DIAMETER SERVICES

City of Greater Sudbury

Automated Meter Reading / Advanced Metering Infrastructure / Advanced Metering Analytics (AMR / AMI/ AMA) Feasibility Study

February 17, 2017

<u>Final Report</u>

Joel Carty, B Comm.
Diameter Services
847 Primrose Crt
Pickering, ON
L1X 2S7
Tel: (416) 305-3409
Fax: 1 (866) 504-8065

Table of Contents

EXECUTIVE SUMMARY 4

1. INTRODUCTION 11

1.1. Approach and Methodology 11

2. PROJECT ASSESSMENT 14

2.1. Water Utilities Challenges and Goals 14
2.1.1. Challenges 14
2.1.2. Business Goals 15
2.2. Water Meter Population Assessment 18
2.3. Service Providers Assessments 21
2.3.1. Water Billing Systems 22
2.3.2. Meter Reading Processes 24
2.3.3. Customer Service and Water Billing 32
2.4. Meter Maintenance processes 33
2.4.1. High/Low Customer Service Calls 33
2.4.2. Meter Applications 34
2.4.3. Frozen water meters 34

3. AMR/AMI/AMA REQUIREMENTS 35

3.1. AMR/AMI Technology Overview 35
3.1.1. Radio Frequency Considerations and Risks 35
3.2. AMR/AMI Technology Types 39
3.2.1. Walk-by AMR 39
3.2.2. Mobile AMR Technology 43
3.2.3. Fixed Base AMI Technology 44
3.2.4. Hybrid AMI/AMR Technology 53
3.2.5. Cellular Radio Transmitters 54
3.3. State of the Market 56
3.4. AMR/AMI Business Drivers 58
3.5. AMI Vendor Network Coverage 70
3.5.1. GSU Existing Smart Meter Network 71
3.5.2. Hydro One Existing Smart Meter Network 71
3.5.3. Other AMI Vendors 72

4. FINANCIAL ANALYSIS 73

4.1. Key Assumptions and Variables 73
4.2. Meter Accuracy Improvements 77
4.3. Operational Improvements 79
4.3.1. Meter Reading 79
4.3.2. Customer Service and Water Billing 81
4.3.3. Water Meter Maintenance 82
4.3.4. Distribution System Management 83
4.3.5. IT Support Costs 85
4.4. Capital Costs 86
4.4.1. Project Scope 86
4.4.2. Installation Cost 87

4.4.3. AMI/AMR Supply Cost 88
4.4.4. Meter Supply Cost 88
4.4.5. Consulting Support 88
4.4.6. Internal Project Support 89
4.4.7. Contingency 89

GLOSSARY 90

City of Greater Sudbury

AMR / AMI / AMA Feasibility Study

Executive Summary

The City of Greater Sudbury (CGS) engaged Diameter Services earlier this year to review the organization's current water meter population, meter reading/billing processes and to provide an *Automated Meter Reading / Advanced Metering Infrastructure / Advanced Metering Analytics (AMR/AMI/AMA) Feasibility Study*. Working with the City's project team we reviewed the information provided, conducted educational workshops and evaluated technology alternatives that would best meet the needs and goals of the utility.

CGS has identified a number of goals that Council has mandated the utility to achieve. The City's Water & Wastewater Services tactical Plan 2015-2018 explicitly stated this study as a high priority project (project 6 – Complete the automated meter reading business plan). After reviewing the Utility's current situation, it was clear that AMR/AMI technology could assist CGS in achieving seven other high priority projects and one low priority project that were identified in the tactical plan. Although, the financials have to be considered this technology upgrade should be seen as tool to assist in achieving 32% of the tactical plan. This investment in technology will position CGS to improve operational efficiency, enhance customer service and will provide a positive financial return on investment.

This report is part one of two, the second report will address implementation strategies, timelines and resources to make the project successful. The alternatives we looked at assumed 100% of the approximately 48,000 water customers were converted to the selected technology. The scenarios we reviewed are illustrated in the diagram below:

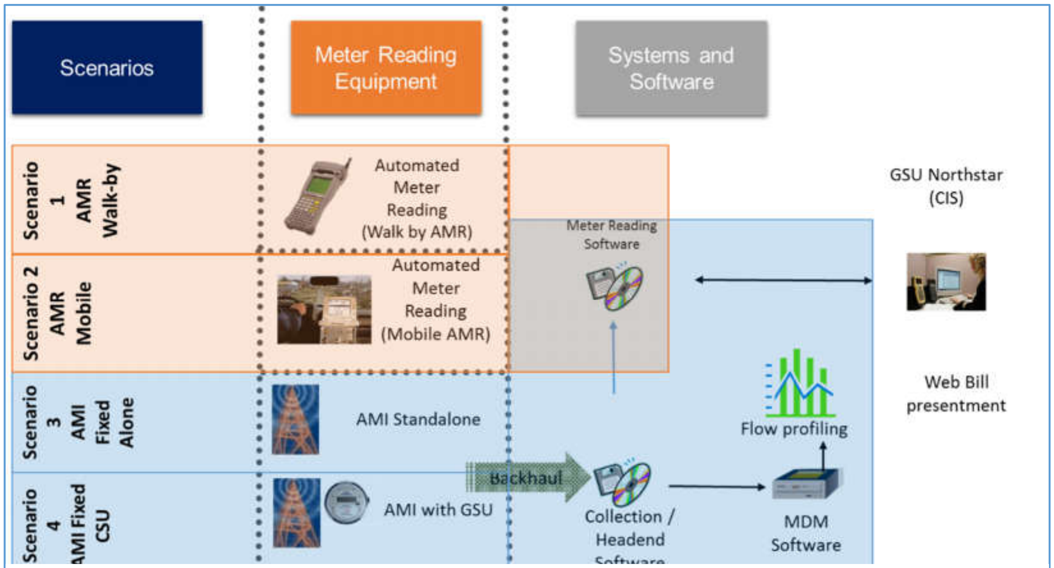


Figure 1

Scenarios 3 and 4 would provide the same technical benefits but had some cost implications when looking to partner with GSU. The three types of technologies (walk-by AMR, mobile AMR, fixed AMI) reviewed have different features and functionality that allows a water utility to perform a number of tasks. CGS project team reviewed 24 technology business drivers and identified 17 that were somewhat (8 drivers) or very important (9 drivers) to helping the utility achieve their tactical plan. These 17 business drivers were then compared to the three technologies to see how well they could support them. We found the following:

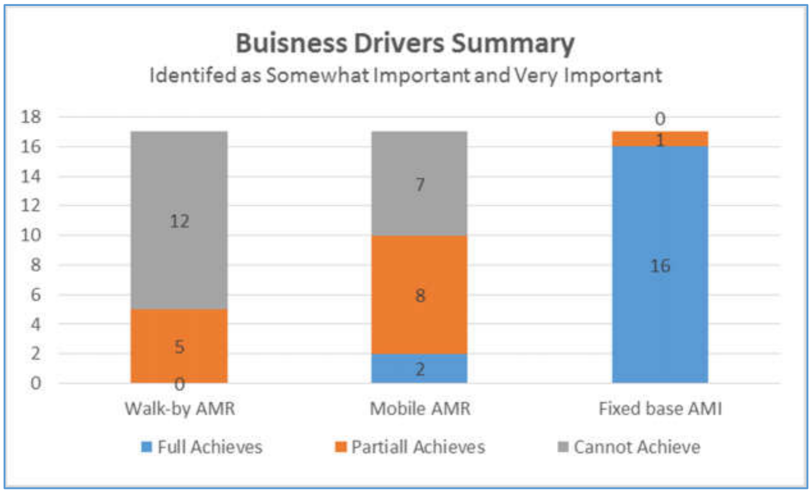


Figure 2

From a functional perspective, it is clear fixed based AMI technology is best suited to meet CGS business requirements. In addition to providing a tool to achieve the tactical plan, fixed base AMI technology will directly and indirectly help CGS address some of the long term water infrastructure challenges identified by WSP and presented to Council on November 22 2016. That study identified five current infrastructure challenges (1-Long Term Water Supply, 2-Water Storage, 3-System Pressure, 4-Fire Flow, 5-Leakage); fixed base AMI technology will provide the necessary data to optimize the significant infrastructure dollars that will be required over the next 20 years. In some cases, system-wide consumption data will require some infrastructure projects to be accelerated, in others, the data will allow CGS to push off some improvements allowing the infrastructure dollars to be prioritized to other systems or projects.

A project of this nature requires a significant investment, in addition to assessing the non-financial benefits CGS could expect, we reviewed financial implications. This report provides estimates of the total capital cost of the project, the cost of operating this system for its estimated 20 year life, as well as the financial impacts to meter reading, meter maintenance, customer service, water billing, distribution system management and IT support. Some of these estimates should lead to direct improvements in CGS financial budgeting, other financial benefits are considered efficiencies that will allow CGS to dedicate resources in other areas.

The table below summarizes the financial results including financial improvements, annual operational cost impacts, capital costs, the resulting payback and net present value calculations.

	Scenarios			
	Scenario 1 AMR Walk-by	Scenario 2 - AMR Mobile	Scenario 3 - AMI Fixed Alone	Scenario 4 AMI Fixed GSU
Year 1 Water & Wastewater Revenue				
Cash Inflows (Annual, 1st)				
Meter Accuracy Improvements	**$1.134M**	**$1.134M**	**$1.134M**	**$1.134M**
Cash OutFlows (Annual, 1st year)				
Total Operational Costs	$1.737M	$1.426M	$1.054M	$1.134M
Operational Improvements	**$.081M**	**$.392M**	**$.764M**	**$.684M**
Capital Costs				
Total Capital Cost	**$15.447M**	**$15.68M**	**$17.12M**	**$16.18M**
Results				
Net Present Value of Cashflows (20 years)	**$6.191M**	**$11.074M**	**$15.873M**	**$15.378M**
Payback (in years)	**12.72**	**10.28**	**9.02**	**8.90**

Table 1

Scenario 4 estimate has the best financial results. The cash inflows stem from the improved revenue by replacing the older less accurate water meters. The operational cost improvements relate to improvements in department costs. These are summarized for scenario 4 below:

	Scenarios		
	Scenario 0 - Manual Touch	Scenario 3 - AMI Fixed Alone	Scenario 4 AMI Fixed GSU
Cash Out Flows (Annual, 1st year) **Operational**			
Operational - Meter Reading	$.391M	$.032M	$.032M
Operational - Meter Maintenance	$.088M	$.048M	$.048M
Operational - Customer Services	$.307M	$.125M	$.125M
Operational - System Management Improvements	$1.031M	$.603M	$.603M
Operational - IT Costs	$0.M	$.246M	$.326M
Total Operational Costs	$1.818M	$1.054M	$1.134M
Operational Improvements	**$.M**	**$.764M**	**$.684M**

Table 2

The $750,146 financial improvement is the difference in expected costs with no AMI system $1,805,907 per year and with a fixed base AMI system $1,055,761. The additional cost of operating an AMI system is reflected in the increased IT costs, currently there are no IT costs related to meter reading and billing.

The capital cost of scenario 3 & 4 is summarized below:

	Scenarios	
	Scenario 3 - AMI Fixed Alone	Scenario 4 AMI Fixed GSU
Capital Costs		
Install	$4.696M	$4.696M
Meter Supply	$3.695M	$3.695M
AMR Supply	$6.133M	$5.225M
Consulting	$.785M	$.785M
Project Support	$.759M	$.759M
Non-Refundable HST	$.291M	$.275M
Contingency -0.1	$.761M	$.745M
Total Capital Cost	**$17.12M**	**$16.18M**

Table 3

The installation costs includes: installation management, meter replacement, installation of radio transmitters on the outside of the property, some valve replacements, plumbing, some carpentry to access the water meter and some wire replacements.

The water meter supply includes all high resolution water meters that are being recommended for replacement. Upgrading the water meter registers on those meters not being recommended for replacement would add approximately $450,000 to the above costs. The benefit of this option would be all water customers would have the same level of service with respect to leak detection within the property.

AMR supply includes the radio transmitters, additional data collection equipment, initial software licensing, AMI vendor deployment management, and handheld equipment for the meter maintenance department. A standalone option (Scenario 3) may add up to $908,310 in additional costs, but this amount is merely an estimate, the exact different should be determined through the procurement process.

Consulting assumes the procurement and full contract management is being conducted by a Water AMI consultant. Depending on the capabilities of the Vendor these costs could be significantly less. We have provided a worst case estimate for these costs.

Project support includes the internal CGS personnel who would need to be a part of the project. In some cases new resources may need to be added, it really depends on the expertise and how much time each person can dedicate to supporting the project.

