing	**10 days**	**Fri 26-06-19**	**Thu 26-07-02**
Initial Appointment Communications	**11 days**	**Fri 26-07-03**	**Fri 26-07-17**
Pre-Construction Meeting	1 day	Fri 26-07-10	Fri 26-07-10
Phase 4: Proof of Concept, Installation and Deployment	**545 days**	**Fri 26-07-17**	**Fri 28-08-18**
Proof of Concept (POC)	**60 days**	**Fri 26-07-17**	**Fri 26-10-09**
First Installation	0 days	Fri 26-07-17	Fri 26-07-17
Installations (POC)	12 wks	Mon 26-07-20	Fri 26-10-09
Progress Meetings / Dashboarding	12 wks	Mon 26-07-20	Fri 26-10-09
Quality Assurance Program	12 wks	Mon 26-07-20	Fri 26-10-09
Pre-Installation Approvals	12 wks	Mon 26-07-20	Fri 26-10-09
Installation Data Management Review	12 wks	Mon 26-07-20	Fri 26-10-09
Post Installation Approvals	12 wks	Mon 26-07-20	Fri 26-10-09
Progress Claim Approvals	12 wks	Mon 26-07-20	Fri 26-10-09
Incomplete (Task) Management Approvals	12 wks	Mon 26-07-20	Fri 26-10-09
Liaison for the District	12 wks	Mon 26-07-20	Fri 26-10-09
Business Process Redesign	12 wks	Mon 26-07-20	Fri 26-10-09
Final User Acceptance Test (F-UAT)	**15 days**	**Mon 26-09-21**	**Fri 26-10-09**
Installation and Deployment	**480 days**	**Mon 26-10-19**	**Fri 28-08-18**

Installations	96 wks	Mon 26-10-19	Fri 28-08-18
Public Education / Communication / Open houses	96 wks	Mon 26-10-19	Fri 28-08-18
Progress Meetings (Weekly)	96 wks	Mon 26-10-19	Fri 28-08-18
Steering Committee Meeting (Quarterly)	**480 days**	**Mon 26-10-19**	**Fri 28-08-18**
Contract Management (Program Management)	**480 days**	**Mon 26-10-19**	**Fri 28-08-18**
Approvals and Oversight	**480 days**	**Mon 26-10-19**	**Fri 28-08-18**
Quality Management	**480 days**	**Mon 26-10-19**	**Fri 28-08-18**
Phase 5: Close Out	**39 days**	**Mon 28-08-21**	**Thu 28-10-12**
Clean up Installations	4 wks	Mon 28-08-21	Fri 28-09-15
System Acceptance	10 days	Mon 28-09-18	Fri 28-09-29
Project Close Out and Reporting	1 day	Mon 28-10-02	Mon 28-10-02
Lessons Learned	5 days	Mon 28-10-02	Fri 28-10-06
Transition Program to Operations	9 days	Mon 28-10-02	Thu 28-10-12

Appendix D: Table of Exhibits