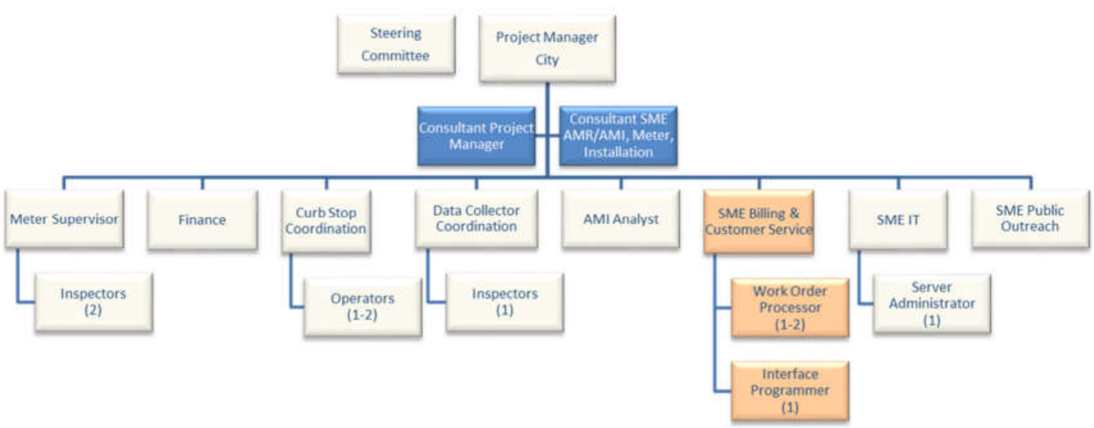
Contingency has been estimated base on some unknown risks of the installation and AMI supply. This contingency is really dependent on the quality of the procurement specifications. The installation costs have included most of the additional work that would be required so there is a good chance this contingency may not be required.

Project Schedule Summary:

WBS	Task Name	Duration	Start	Finish
1	**City of Greater Sudbury AMI Implementation Schedule**	**802 days**	**Mon 17-03-06**	**Tue 20-03-31**
1.1	**Project Management**	**802 days**	**Mon 17-03-06**	**Tue 20-03-31**
1.1.1	Project Start	1 day	Mon 17-03-06	Mon 17-03-06
1.2	**Pre-Procurement Task**	**120 days**	**Tue 17-03-07**	**Mon 17-08-21**
1.2.1	Develop and Award Consultant RFP	80 days	Tue 17-03-07	Mon 17-06-26
1.2.2	Compile Potential Data Collector Locations	60 days	Tue 17-03-07	Mon 17-05-29
1.2.3	**GSU Engagement**	**100 days**	**Tue 17-03-07**	**Mon 17-07-24**
1.2.4	Secure Project Team	20 days	Tue 17-07-25	Mon 17-08-21
1.3	**Procurement Phase**	**150 days**	**Tue 17-06-27**	**Mon 18-01-22**
1.3.1	**Water Meter Procurement**	**75 days**	**Tue 17-06-27**	**Mon 17-10-09**
1.3.2	**AMR / AMI and Installation Vendor Procurement**	**150 days**	**Tue 17-06-27**	**Mon 18-01-22**
1.4	**Startup Phase**	**85 days**	**Mon 18-01-08**	**Fri 18-05-04**
1.5	**Installation / Deployment Phase**	**497 days**	**Mon 18-05-07**	**Tue 20-03-31**
1.5.1	**Proof of Concept Phase (POC)**	**110 days**	**Mon 18-05-07**	**Fri 18-10-05**
1.5.2	Issue Notice to Proceed with Installation	0 days	Fri 18-10-05	Fri 18-10-05
1.5.5	Substantial Completion	0 days	Tue 20-03-31	Tue 20-03-31

A detailed project plan is included in the implementation report.

The project Team necessary to support this project is as follows:



Recommendations

Based on the CGS current situation and financial results we are recommending CGS implement the following recommendations:

1. CGS should implement a fixed base AMI system across 100% of 48,000 water meter population.
2. Teaming with GSU may be a viable and cost effective solution, but this decision needs to be made once proposals have been received from all the different AMI vendors. Making this decision to team with GSU now, will mean a large part of the project ($5M to $6M) would need

to be sole sourced. Without competitive pressure on the cost of the radio transmitter (85% of the AMI system cost) the cost may rise above a market proven prices.

3. CGS should procure, implement and operate their own Meter Data Management (MDM) software that will support the City's identified business drivers, although during the pre-procurement GSU meter sense should be reviewed in terms of functionality it is likely the restrictions to customize the MDM to meet CGS needs will be difficult.
4. CGS should continue with GSU online customer portal, but as a part of the MDM implementation the consumption profiling functionality should be interfaced with real hourly consumption data.
5. Regardless of the scenario approved by Council, CGS should contract the meter reading services directly from Olameter or another proven meter reading service provider. This contract should be administered by CGS meter maintenance department, this will ensure meter reading and meter maintenance are working together to keep meter reading costs low. Sign off of all meter reading invoices should be the responsibility of the meter maintenance department (currently this occurs in the finance department), ensuring there is more accountability to the money being spent.
6. Water meter reading types (inside read, outside read, commercial read, special reads) should be controlled by the Northstar system. Currently the meter readers are the ones controlling the type of reads being charged. CGS will need to work with GSU to investigate why this is not being done and what changes to the system and contracts are required to put this data into the system.
7. The project should be completed over an approximately 36 month period, with the first year focused on procurement and start up and the remaining 24 months left for the production phase.
8. We are recommending the following water meter replacement criteria:
    a. 15mm to 20mm sized water meters be replaced that are older than 5 years.
    b. 25mm and greater sized water meters should only be replaced where a radio transmitter cannot be installed due to the age of the meter register technology. The City's existing commercial water meter program has done a good job of keeping these meters current. This program should continue and start to incorporate AMI data analysis to help prioritize the meters that should be tested and refurbished.
    c. As an option, CGS should consider upgrading water meter registers (that are not being replaced) to a high resolution meter register. This will help the City maintain the same service levels across all customer for leak detection. The total optional cost of this upgrade is approximately: $450,000 for new registers.
9. CGS should plan for the design and contract management functions to be outsourced to a single water focused AMI consultant. The industry expert who designs the procurement specifications needs to be accountable to ensure the AMI vendor and installation contractor meet the functional requirements of the implemented AMI system.
10. There are a number of procurements that will be required to support this project. Council should expect the following procurements as a part of this overall project:

Component	Type of Procurement	Estimate Value
AMI System		$9.9M to $10.8M

Installation	Supply and Install AMI System Request for Proposal	
Meter Supply	Request for Proposal	$3.7M
AMI Subject Matter Expert Consultant	Request for Proposal	$785K
Northstar Changes	Sole source	$65K to $100K
GSU poles rental & project support	Increase scope on existing contract	$140K to $200K
CGS Internal project staffing	Existing staff New staff	$375K $375K
Cellular Providers	Increase scope on existing contract	$25K to $45K / year
Curb stop Locate and repairs	Using existing staff	None.

11. To prepare for this project CGS should collect key information about the existing CGS owned facilities including: type of facility, contact information, height/stories of the building, access to AC and Intranet.

1. Introduction

1.1. Approach and Methodology

Information requests, technology education workshops, business requirements workshops and written reports were the tools that Diameter Services used to develop the AMR/AMI/AMA Feasibility Study for the City of Greater Sudbury. It was important that key stakeholders participated in these sessions to ensure that the needs of CGS were well represented. Core members of the team included: David Brouse, Nick Benkovich, Dion Dumontelle, Shawn Turner and Gilles Bonhomme.

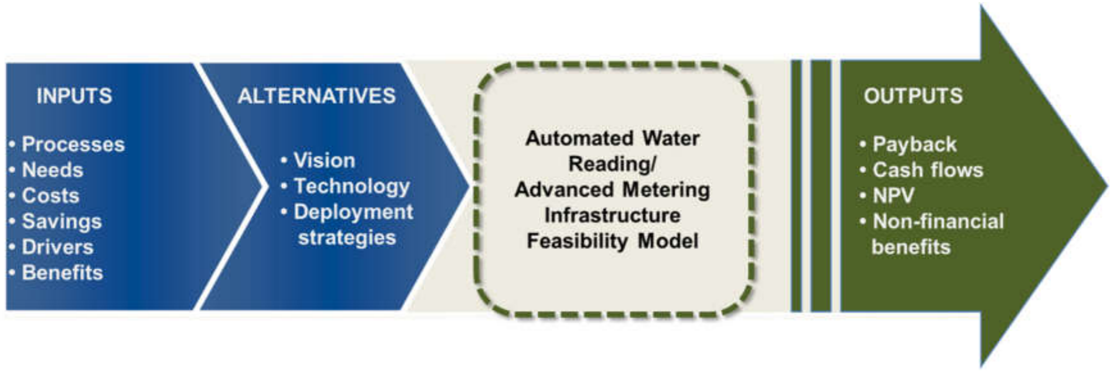


Figure 3

The above diagram shows how our approach led to our recommendations. The management team's contributions to our understanding of CGS business processes was critical in preparing this report so that the outputs were realistic and achievable. The steps that we followed were as follows:

Step 1 – Information Request

Diameter Services conducted an extensive survey at the onset of the project to collect data and information about CGS's current water meter population, organizational structure, meter reading equipment, current business practices related to meter reading, billing and maintenance, and existing software. The CGS management team gathered all the required information, often digging deeper than would normally be expected to ensure the information required to understand a process was accurate and clear. Collecting and analyzing this information prior to the business requirements workshops (see Step 3 below) ensured that Diameter Services arrived at the table with a solid understanding of CGS's existing program, which made for greater productivity in these initial meetings.

Step 2 - Educational Workshops

On a water meter and Automated Meter Reading (AMR) / Advanced Metering Infrastructure (AMI) project (See Glossary), the best decisions are made when each stakeholder has a reasonable level of industry and market knowledge. Educational workshops were used to ensure all team members (regardless of their existing level of expertise) were brought up to speed with respect to the products, systems, software and business processes that will be impacted by an AMR/AMI system.

Workshops Included:

- AMI/AMR Technology Review
- Water Meter Technology
- AMI/AMR Technology Drivers
- State of the Market

Step 3 – Business Requirements Workshops

Diameter Services conducted a series of business requirements workshops to validate and analyze the information that was provided during the information request. The workshops led the project team through discussions on critical issues that would have to be addressed for a water meter project of this size.

Workshops Included:

- Water Utility Challenges and Goals
- Existing Operations Assessment
- Meter Compatibility Requirements
- Small Water Meter Assessment
- Large Water Meter Assessment
- Meter Reading Equipment

Step 4 – Financial Analysis

Diameter Services worked with CGS to establish a financial model to derive a reasonable capital cost budget for all aspects of the project. Cost considerations included the AMR/AMI system, the meter data management system, water meters, installations, contract support, data collector location costs, backhaul and installation data management.

We reviewed four different financial scenarios:

Scenario 1 – Walk-by AMR Technology – this scenario assumes AMR radio transmitters would be installed on 100% of the water meter population. Meter reading would continue to be performed via a person walking by the property on a quarterly basis.

Scenario 2 – AMR Mobile technology – this scenario assumes AMR radio transmitters would be installed on 100% of the water meter population. Meter readings would be collected on a monthly basis by using a mobile driver by data collector.

Scenario 3 – Fixed base AMI (Standalone) – this scenario assumes AMI radio transmitters would be installed on 100% of the water meter population. Hourly meter readings would be collected daily using a CGS dedicated fixed base data collection network. This system would support monthly water billing.

Scenario 4 – Fixed base AMI (shared with GSU) – this scenario assumes a Sensus AMI radio transmitters would be installed on 100% of the water meter population. Hourly meter readings would be collected daily using the existing GSU fixed base data collection network and software. This system would support *monthly water billing.*

Step 5 – Recommendations

In this report Diameter Services has provides the conclusions and decisions reached as a result of Steps 1 through 4 above. The report includes clear recommendations on the type of technology that should be selected, the support it would need to be successfully implemented in the field, detailed descriptions of the preferred implementation strategy, and a roadmap from procurement to final completion.

Step 6 – Implementation Strategy

The implementation strategy really depends on the technology CGS decides to move forward with. The implementation strategy will discuss the resources, timelines and tasks required to implement the project.

2. Project Assessment

2.1. Water Utilities Challenges and Goals

The City of Greater Sudbury's (CGS) decision to carefully review the financial and operational benefits of AMR and AMI technologies was wise. Different meter reading technologies can improve the meter reading and billing process to reduce costs and improve billing accuracy. As a part of this exercise we looked beyond just meter reading and billing and tried to understand some of the challenges CGS experiencing as a utilities as a whole. It is important that water utilities take the time to really understand the full benefits of the more advanced technologies available. This engagement will provide the necessary information to ensure that CGS understands the available technologies and confidently selects the appropriate technology to meet their goals.

2.1.1. Challenges

Within the Challenges and Goals workshop and through our assessment of the CGS current practices, we have identified a number of challenges this study may face. The project team wanted to ensure this report addressed the following:

Reference	Challenge	Description	Plan to Address
C1	Full disclosure to Senior Management and Council	The project team wanted to make sure senior management and council were given enough summarized information to make the decision on moving forward, but still include all details for those who wanted more information.	The final report will include an executive summary with enough information to understand the financial and non-financial benefits of the different technologies. The full report will provide additional information to contributed to the final recommendations
C2	Avoid surprises in cost of program / staffing	The project team wanted to make sure the project costs (as much as possible) reflect a conservative cost estimate that included all staffing required on the utility to ensure the project is a success.	The report will be based on the most up-to-date market costs and will detail the areas of cost that may be more risky. AMI Vendors will be engaged to ensure the fixed network implications and costs are fully understood. The implementation plan will include estimated staffing level required to manage the project.
C3	Controlled message to the public	The team wanted to make sure the public is properly informed of the project (if approved) and promote the benefits of the program.	The installation cost estimate will include public outreach program to achieve this.

Reference	Challenge	Description	Plan to Address
C4	Fairness of rates / Fair Share (true cost equitability)	There was a concern that some of the benefits may not be reflected in water rates.	The financial model included both direct financial improvements and anticipated improved efficiencies as the team felt these would realistic to help keep water rates down in the long term.
C5	Vocal community relating to water conservation	The community is surrounded by fresh water, the importance of water conversation is more difficult to convince the public of.	Where possible the report should focus on the operational and customer service improvements, as the overall driving benefits of applying the technology to.
C6	The cost of water continues to rise	Total water produced and total water consumed continues to drop, but the cost of delivery of the water continues to increase (Operational and Capital projects).	Within the implementation plan some consideration should be given to how the project will be paid for. It may be beneficial to include an additional cost for the project on the water bill so customers know once the project is paid for the extra cost is removed.
C7	Balancing non-financial benefits of technology with the financial costs of implementing it.	Often capital projects are viewed strictly from a financial feasibility perspective but there are many non-financial benefits that need to be emphasized and considered.	The report will provide a quantitative measure of both the financial and non-financial benefits of the six technology options considered.

Table 4

2.1.2. Business Goals

Throughout the workshop's CGS's management team provided detailed information and commentary about the utility's organization, business processes, challenges, and goals with the idea of looking beyond just the meter reading and billing functions. CGS has done an excellent job documenting the utility's vision, values and areas of focus within the *Water & Wastewater Services Tactical Plan 2015-2018*. It is safe to say that*,* AMR/AMI technology will further contribute to CGS's vision of:

> "A growing, world-class community bringing talent, technology and a great northern lifestyle together."[1]

AMR/AMI technology can improve the Utilities focus on Customers, Employees and Business. Within the tactical plan, there were 34 prioritized projects (22 High, 5 medium, 7 low), this feasibility study directly meets Project 6 - *Complete the automated meter reading business plan.* CGS should also be

[1] Water & Wastewater Services Tactical Plan 2015-2018.

aware that by implementing smart metering technology, it can contribute to a number of other projects that were identified in the plan, namely:

Priority	Project Number	Project Description
High	P2	Implementation of community engagement program (improve information availability & transparency)
High	P5	Data Management process improvement
High	P6	Complete the automated meter reading business plan
High	P7	Deliver Council report & implement backflow / cross connection bylaw and program by the end of 2015
High	P11	Use of previous reports and data to prioritize inflow & amp; infiltration reduction target areas, water loss control / leakage reduction
High	P12	Develop a framework & execute a plan to use existing data to reduce non-revenue water in the Vermillion distribution system
High	P14	Presenting more operational KPI's; preventive maintenance, quarterly reporting by activity
Low	P31	Energy savings with new monitoring / billing

Table 5

The project team discussed and agreed to a number of goals they would want the AMR/AMI technology to achieve. The table below identifies these technology goals and links how they will help achieve the prioritized projects from the tactical plan:

Reference	Goal	Description	Prioritized Projects reference
G1	Leak Detection	The team wants to be able to identify two types of water leaks: • Customer leaks – to avoid / minimize high water bill complaints. • Distribution system leaks – to reduce the total unaccounted for water.	P2, P6
G2	High Bill complaints	Reduce the high bill complaints through: • Provide all customer monthly non-estimated meter readings. • Provide customer/billing staff with web access to hourly consumption information to allow them to better understand the reason for high bill complaints.	P2, P6
G3	Backflow detection	Use technology to identify backflow events. This would assist CGS in identifying those customers who need to be prioritized in installing backflow devices and customers that may require testing of the device.	P6, P7
G4	Reduce meter Tampering	Water meter maintenance has identified 10% of the meters removed from service had evidence of meter	P6, P11

Reference	Goal	Description	Prioritized Projects reference
		tampering. CGS wants to use technology to identify tampering quickly to be able to respond accordingly.	
G5	Client access to consumption information – customer portal	Giving customers hourly consumption information via web to improve customer service. Also give properties new tools to monitor their consumption – via e-mail alerts.	P6, P2
G6	Reduce / minimize billing estimates	Water billing estimates were at 7.2% in 2015. CGS wants the number of estimated to be reduced.	P6
G7	Reduce consumption credits due to high water bills	Water credits is quite involved and takes a number high level staff to review and approve. CGS wants the technology to allow GSU tools to avoid the need to perform credits. This can be achieved by improving meter reading data and the ability to view hourly consumption information.	P6, P11
G10	Reduce unaccounted for water	Unaccounted for water accounts for 26%. The team wants technology to reduce unaccounted for water.	P6, P5, P11, P12, P14, P31
G8	District metering	The project teams wants technology to implement district metering initiatives to understand what water systems/districts are contributing to unaccounted for water the most. This would allow capital infrastructure to prioritize money to go to the system with the highest need.	P6, P5, P11, P12,
G9	Temperature flags from the meters to alert the Utility/customer of the potential of freezing water services	There are about 300 customers whose water services are a significant risk of freezing. To avoid the freezing, the City has these customer run water continuously. A temperature flag that is triggered when water temperature drops below zero may help reduce the amount of water being credited back to customers.	P6, P11
G11	Providing commercial customers with hourly consumption data in an efficient manner	Some commercial customers would find hourly consumption information very valuable in understanding when the water is used.	P6
G12	Maximize any synergies with GSU or Hydro one systems.	There is an existing electric based smart metering system already in place. CGS wants to understand the benefits and drawbacks of piggybacking on these existing deployments.	P6
G13	Improve financial reporting	Due to the two month billing and reading cycles the data used for financial reporting is always an estimate and often requires adjustments to	P6, P5, P14

Reference	Goal	Description	Prioritized Projects reference
		forecasts. A Technology that allows for accurate reporting of revenues is important.	

Table 6

As we move throughout the document, references back to the prioritized projects, challenges and goals discussed above may be used. In this way, we will be able to connect the recommendations with achieving the goals that the CGS team has identified as important.

2.2. Water Meter Population Assessment

At the onset of this study, Diameter Services requested that CGS provide a database with specific information pertaining to all of the active water accounts. In preparation for the initial workshops, an analysis of this information was conducted to identify: Account Type, Age and Size of Meter Population, Water Systems, Meter Type, Register Type, Number of Dials being Read and Read Frequency. During Workshop 1 – Project Assessment, the information outlined below was presented to the Project Team to validate for accuracy and minimize assumptions going forward.

Account Type

Account Type	Total
Metered	47,972
Flat Rate	217
Total	**48,189**

Table 7

- CGS is 99.5% metered with only a few Flat Rate accounts remaining.

Age and Size of Meter Population

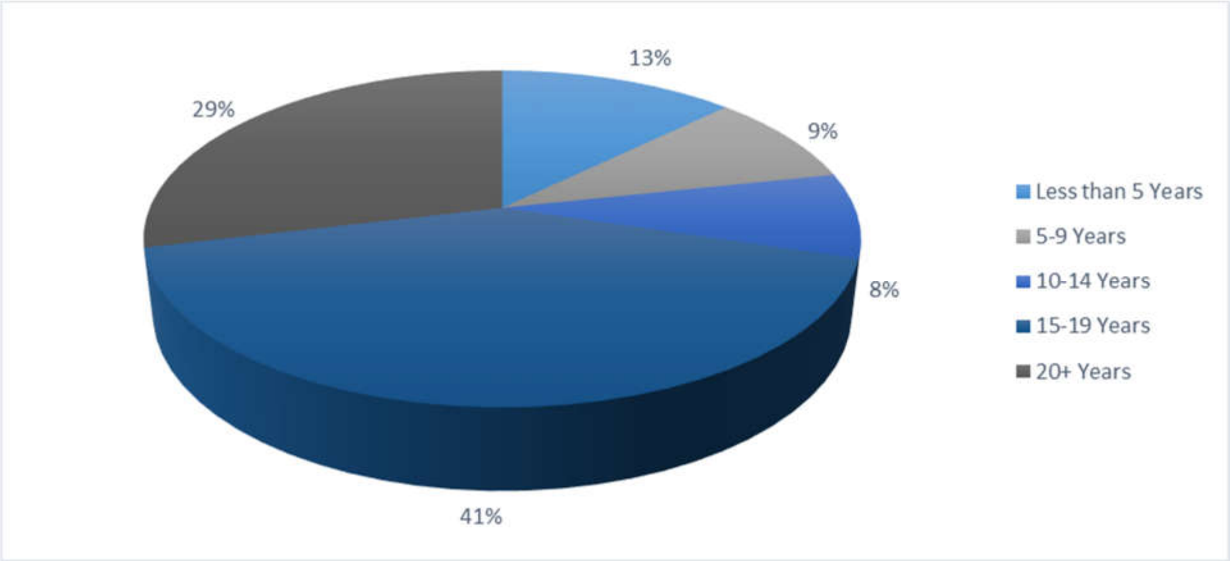


Figure 4

Meter Age	Percentage	Total
Less than 5 Years	13%	6,095
5 – 9 Years	9%	4,271
10 – 14 Years	8%	3,914
15 – 19 Years	41%	19,897
20 + Years	29%	13,795
Total	**100%**	**47,972**

Table 8

- CGS meter population is aging, with 70% of the meters 15 years and older.
- 99% of the meters that are 15 years and older are residential small meters ranging in size (5/8" – 1").
- Intermediate and Large Meters (1.5" and greater) have benefited from an active meter maintenance program, with 75% of the meters being less than 5 years old.

Water Systems

Within the database 21 regions were identified across CGS. A breakdown of the number accounts per region is outlined below:

Rank	Region	Totals
1	Sudbury	25,036
2	Hanmer	3,693
3	Chelmsford	2,952
4	Val Caron	2,697
5	Garson	2,639
6	Lively	2,421
7	Azilda	1,714
8	Capreol	1,307

Rank	Region	Totals
9	Coniston	828
10	Copper Cliff	778
11	Dowling	633
12	Val Therese	628
13	Levack	563
14	Wahnapitae	470
15	New Sudbury	414
16	Naughton	396
17	Onaping Falls	301
18	Falconbridge	284
19	Blezard Valley	260
20	Whitefish	173
21	Markstay	2

Table 9

- During Workshop 1, the project team worked to identify the relationship between region and Water System so that account volume / system could be understood.

Water System	Total
Sudbury / Wanapitei / Sudbury David	26,750
Valley / Capreol	13,251
Vermillion / Vale	3,768
Garson Wells	2,639
Levack / Onaping Wells	864
Dowling	633
Nickel Rim Well	284
Total	**48,189**

Table 10

Meter Type

The analysis of Meter Type identified that Neptune Technology Group was the predominant meter manufacture across all sizes. In some cases, assumptions had to be made with respect to meter type using a combination of meter size, number of registers and any potential comments the database included.

Meter Type	5/8"	3/4"	1"	1.5"	2"	3"	4"	6"	8"	Unknown	Total
Positive Displacement	45,834	5	1,130	464	465						47,898
Turbine						11	3	1	1		16
Compound					2	27	12	6			47
Mag								1			1
Fireline								3			3
(blank)							1	5		218	224
Total	**45,834**	**5**	**1,130**	**464**	**467**	**38**	**16**	**16**	**1**	**1**	**48,189**

Table 11

- 99% of the Meter Population is Neptune.
- Large Meters
  - Turbine = HP Turbine
  - Compound = Tru-Flo
  - Fireline = HP Protectus
  - Mag = Endress & Hauser

Register Type / Unit of Measure

In line with a Meter Population of Neptune Meters, when looking at Register Type in CGS you see an evolution of the Neptune product line.

Meter Size	ARB	Pro Read	E-Coder	Total
5/8"	8,891	36,004	939	45,834
3/4"		5		5
1"	57	873	200	1,130
1.5"	1	392	71	464
2"	7	415	45	467
3"		31	7	38
4"	1	13	2	16
6"		16		16
8"		1		1

Meter Size	ARB	Pro Read	E-Coder	Total
(blank)		218		218
Total	**8,957**	**37,751**	**1,264**	**48,189**

Table 12

- Majority of the Meter population contains Pro Read Registers.
- Within the last couple years, CGS upgraded to the E-Coder register on all new meters.
- 99.9% of the Registers are read in Cubic Meters M^3.

Number of Dials

CGS water meter population is currently configured to be read down to the billable unit. A billable unit is equal to 1 cubic meter of consumption or as summarized in the chart below, 5 dials.

Meter Size	4	5	6	8	10	(blank)	Total
5/8"	8,871	36,942	3		1	17	45,834
3/4"		5					5
1"	35	1,090	4			1	1,130
1.5"		464					464
2"		10	457				467
3"			38				38
4"			16				16
6"			14	2			16
8"						1	1
(blank)		1				217	218
Total	**8,906**	**38,512**	**532**	**2**	**1**	**19**	**48,189**

Table 13

- In order to achieve meaningful leak detection across CGS customer base, it will be important to move to a higher resolution water meter registers.

Read Frequency

CGS currently has 3 different read frequencies across 66 Cycles, as can be seen in the chart below.

Read Type	Cycle	Total
Monthly	90	403
Bi-Monthly	1 - 63	47,444
3 Times / Year	93	341
Other	95	1
Total	**66**	**48,189**

Table 14

- Mandated movement for GSU to move to monthly billing for Electric Meters, will see estimation occur every other month for 47,444 water customers.
- Accounts that are read 3 times / year are customers who have to run water throughout the winter months to avoid freezing.

2.3. Service Providers Assessments

CGS has a number of organizations, each with their own systems throughout the water meter reading, billing and maintenance business processes. The primary service provider is Greater Sudbury Utilities (GSU) who performs meter reading, billing and collections on behalf of CGS. The meter reading is actually sub-contracted to Olameter, whose costs are embedded in the monthly water billing cost GSU charges CGS. It should also be noted that GSU is solely owned subsidiary of CGS with Council members sitting on GSU's board.

2.3.1. Water Billing Systems

Each organization has different systems that support the various components of the business process. The diagram below depicts the pertinent software that was reviewed as a part of this project assessment.

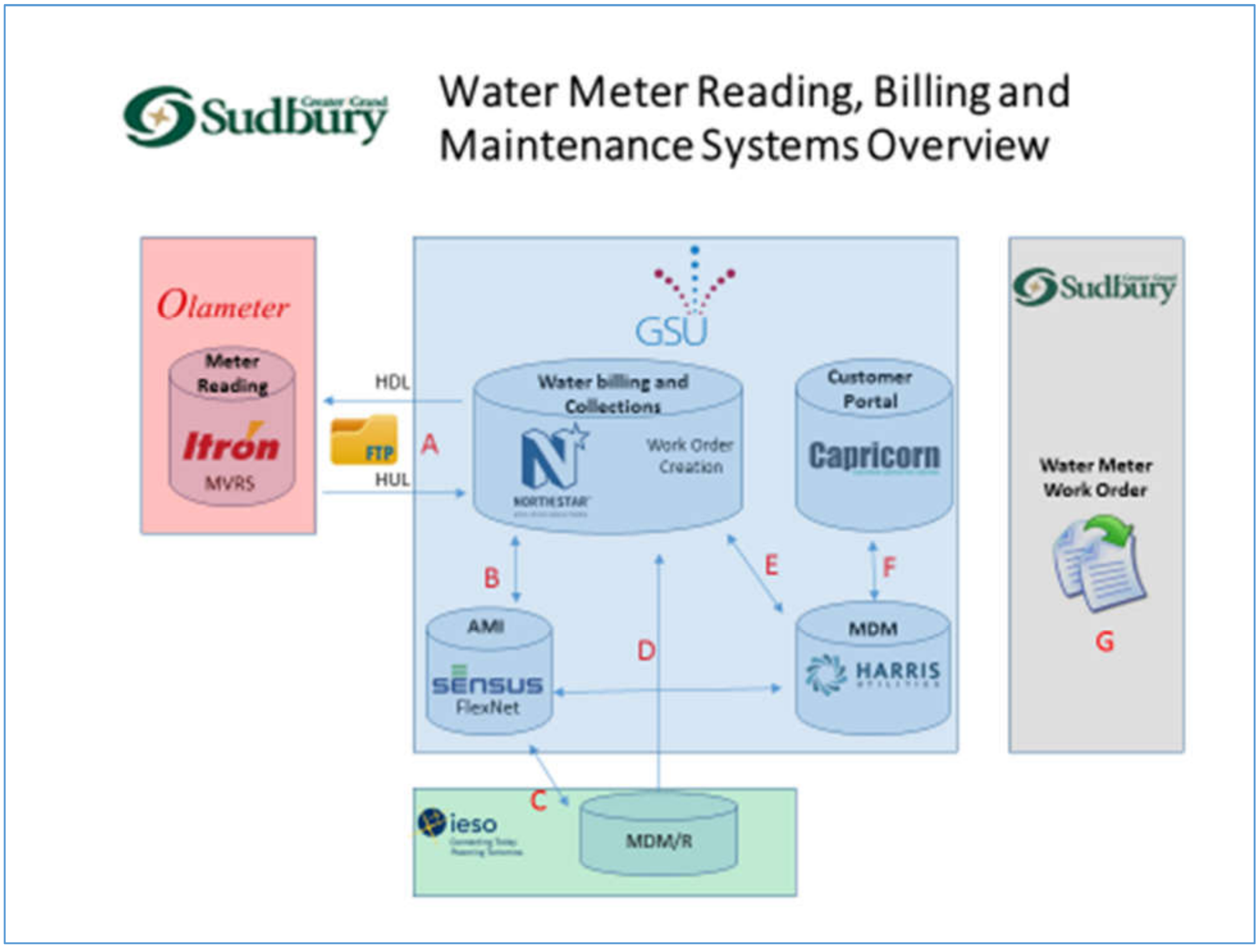


Figure 5

GSU Northstar billing system is interfaced with a number of different systems and depending on the type of technology that is implemented CGS could benefit from utilizing an existing system or interface. The table below shows what systems, interfaces and process that may be affected by the different scenarios being considered.

System / Interface	Scenario 1 – Walk-by AMR 2 – Mobile AMR 3 – Fixed AMI (alone) 4 – Fixed AMI (with GSU)	Implications for CGS
Itron MVRS Interface A (HUL and HDL)	1, 2, 3, 4	This software would need to be replaced with the AMI/AMR vendor. The interfaces would need to be developed from scratch.
GSU Northstar	1, 2, 3, 4	The Northstar system can receive AMR and AMI data for billing purposes from all the major technology vendors. Some work will be required to setup and test the system. Business requirements will be required once a system has been selected. The capital cost has included some costs for Northstar to implement changes.
Sensus Flexnet Interface B Interface C Interface D	1,2	This system or interfaces would not be used.
	3	The Sensus Flexnet system would be replaced with the AMI vendor software. This would likely be installed with CGS's IT network or be hosted by the vendor. Interface B - would need to be developed from scratch with the assistance of the vendor. *Interface C* – would not be required. *Interface D* – would need to be developed and tested with the assistance of the vendors of the AMI (Sensus) and MDM systems.
	4	This system would be shared for both electric and water meter readings. GSU and Sensus has confirmed there is capacity to collect and store the meter readings with the existing software. Additional data collector infrastructure would need to be installed across the communities that are serviced by Hydro One. *Interface B* – it is likely the existing interfaces would be suitable for water purposes although some review and testing would be required. *Interface C* – would not be required. *Interface D* - would need to be developed and tested with the assistance of the vendors of the AMI (Sensus) and MDM systems.
Harris MDM (Meter Sense) Interface D Interface E Interface F	1,2	This system or interfaces would not be used.
	3, 4	It is unlikely this system would be utilized a fixed based AMI system. This system is setup for the electric utility, it is likely that there are limits to how water could be setup that would not allow CGS to fully meet the business

System / Interface	Scenario 1 – Walk-by AMR 2 – Mobile AMR 3 – Fixed AMI (alone) 4 – Fixed AMI (with GSU)	Implications for CGS
		requirements. It is recommended, once MDM specifications are developed, to allow Harris to propose how they could meet the needs of the software either through using GSU or having CGS stand up their own Meter Sense MDM software. *Interface D* - would need to be developed and tested with the assistance of the vendors of the AMI (Sensus) and MDM systems. *Interface E* - would need to be developed and tested with the assistance of the vendors of the Northstar and MDM systems. *Interface F* - would need to be developed and tested with the assistance of the vendors of the Capricorn and MDM systems.
ieso MDM/R	1,2,3,4	This system or interfaces would not be used.
Capricorn customer portal Interface F	1,2,3,4	It is recommended CGS would use this customer portal system to provide customer access to their water consumption information. Unless CGS is planning a customer portal for other utility business, then an evaluation of the system should be conducted to determine the best location for customer to access water consumption information. Interface F - would need to be developed and tested with the assistance of the vendors of the AMI (Sensus) and MDM systems.
CGS paper work order process	1,2,3,4	Many of the AMR and AMI system require programing and testing of the radio transmitter at the time of installation. Best practices would recommend movement away from a paper based system to electronic data capture so that the same handheld equipment can be used to program and test the AMR / AMI radio transmitters.

Table 15

2.3.2. Meter Reading Processes

2.3.2.1. Organizational Structure

Water utilities in Ontario often have the electric distribution company provide water billing and reading services, even though they have already moved to smart electric meters. It is also very common for the billing service provider to control and contract out the meter reading services to a private company. In the case of CGS, GSU contracts these services out to Olameter.

This organizational structure was a necessity when the electric smart metering systems were being deployed. Today, there are some strong benefits that can be realized when reconsidering this structure.

The electric utility no longer requires manual meter readings and often the quality of the readings obtained is overlooked. This may be one of the contributing factors that has led to higher water billing estimates. In this historical structure, the water utility has limited ability to dictate terms, specifications and types of equipment that need to be used to collect the readings. For CGS, meter reading performance has been an issue and their ability to address is limited due to the contract being with GSU.

Regardless of the technology being selected, the following changes are recommended:

1. The Olameter contract be moved from GSU to CGS.
2. The meter reading contract should report into CGS meter maintenance department.
3. CGS remove meter reading equipment from the Olameter contract, instead CGS should procure their own meter reading handheld equipment, so targeted AMR / AMI radio transmitters can be deployed to high read cost meters.
4. CGS should own the meter reading software that would load the handheld equipment for Olameter meter readers.

2.3.2.2. Meter Reading Equipment and Software

The meter reading handheld equipment and software is owned and operated by the meter reading contractor, Olameter. They use 4 to 5 Itron FC200 handhelds with Itron's MVRS meter reading software, as well as a Neptune boomerang reading device.

Figure 6

Meter reads are obtained from a Neptune touchpad or ARB pin remote, the boomerang device displays the register ID and meter reading. The meter reader then manually enters the readings into the Itron FC200 handheld. This process is prone to manual key entry errors.

The current equipment is reaching the end of its useful life and would have limited ability to read water meters with an AMR radio transmitter installed. This is an opportunity for CGS to replace the equipment themselves with a handheld and meter reading software that can collect readings from their preferred AMR provider.

It is recommended that this equipment be replaced with CGS selected meter reading equipment and software that would allow the use of even a limited number of AMR radio transmitter devices.

2.3.2.3. Detailed Meter Reading Costs

The of meter reading were broken in three components, direct meter reading costs that are conducted by Olameter, meter reading coordinator cost expect to be provided by GSU and CGS's meter reading department who are performing some re-reads as a result of billing estimates.

2.3.2.3.1. Direct Meter Reading Costs

Getting the right information to analyze the meter reading costs was difficult. The meter reading rates were easy to obtain, the 2015 rates are summarized in the table below. But we were not able to reference these rates to the database of meters we analyzed, so we initial made a number of assumptions about what fields of data drove the read rates.

Meter Reading Rate Description	Rate ($ per reading)	Understanding of when rate is applicable, and Northstar field we referenced
Residential Outside, Water Only	$.545	Residential properties with an outside touch pad. NS field "category" = R1 (46,044)
Residential Inside, Water Only	$.93	Residential properties with an no touch pad. NS field "category" = R1 (no inside indicated so we had to estimate)
Residential Outside-Freezing, Water Only	$.635	Residential properties with an outside touch pad that keep water running due to potential of freezing. NS field "category" = R1 & route 317-327 (340 accounts)
Residential Inside-Freezing, Water only	$.982	Residential properties with an no touch pad that keep water running due to potential of freezing. NS field "category" = R1 & route 317-327 (340 accounts), no inside indicated so we assumed none.)
Commercial Outside, Water Only	$1.987	Commercial or multi-unit residential properties (touch pad did not matter due to no difference in cost). NS field "category" = R2 (484), M1 (74), C1 (1,505), C2 (50), C3 (32), for a total of 2,145
Commercial Inside, Water Only	$1.987	
Special Reading Service	$7.990	These readings were used for finals readings or a re-read (3,836 in 2015)

Meter Reading Rate Description	Rate ($ per reading)	Understanding of when rate is applicable, and Northstar field we referenced
		where the meter reader was confirmed correct (no quantity provided).
Initial Calls	Unknown	This was to compensate the meter reader for traveling to the remote water systems.
Bi-monthly readings	See above	All readings were assumed to be read six times per year except very few monthly reads.
Monthly readings	See above	Meters with a category M1 (74)

Table 16

When we attempted to use these assumptions to calculate the total annual meter reading cost, but we could not come up to the approximate $235,050.35 approved in 2014. One issue that came up is no one in the meter department had reviewed or approved the meter reading invoices. So although the meter reading department was able to resolve issues (install an outside remote) to bring the cost of meter reading down, they did not know if the cost were actually decreasing.

To resolve the confusion we provided some additional resources to digitalize the 2015 Olameter invoices. The table below shows what the CGS was invoiced by the Olameter read rate description.

Read Rates	Unit Prices	Invoiced Qty	Invoiced $
Residential Inside	$ 0.930	837	**$ 781.76**
Residential Outside	$0.5450	247,591	**$134,937.10**
Residential Freezing	$ 7.990	1,646	**$13,151.54**
Commercial	$1.987	23,778	**$47,246.89**
Special Reading	$ 3.060	4,397	**$13,446.03**
Special Reading	$ 7.990	3,656	**$29,211.44**
Initial Call	$22.49 to $68.19	384	**$12,832.64**
Turn-Off of Water Service	$17.080	493	**$ 8,421.43**
Turn-On of Water Service	$17.080	74	**$ 1,264.07**
Negotiation of Payment	$11.81 to $25.15	762	**$ 9,025.90**
No. Customer Contact Required	$2.84 to $9.35	858	**$ 2,457.95**
		Total Invoiced	**$272,776.73**

Table 17

This work allow us to compare reading costs and understand the quantity of each reading rate Olameter charged CGS (through GSU). There were a few things this highlighted:

- There was a lower special reading rate of $3.060, after investigating where this rate was applied it was clear these were only related to special reads performed in the City of Sudbury water system.
- There were $21,167 other services that were performed by Olameter that is unrelated to meter reading. We assumed this cost would be required moving forward. Total meter reading costs for 2015 were actually $251,609.

The second step in the anaylsis was to compare the quantities invoiced in 2015 to what we would expect based on the analysis of the database. The table below provides this comparison and shows the delta between what was expected and what was invoiced.

Read Rates	Expected (formula and qty)	Invoiced	Delta
Residential Inside	109 * 6 reads per year Total reads / year: 654	837	**183**
Residential Outside	(46,044 R1 less 109 inside reads)*6 reads per year Total reads per year:275,610	247,591	**(28,019)**
Residential Freezing Expected rate of $.635-$.982 / read Invoiced rate of $7.99 / read	340 reads * 3 reads per year Total reads per year: 1,020	1,646	**626**
Commercial	2,145 less 74 monthly *6 reads per year + 74 monthly*12 = Total reads per year:13,314	23,778	**10464**
Special Reading at $3.06	3836 final reads per year	4,397	**4,217**
Special Reading at $7.99		3,656	
Total Readings	**294,434**	**281,905**	**(12,529)**
Initial Call	No information was given to provide an estimate	384	**N/A**
Turn-Off of Water Service		493	
Turn-On of Water Service		74	
Negotiation of Payment		762	
No. Customer Contact Required		858	

Table 18

CGS will need to dig a little deeper in order to full understand why there are differences in the expected versus what was invoiced.

During the process of trying to obtain the critical Northstar field(s) that are used to drive meter read rates, Olameter indicated that GSU does not maintain a field that allows them to apply meter read rate using the MVRS reading file. Instead a few years ago they moved to relying on the meter reader to indicate what read rate would be used. So in essence, GSU has limited control over the rates are to be charged by Olameter. Meter readers are usually paid in a similar fashion as the meter reading contractor is paid (piece rate), this could provide a financial incentive to assess some properties in the higher read rate categories. If a field was maintained within Northstar that drove meter read rates it would provide a lot more control to the meter department on the reads that are being charged.

Some other discrepancies that should be investigated by CGS:

- Residential freezing rate – it appears the read rate should be $.635 per read, but they charged $7.99 per read. There may have been an un-disclosed agreement to this rate change, this should be better understood.
- Residential freezing rate – the quantities where higher than expected and in 2015 it does not appear all meters were read three times. The May 31, 2015 reading in Sudbury was much higher than expected.

Read Date	Capreol	Chelmsford	Dowling	Levack	Sudbury	Grand Total
31-May-15	No Reads	3	87	43	812 More than expected	945
14-Jun-15					7	7
27-Sep-15	69	3	No Reads	44	239	355
27-Dec-15	69	3	No Reads	26	241	339
Grand Total	**138**	**9**	**87**	**113**	**1,299**	**1,646**

Table 19

- The commercial readings – what was invoiced appears to be 10,464 more than what was expected based on what is in the Northstar system. A couple possible reasons for the discrepancies are 1) the category was not updated to the correct one, 2) meter readers and GSU have a difference of opinion on what is consider commercial. Having Northstar control what is considered a commercial read will give CGS back control of these costs. CGS may need to go out into the field with a meter reader to determine what they consider a commercial reads. This may lead to a cost savings or re-categorization within Northstar.
- Special readings – the quantity of special reads was higher than the total final reads. This may be due to re-read requests by GSU, but it would lead to the question of why are these re-reads required. CGS meter shop has already started to investigate these re-read requests and is finding about 72% may be preventable. Refer to the *Water Billing Estimate* section of this report. With CGS taking over the re-reading effort these extra costs may be better controlled.
- Lastly we reviewed the rates being charge to travel to the remote water systems we did not find any irregularities. See the table below that summarizes these costs:

System	Rate	Qty / year	Extended	Estimated Km from GSU office
Van Caron	$ 22.49	33	$742.30	16.8Km
Garson	$ 22.49	58	$1,304.65	14.8Km

System	Rate	Qty / year	Extended	Estimated Km from GSU office
Lively	$ 22.49	40	$899.76	15.0Km
Chelmsford	$ 28.63	62	$1,775.12	20.5Km
Naughton	$ 28.63	11	$314.94	17.7Km
Val Therese	$ 28.63	13	$372.20	23.8Km
Wahnapitae	$ 28.63	25	$715.51	18.6Km
Hanmer	$ 34.09	69	$2,352.00	26.6Km
Whitefish	$ 51.14	6	$306.82	33.7Km
Dowling	$ 51.14	27	$1,335.69	31.1Km
Onaping Falls	$ 67.13	13	$872.65	37.4Km
Levack	$ 68.19	27	$1,841.00	45.0Km
Grand Total		**384**	**$12,832.64**	

Table 20

The costs and quantities appear to be in line with the distance the meter reader needs to travel. As well we review the number of reads per day that were performed and there was a good correlation between the further the drive the few meters were read per day.

2.3.2.3.2. GSU Meter Reader Coordinator

The contract between CGS and GSU contemplated a meter reading coordinator position to manage the day to day activities of the Olameter contract. The contract allows for $75,000 per year in additional budget to cover the cost of this position. Although GSU has not filled this position and therefore has not charged for this cost some of the issues highlighted in this report could be improved with more resources being dedicated to managing the meter reading contract and business practices.

We are recommending this position be filled with someone within CGS meter maintenance department so they can direct efforts relating to meter maintenance that will benefit the cost of meter reading and the service level the City's customers are receiving (fewer estimated bills). This would be done in conjunction with moving the meter reading contract from GSU to CGS.

2.3.2.3.3. CGS Re-read Costs

CGS meter staff have started to perform the re-reads to try and determine what is causing some of these issues. Between March and October of 2016, CGS staff found the following:

Month	Customer Issue	Estimate	Inside Read	Maintenance	Re-read	Re-read Lockbox	(blank)	Total
(blank)				1	24		5	30
Mar	5	2	8	9	68	21	4	117
Apr	6		14	20	146	44	1	231
May	1		4	16	38	34	1	94
Jun	1		2	14	52	5		74

Month	Customer Issue	Estimate	Inside Read	Maintenance	Re-read	Re-read Lockbox	(blank)	Total
Jul	10		6	27	53	7		103
Aug	14		8	24	70	39	3	158
Sep	20		3	21	55	6	2	107
Oct	3		4	10	26	4		47
Grand Total	**60**	**2**	**49**	**142**	**532**	**160**	**16**	**961**
Non Preventable	**60**	**2**	**49**	**142**	**0**	**0**	**16**	**269 (28%)**
Preventable	**0**	**0**	**0**	**0**	**532**	**160**	**0**	**692 (72%)**

Table 21

This would indicate that 72% of the re-reads that occur may be preventable through either better meter reading management or the use of AMR radio transmitters, to avoid the meter reader from being locked out. These finding support our recommendation for CGS to take over the Olameter contract and manage it directly.

Assuming no AMI/AMR technology is implemented we have assumed the cost of re-read meters due to weather or meter reading performance will continue. The cost are summarized below:

Type of Reading	Quantity	Cost per occurrence	Extended
CGS staff re-reads	1,260	$35.00	**$44,100.00**
Total Cost			**$44,100.00**

Table 22

2.3.2.4. Total Meter Reading costs and recommendations

The total meter reading costs used in the model are summarized below. It should be noted that the model does not match exactly the above findings due to formulas being used in the model.

Meter Reading Cost	Extended
Olameter – Reading costs	$ 250,983
Olameter – Other Services	$ 21,167
Meter Reader Coordinator	$ 75,000
CGS re-read costs	$ 44,100
Total	**$391,251**

Table 23

We are making the following recommendations:

1. Meter reading codes be setup in GSU Northstar system that will drive Olameter's meter reading costs. This would allow CGS to control the types of readings that are being performed.
2. Change the agreement with GSU to remove the meter reading portion from their contract and assign it to the meter maintenance department.

3. Purchase new meter reading equipment that would allow a CGS selected AMR capable meter reading handhelds. This would allow specific higher cost meter readings to be collected a lot cheaper.
4. Hire a meter reading coordinator to manage the meter reading contract. This position may change depending on what technology is approved.
5. Investigate the irregularities identified in the meter reading costs section of this report. Should be done at the same time as the switch of control of the meter reading contract.

2.3.3. Customer Service and Water Billing

GSU provides all water meter reading, billing and customer service functions for all CGS customers, including those customers who are serviced by Ontario Hydro (approximately 12,000 of the 48,000 customers).

2.3.3.1. Water Billing Estimates

GSU produces approximately 288,000 water bills per year. In 2015, 20,753 of these bills were estimated. This amounts to 7.2% of the bills produced. The current number of estimated bills would be higher than that of other water utilities of similar size and setup.

The reasons for these estimates are not tracked. It could be due to weather preventing the meter reader from obtaining a reading, it could be related to remote or wiring issues that require maintenance or it could be due to meter reader issues.

2.3.3.2. High/Low Customer Interactions

In 2015, GSU found approximately 1,080 High/Low complaints that resulted in a service call being issued to CGS meter department for investigation. High/Low complaints can be a result of a customer using more/less water than was expected, the meter readings being incorrect or theft/tampering occurring at the property. These types of complaints are costly to investigate and resolve given that all GSU and CGS staff have are the past bi-monthly readings (if they were actually collected).

From a customer service perspective both the GSU call center and billing staff currently have limited tools to help the customer explain the high bill complaint. This results in service orders being created for CGS staff to investigate and perform additional customer service to assist in explaining the high water complaint. If CGS staff are lucky, the problem can be found (continuous consumption occurring at the property) but often the issue may be very difficult to provide a reasonable explanation to the customer.

Although this level of customer service has been accepted over the years, advances in technology have raised the level of what is possible and more detailed consumption analysis tools are available. Customers have gotten used to this level of service being provided for their electric bills and it is expected that more requests for detailed hourly consumption will become the new standard of what customer service should be available to provide within the water industry.

2.3.3.3. Customer Service

In addition to the High/Low customer complaints, GSU receives calls about their water bills daily. Customer service staff spend time on the phone answering questions about their water bills, payments and maintenance that has occurred on their property. Providing a customer service online portal (which GSU currently does) can reduce these call volumes as more people change their expectations on using the internet instead of the phone for more information. The issue with the existing GSU on-line portal for water customers is there is no hourly consumption information available, although the Capricorn customer portal allows for it. The only information they can get is the total consumption for the last billing period. By providing better information on this portal it is likely this will be the first place customer turn to get water billing information. Overtime, if the information that the portal displays is of value to the customer there should be reduced call volumes.

2.4. Meter Maintenance processes

The CGS meter department has three water meter technicians that perform work on both commercial and residential properties. Their duties include: performing water meter replacements, investigation, wire and remote repair and replacement, new home installs, high water complaints, tamper and theft investigations and refurbishing water meters 25mm and greater. Some meter replacements are outsourced due to Ontario licensing requirements.

It was very apparent in our analysis that the department has been proactive with regards to their large consumers and large sized meters. This focus has resulted in the larger sized water meters (25mm and greater) being significantly newer than the smaller sized water meters.

Meter Size	Average Age
5/8"	16.8
3/4"	6.0
1"	6.1
1.5"	4.1
2"	4.6
3"	3.9
4"	4.8
6"	5.0

Table 24

Compared to other water utilities of similar size, the proactive water meter program for commercial sized meter is much better than most. This focus will allow any type of large AMR/AMI project to focus on replacing the older residential (less than 25mm) sized meters and only having to upgrade or just install a radio transmitter on the commercial meters.

2.4.1. High/Low Customer Service Calls

As discussed in the Customer Service and billing section there were 1,080 High/Low water complaints that result in a service call to the customer's property. We have estimated that these take approximately 1 hour per service call to complete. This amount is equivalent to 50% of an FTE or approximately 17% of the department's effort. Often the technician customer service skills are key in explaining why their water consumption was higher than expected. Technology would see the number of these types of service calls reduced and would likely lead to a more positive customer service experience for CGS customers. There would also be a benefit for the technician, making the explanation or investigation of what caused the high or low consumption more efficient.

2.4.2. Meter Applications

CGS meter staff currently uses industry rule of thumb when it comes to water meter sizing and applications. Primarily install a water meter one sized smaller than the service size. Given it is difficult for a customer to show their consumption profiles with no water meter or data collection equipment being in place.

With AMI/AMR equipment CGS meter maintenance will be able to start to analyze hourly consumption profiles to ensure meters are the right type and size.

2.4.3. Frozen water meters

The cold winters CGS experience has led to a number of frozen water meter that require replacement and can lead to damage at the property. On average CGS experiences about 80 frozen water meters per year. This number could be much higher if they did not have the approximately 300 properties whose water service is too shallows to keep their water running through their winter months.

These emergency calls out and water being flushed down the drain could be reduced with the use of temperature gauges. Although these types of devices are still leading edge, depending the type of technology there may be some additional tools to help CGS reduce and control these types of costs.

3. AMR/AMI/AMA Requirements

3.1. AMR/AMI Technology Overview

3.1.1. Radio Frequency Considerations and Risks

Automated meter reading technology is based on readings sent wirelessly through radio frequency (RF) transmissions. All AMR/AMI manufacturers use RF technology, so by accepting the recommendation to implement AMR/AMI technology the utility must accept any perceived risks relating to the technology.

3.1.1.1. Proprietary RF Protocols

All water based radio transmitting products have a manufacturer specific, proprietary RF protocol. For a radio transmitter to be "heard" by a radio receiver (handheld RF receiver, mobile or fixed base collector) the manufacturers of those two products must have a formal agreement. The reality in the water AMR/AMI industry is that most manufacturers only allow their own products to work together.

Manufacturers keep tight control over their RF protocols to eliminate competition for future radio transmitters. Once a utility has purchased and started using a particular brand of data collection equipment, headend software, and interface for their water billing system, there can only be one future manufacturer of the radio transmitter. Any future procurement will either have to be sole sourced through the manufacturer or their distributer, or a competitive bid will have to be released that limits the products available for the project to that single manufacturer. Some of the manufacturers award exclusive territory to distributors in their network, so in some of these cases only one distributer might be able to respond to a RFP or tender. The risk here is that the manufacturer or distributor would be able to raise prices with minimal consequences, as the utility would be limited in their ability to find a more cost effective solution within some significant initial cost for new equipment.

Implications for CGS:

The best way for the utility to mitigate this risk is for any procurement to address 100% of the meters within the utility's population. For the CGS, there would be approximately 48,000 water meters that require radio transmitters. Once AMR/AMI technology is approved, the procurement document should include 100% of the transmitters, even if the deployment of the radio transmitters is over a longer period of time.

3.1.1.2. Regulation Implications

All AMR/AMI products conform to both Industry Canada's (IC) and the Federal Communication Commission's (FCC) regulations. Both countries have very similar regulations that define the frequency bandwidths that wireless products are allowed to operate within. AMR/AMI products are designed to minimize conflicts with other common products such as cell phones, baby monitors, wireless phones, remote garage door openers, etc.

Implications for CGS:

Any AMR/AMI system would need to comply with Industry Canada's Safety Code 6, Radio Standards Specifications 102, and Radio Frequency (RF) exposure Compliance of Radio communication Apparatus (All Frequency Bands).

3.1.1.3. Licensed and Unlicensed Systems

When an AMR/AMI system operates on an unlicensed band, it means that there may be other products using the same frequency. Although, most manufacturers have designed their radio transmitters and receivers to filter out RF signals that are unrelated to the transmitter the receiver is looking for, in some cases there can still be conflicts with competing RF signals. If a conflict does occur it may prevent an RF transmission from reaching the data collector/receiver. To minimize this potential issue, most manufacturers have designed their products to use a process called frequency hopping: if there is an RF conflict on a specific frequency, then the next transmission is sent out on a slightly different frequency. We are not aware of any water utility that has run into a significant RF conflict of this kind.

Implications for CGS

The utility should require all RF licensing costs and responsibility be with the AMR/AMI vendor.

3.1.1.4. Radio Frequency Safety Considerations

In the water, gas, and electric industries, RF products are often referred to as "smart meters". There has been some push back from grassroots organizations that fear the RF transmissions pose risks to human health. To date there has been no credible studies produced that have proven that AMR/AMI RF technology is hazardous to peoples' health.

Industry Canada has regulations that ensure that RF technologies operating in Canada adhere to strict guidelines that comply with Health Canada's Safety Code 6 (SC6). This code defines the acceptable exposure limits to RF electromagnetic fields in the frequency range from 3 kHz to 300 GHz. Products approved by Industry Canada must not exceed this exposure limit. There are many products that are governed by this code, including cell phones, microwave ovens, and computers on wireless networks, cordless phones, baby monitors and AMR/AMI technologies. RF exposure is defined as an increase in tissue temperature of more than 1 degree Celsius after being exposed to the RF signal for a 6 minute period. The wording in the code is as follows:

- "[...] Temperature increases in living tissue due to RF energy absorption follow a well-defined pattern with a time constant of approximately 6 minutes (thermal time constant), where **63%** of the steady state temperature increases in living tissue within 6 minutes due to RF energy absorb
- Tissue temperature rises >1ºC

The code defines how this test must be performed to be considered valid, including the frequency of the RF transmission, the strength of the transmission, and the distance from the source; all of which make worst case assumptions when evaluating a product.

Quebec Hydro performed a study showing typical household products and their measured emission levels. As you can see in the diagram below, a next generation electric meter is less than 120,000 times Industry Canada's allowable limit.

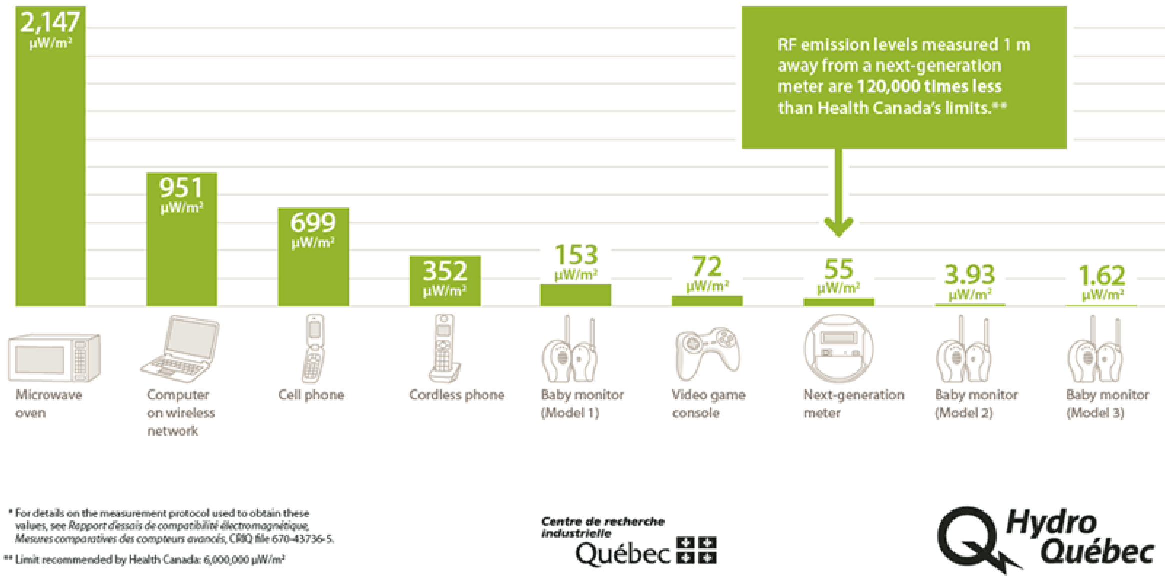


Figure 7

Even with substantiated evidence that supports the fact that AMR/AMI products are safe, people will still come forward voicing concerns about the safety of the products. A small percentage of the utility's customers will never be completely convinced that these products are safe to use. A very vocal minority can and have a major impact and have successfully stalled a few AMR/AMI projects.

Implications for CGS

To ensure the Utility is prepared to address these concerns the following steps should be taken:

1. Proof of the successful AMR/AMI product emission compared to Safety Code 6 should be readily available to customers on the utility or manufacturer websites.
2. During the procurement process, as a part of the evaluation, vendors should be required to show the testing and calculations done to prove that their products meet Industry Canada's emission limits.
3. Any public outreach program should include extensive information relating to the safety of the vendor's AMR/AMI products.

4. An opt-out program could be allowed. Typically this would come with additional charges to the customer for the additional labour and equipment the utility would need to perform a manual read process.
5. AMR/AMI products could be installed on the outside of the building in specific cases.

These are the tactics other utilities have used to successfully mitigate RF concerns and although they may not resolve all issues, they should help the utility avoid any major disruptions to the project.

3.1.1.5. High Resolution Water Meters

The resolution on the water meter register is defined as the lowest increment of water that a meter can register. Residential meters with six moving digits on the register typically read down to the 10th of a cubic meter (100 litres). The one exception to this rule is the Neptune Autodetect/ProRead meters where the digit furthest to the right only encodes a 0 or a 5, making the lowest increment of consumption 500 litres.

For AMR/AMI radio products that take hourly readings, the consumption for many hourly periods will be zero as the diagram below demonstrates.

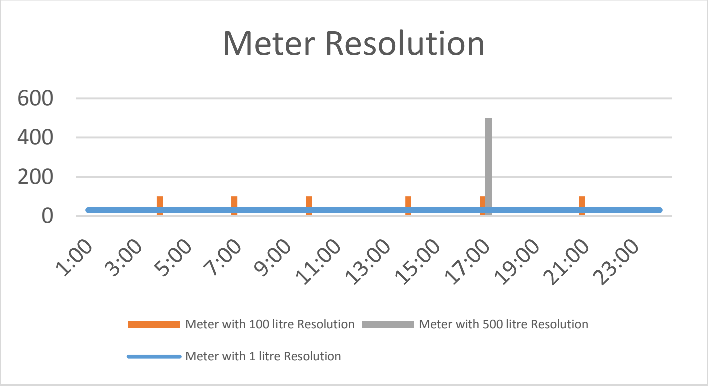


Figure 8

For a customer who has a significant leak of 30 litres per hour, a high resolution meter will flag the leak since all 24 hourly periods will show some consumption. Lower resolution meters (100 or 500 litre per hour resolution) with a leak of this size will never flag it because it will be impossible to differentiate the leak against normal consumption. The table below shows the number of hourly periods with zero consumption at each level of resolution, given the exact same rate of flow.

15mm Meter Resolution (based on a leak of 30l per hour)	Number of Hourly periods with Consumption	Number of Hourly periods with Zero Consumption	Would AMR / AMI Radio transmitter pick up leak
8 digit meter - Meter with 1 litre resolution	24	0	Yes
7 digit meter – meter with 10 litre resolution	24	0	Yes
6 digit meter - Meter with 100 litre Resolution	6	18	No

15mm Meter Resolution (based on a leak of 30l per hour)	Number of Hourly periods with Consumption	Number of Hourly periods with Zero Consumption	Would AMR / AMI Radio transmitter pick up leak
6 digit meter (existing if Pro-read meters are re-programmed) - Meter with 500 litre Resolution	1 or 2	22 or 23	No
5 digit meter (existing Pro-read meters without programming) meter with 1,000 litre resolution.	0 or 1 (with only 720 litres per day, not every day will show consumption)	23 or 24	No

Table 25

The table above shows that even if you have a radio transmitter that reads the meter on an hourly basis, it will only trigger the leak flags if the meter resolution is at least 7 digits reading down to the 10 litre. When reviewing some of the features (specifically leak and backflow flags) of an AMR/AMI system, the utility needs to consider the existing water meters' current resolution capability to ensure that the feature can be supported.

Implications for CGS

Currently the majority of the existing CGS water meter have Neptune ProRead and auto-detect 6-digit registers, but are programmed only to provide 5 digits to the billable unit (1 M3). A small % of the meters are considered high resolution. Those meters that require replacement will also get a higher resolution meter, but the remaining meters that have not yet reached the end of their useful life will either require a replacement or register upgrade in order for all customers to receive the benefits of the leak detection feature. The alternative would be to accept not all customers will get this feature until their water meter is replaced over time.

This is really a question of the service level that CGS wants to achieve and if all customers get the same features an AMR/AMI technology can deliver.

3.2. AMR/AMI Technology Types

3.2.1. Walk-by AMR

The diagram below shows the critical pieces of a walk-by system.

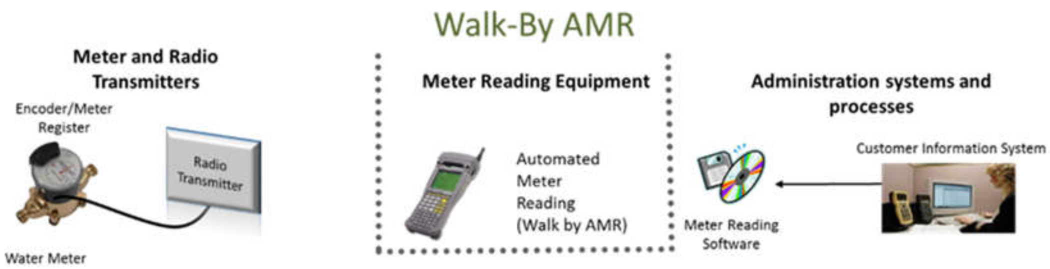


Figure 9

3.2.1.1. Functionality

At its core, AMR technology is comprised of a handheld computer that contains a database of property numbers along a meter reading route and the corresponding stored readings for each property. Efficiencies are created for the meter reader as the handheld computer logically directs him or her to each property that requires a reading.

Handheld meter reading equipment allows for three ways of capturing reading information. The first way is to manually type in the reading for each property. This is required for direct read and pulse generated meter registers. Properties with touchpad remotes may still require a manually entered reading, if the touchpad reading device does not communicate directly with the handheld. Readings that are keyed in are always prone to some human error.

The second way to get the reading information into the handheld is for the meter reading device (touch reader) to communicate directly to it. This method is available only with encoder technology. The meter reading device and handheld communicate through the wire or radio frequency connection. Readings are recorded in the handheld database according to the corresponding meter ID number. This method eliminates the need to key in each reading, thus improving the accuracy and efficiency of the meter readers. Although this method is an improvement to manually entering meter information, it still requires the meter reader to gain access to the remote receptacle at each property.

The third method of collection meter readings is for a radio transmitter to be attached to the water meter register and transmit the readings via RF to the handheld meter receiver. The readings will automatically associate with each property through the radio transmitter identification number. The meter reader would not have to touch the device on the building itself, likely all readings would be read by just waking by the property. 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 handheld, at the end of each day, the handheld is downloaded to the utility's CIS via manufacturer-specific meter reading software. This software then transmits all readings within the book/route to the water billing CIS system.

3.2.1.2. AMR Radio Transmitter Features

Once a radio transmitter has been introduced as a part of the meter reading equipment there are a number of features and benefits that were not available with touch pad technology. These features are the same regardless of the device that reads them (AMR walk-by or AMR mobile). So the next sections will apply to both types of reading methods.

3.2.1.2.1. Radio Transmitter Alerts and Flags

Algorithms that are able to detect certain consumption patterns can be performed in either the meter register or the radio transmitters. For most walk-by, mobile, and some fixed base radio transmitters these calculations are able to determine leak, backflow, or zero consumption conditions. It is important to note that although some manufacturers provide this functionality within the register head, most have moved towards providing this same functionality within the radio transmitter.

3.2.1.2.2. Leak Detection Flag

A continuous leak detection flag checks for changes to readings on an hourly or 15-minute interval (depending on the product) and stores a 1 (if the read changed) or a 0 (if the read did not change) for 24 hours or 96 intervals every day. At the end of the day, if all periods hold a "1" then it assumes there was continuous (consumption in every time periods) consumption for that day. The algorithm will send a flag to the data collector once 30 to 45 days are registered as having had continuous consumption, indicating that there may be a leak occurring at that property. This will allow the utility to either warn the customer via water bill, a phone call from customer service, or web portal that a leak may be present at their property and that a higher water bill may be the result.

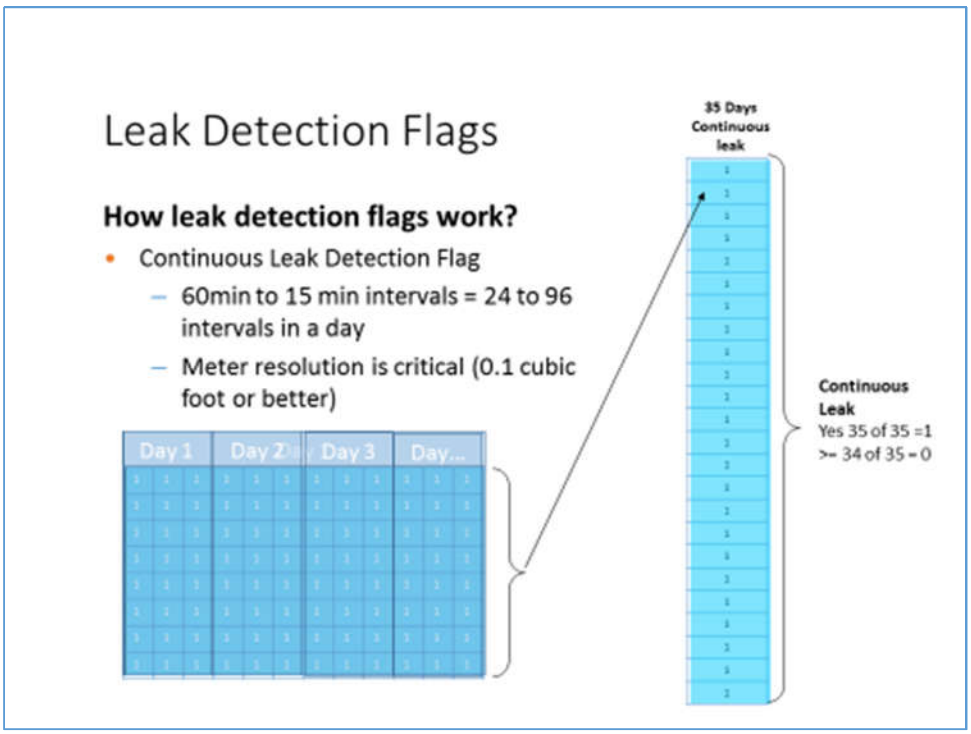


Figure 10

These algorithms are highly dependent on the resolution of the water meter. If only a billable unit (CCF, M3, 1000 Gallons) is being encoded then only the largest of leaks or backflows would be detected. On the other hand if the resolution is very low (.001CCF, .0001M3, 1 gallon) then a large number of customers may experience this flag. Reacting to each one could become costly.

3.2.1.2.3. Backflow Detection Flag

Similar to leak detection technology, certain register heads have the ability to detect if backflow occurred or is occurring at a property. This information is sent through the meter reading equipment in the form of a flag. The water utility can then take corrective action to eliminate this risk to the water system. In order to be detected by the meter, the backflow event has to cause the meter to read negative volume. If the register is read every fifteen minutes, then the volume of backflow during this time must exceed the volume of water being consumed. Short, small volume backflow events will not normally be detected by these register heads.

3.2.1.2.4. Zero Consumption Flag

There are register heads that can determine if zero consumption has taken place for an extended period of time. Zero consumption is often a symptom of water theft. With this information the water utility can send a crew to investigate the situation.

3.2.1.2.5. Low Radio Transmitter Battery Flag

Most manufacturers' radio transmitters monitor the voltage level of their own battery and send an alarm six months before it's expected to die. This may provide some notice to the utility to get out and replace the radio transmitter before the battery failure, so that fewer readings are missed.

3.2.1.2.6. Tamper Flag

Radio transmitters often know 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. In some cases this flag may alert the utility to a legitimate customer tampering with their meter, but there will be other cases that are unintentional maintenance issues. These flags would initiate a response in the field to investigate and resolve the issue.

3.2.1.2.7. Data Logging

Certain manufacturers' radio transmitters store the daily and hourly readings for the last 30 to 40 days. This additional information can be used to resolve customer complaints. This data logging feature can provide the same type of hourly reading information a fixed base system produces for individual customers who may request this information.

Implications for CGS:

These benefits and feature of an AMR radio transmitter should help CGS meet the business drivers that are consider somewhat and very important that is identified later in this document.

3.2.2. Mobile AMR Technology

The diagram below shows the critical pieces of a Mobile AMR system.

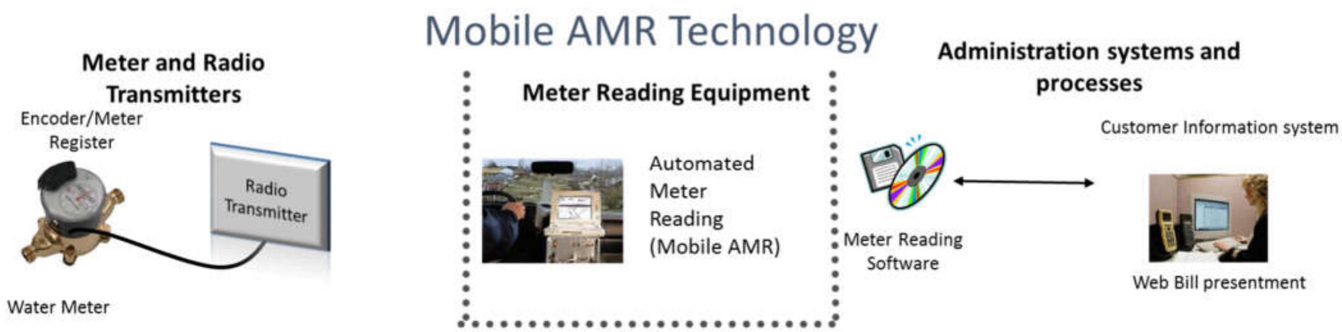


Figure 11

All manufacturers of Mobile AMR systems ensure that their solution is also compatible with an AMR walk-by system. When a Mobile AMR solution is selected, often handhelds are purchased alongside the mobile unit, as a backup or for radio transmitter installation verification.

3.2.2.1. Functionality

Mobile meter reading systems are comprised of a laptop computer which is connected to a radio receiver that is in turn connected to an antenna mounted on the outside of a vehicle. This system has a more powerful radio receiver than the typical handheld and is capable of picking up multiple readings from several radio transmitters by driving past the metered properties. A mobile reading system often has multiple receiver channels that enables the system to do this very efficiently.

The laptop comes with mapping software that allows the meter reader to easily track his/her progress and shows him/her where to drive to collect any readings not yet captured. The map display often has different coloured dots to show if the meter at a property has been read, not read, or has an alert (leak, tamper, backflow, etc.).

Utilities can eliminate almost all the safety risks associated with having meter readers in the field by using the drive-by system. It also increases the speed at which the readings can be collected, far fewer human resources are required to conduct meter readings. Mobile AMR allows for a monthly billing cycle, due to the speed with which the meters can be read. The added consumption information can start to be used for other purposes beyond just water billing such as: water loss calculation, leak detection, district metering, and the ability to identify areas of peak demand.

3.2.2.2. Features

3.2.2.2.1. Radio Transmitter Alerts and Flags

The radio transmitter for a mobile AMR system is the same as the one provided for a walk-by system, so all the same alerts and flags are provided to the mobile data collector that were discussed in the walk-by AMR section.

3.2.2.2.2. Mobile Lite Device

Some manufacturers also market a product in-between a walk-by and mobile device. The product allows reading to be collected while driving but does not have the laptop with the mapping capabilities. Basically this solution uses a handheld connected to a vehicle-powered receiver with external antenna. This system is used sometimes by utilities that either want a more powerful back up system or want to reduce the initial capital cost.

3.2.2.2.3. Data Logging Collection During Regular Reading Route

As discussed in the walk-by AMR system, many radio transmitters are able to provide hourly reading information for the previous 30 to 45 days. This is usually performed outside the normal meter reading process, but some manufacturers have incorporated this feature into the normal reading process. The utility would indicate for a specific account if daily or hourly consumption information is required. When the meter reader passes the address the additional reading information is collected automatically. This would help the utility in a couple ways. First, if a customer complained of a high bill the utility could get hourly information the next time they were reading that address to help the customer understand their consumption pattern. Second, if a customer sells their house and it requires a reading on a specific day, the meter reading could collect the daily reads for the meter so the bill could be closed out properly. This would eliminate a meter reader from making a special trip.

Implications for CGS:

Greater Sudbury Utilities (GSU) is required to move to monthly reading and billing, with the water meters being read bi-monthly, GSU will have to start to estimate every other month (at a minimum). Mobile AMR technology will allow collection of monthly readings to eliminate the majority of these billing estimates. Many of the flags that are discussed in the Radio Transmitter features section of the report are dependent on reading the meters in the population every 30 days.

3.2.3. Fixed Base AMI Technology

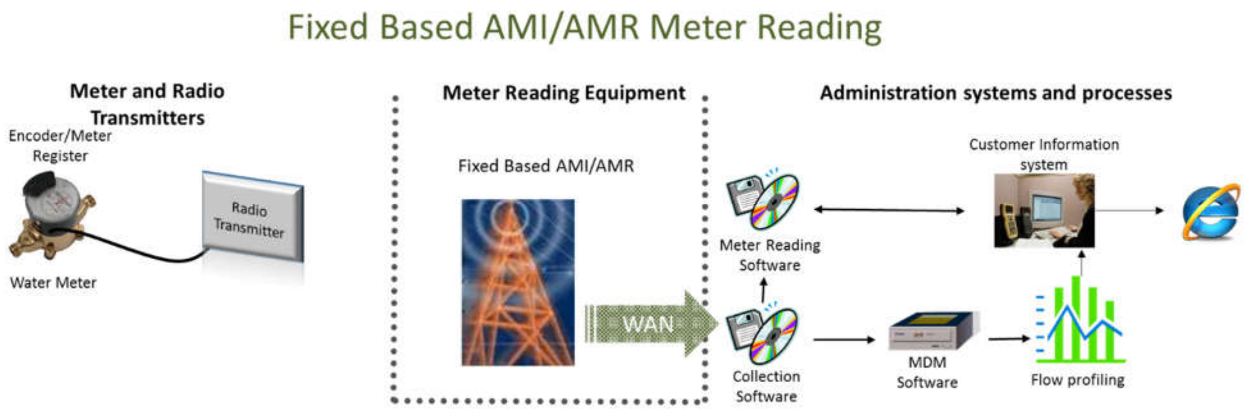


Figure 12

In a fixed area network (FAN) configuration, radio transmitters are installed on each water meter and are read by permanently installed radio collectors (receivers) or "data collectors". These data collectors are strategically deployed around 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 varies depending on what the data collector location has available: directly to the City network via a secured router of fiber optics network or cellular cards integrated within the collector itself. The collectors are constantly receiving data from the radio transmitters in the population and transmitting this back to the collection software.

3.2.3.1. Functionality

3.2.3.1.1. Collection Software

A fixed base network requires collection or headend software that receives all the reading information from the collection network. This software monitors the network devices (collectors and radio transmitters) and is able to display and report on the different components in the field and their status. The headend software passes the daily billable readings required to produce a water bill to either the CIS or the meter reading software (similar to walk-by or mobile AMR). Another function of the software is to pass all readings and alert information collected under the network to the Meter Data Management (MDM) software.

3.2.3.1.2. Meter Data Management Software

Meter Data Management software is required in a fixed base AMI system, due to the large amount of reading and consumption data that needs to be accessed and reported on. This separate piece of software can be procured with an AMI system or separately. Some manufacturers have their own MDM, and others rely on independent software companies to perform this role. The MDM has a number of functions:

1. Data Repository – The software is optimized to store the amount of data required from an AMI system. For an AMI system that provides hourly readings, the MDM will need to store 8,760

readings 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 on quickly. Most utilities store up to seven years of consumption data.

2. Data Validations – Depending on what the data is being used for, a utility may want the software to discharge and create estimates with certain types of bad data (non-numeric reading, unknown high readings, and missing readings). An MDM 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 be limited.

3. Reporting – Another function of an MDM is the ability to produce different types of reports in an efficient manner. Given the amount of data that is accessible, report generation can be problematic and can take up significant IT resources. MDMs usually come with 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.

4. Utility Management – MDM for water utilities should have modules that are capable of performing certain water utility functions such as: district metering, leak detection, misapplied meters, and water consumption program monitoring. Ideally the MDM will have a both reports and user interface application that will allow the user to easily use this functionality.

5. Water Customer Web Portal – In an effort to improve customer service, utilities are now providing online access to the consumption data of their rate payers. This can be achieved in a number of different ways, either by passing the consumption data to the CIS or web portal or in some cases, the MDM can allow customers to log in directly and view their consumption. The issue with the MDM providing customers with this type of access, is that there is a limit to what a customer can view. Utilities are moving towards more advanced customer engagement software that allows water customers to view the water bills, payment history, tax bill, service requests on their account, as well as consumption history. A standalone MDM does not have all these capabilities.

MDM and collection software can also be interfaced with other utility systems like GIS, Scada, 311 and works management software. These interfaced connections to other systems need to be well planned to make sure the costs and effort to make them possible 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.

3.2.3.1.3. Data Collection Network

Establishing the data collection network of a fixed base system can be one of the more challenging parts of a deployment effort. This is not due to the fact that data collector installations are difficult. Finding and getting 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 and Redundancy - Planning the right amount and location of equipment is done through a propagation study performed by the manufacturer of a proposed solution. This "prop" study provides a theoretical performance of the system based on a number of factors including: the topography of the geographic area being covered, the strength and frequency of transmissions, location of the radio transmitter (inside or outside), the number and location of data collectors. Once a radio transmitter is installed, there are many factors that can block or redirect transmissions and prevent a data collector from hearing the signal. An AMI system requires redundancy in order to ensure that if one data collector misses a radio transmission, another is in a position where it can receive it. This is achieved by having overlapping coverage areas where every single radio transmitter can be heard by at least two different data collectors.

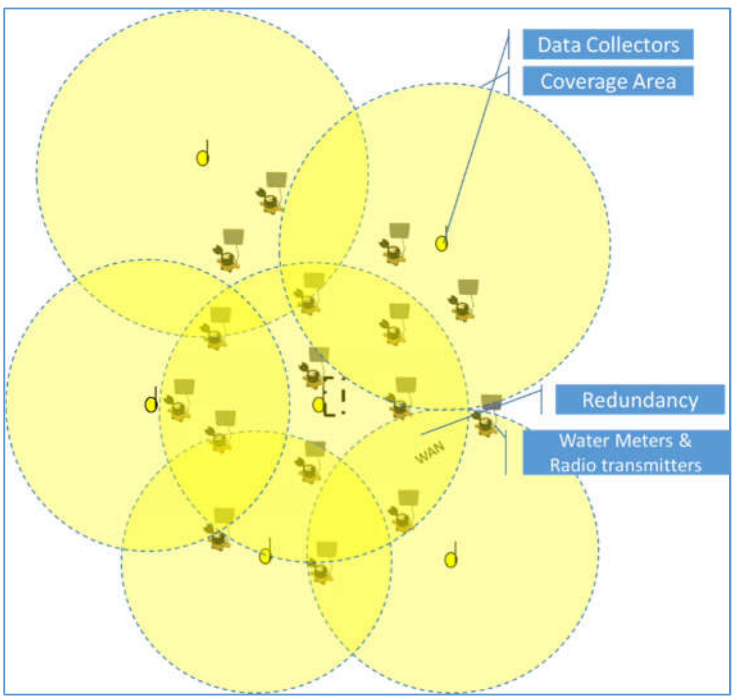


Figure 13

Data Collector Location and Approval – Most utilities prefer to mount the system's data collectors on buildings, pump houses and water towers that the utility or municipality already owns. Installing data collectors on the roof of these locations (buildings, pump houses, water towers, schools, fire and police halls, etc.) often avoids rental fees when installing the device. AC power is also (usually) readily available and relatively easy to wire to the device. Another advantage to these locations is that the utility's intranet may be available eliminating additional data costs. In order to achieve the 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 buildings, most utilities try to install data collectors on existing power or light poles that the utility owns and has full control of. Depending on where they are located this infrastructure may be the next cheapest way of installing a collector. Installation on these types of poles may require additional costs for connection (including electric meter) to the electric grid. Some systems allow for optional solar panels to power the collector to avoid the need for a direct link to AC power.

After all previous locations have been exhausted the next option would be for the utility to install 25’ to 30’ poles (usually the higher the better) in the areas that have no other place to install a data collector. This option is often frowned upon because it’s usually not popular with the public or politicians. No matter how unappealing this option may be for a utility, the reality is that a certain portion of the network will likely require newly installed poles to get full coverage. The utility should position this option as a reality when selling the concept of a fixed based system.

Drawing and Approvals – Understanding the 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. 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 a smooth deployment.

Wide Area Network/Backhaul – When planning for a fixed area network, consideration has to be given to the type of backhaul that will be required, in order to allow the collectors to pass data back to the collection software. Usually, the most cost efficient WAN process would be to connect to the utility’s intranet through the use of a secured modem. This option would eliminate any 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 or if the headend software is hosted.

3.2.3.2. Features

There are a large number of manufacturers of fixed base AMI/AMR systems. Which in turn, creates variety with regard to the features and functionalities that are available. 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.

3.2.3.2.1. Radio Transmitter Alerts and Flags

Similar to walk-by and mobile AMR systems, fixed base radio transmitters may have algorithms within the radio transmitters that allow for various flags. Some fixed base systems have not added this feature to their radio transmitters because the same functionality can be achieved at the collection/headend or MDM software by analyzing hourly consumption.

3.2.3.2.2. Data Logging

With a fixed network AMR/AMI system, hourly read information is delivered to the collection software, so there is limited value to having the radio transmitter store reading information. Some systems have designed their radio transmitters to store readings for a day or two, which can act as another means of redundancy within the overall system. These radio transmitters will transmit past readings as well as new ones, so if a transmission was not heard by a data collector, the headend software can backfill these readings during a future transmission.

3.2.3.2.3. Software Hosting

Both Collection and MDM software are capable of being installed in-house on utility-provided server hardware or in a professionally managed/hosted environment (often by the AMR/AMI software manufacturer). The decision to host or not to host certain pieces of software depend on a number of factors that include the following considerations:

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

These considerations and their level of importance to the utility should be reviewed prior to procurement documents being finalized. This will ensure that the utility gets all the information they require from the vendors in order to make the correct decision. This report provides details of the benefits and drawbacks of a hosted system vs. an in-house solution.

3.2.3.2.4. Time Synchronized Readings and Two-way Communication

A key specification for a fixed based AMI system is whether the system is considered a “two-way” system. Often manufacturers of a two-way system promote a number of benefits this specification allows and they use this to eliminate one-way fixed based AMR/AMI systems from procurement. Our recommendation is for the utility to consider the features and functionalities they are looking to achieve, then review how a one-way and two-way system achieve them (or not). In order to understand the nuances between the systems, we will explain the features of a two-way system and then compare how a one-way system operates. Radio transmitters in both systems communicate to a data collector (handheld, mobile or fixed based). It is important to note however, that only a two-way radio transmitter is able to receive data and commands from the data collectors to the radio transceivers. Two-way communication has both benefits and drawbacks. The additional functionality of a two-way system are:

Time Synchronized Top of the Hour Readings - Meter readings can be time synchronized to allow all readings in the utility's network to be read at the same time. This feature requires a two-way radio transmitter, in order to receive the time stamp from the data collector. 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, as the diagram below demonstrates.

The diagram illustrates that a customer's consumption can be easily compared between the times 12:00 and 2:00.

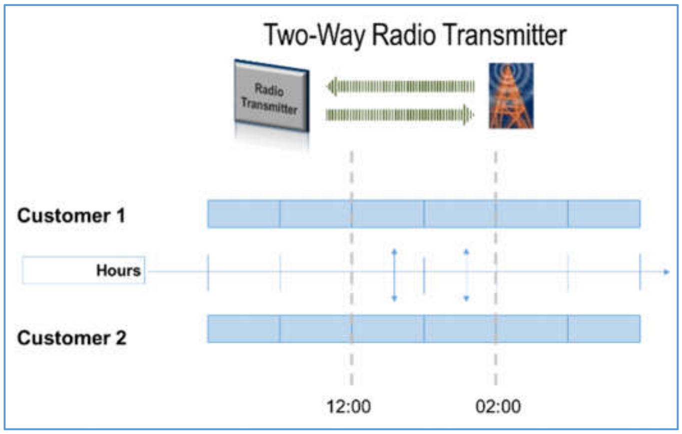


Figure 14

A one-way radio transmitter in a fixed base AMR system can lead to some confusion while comparing consumption as the diagram below shows.

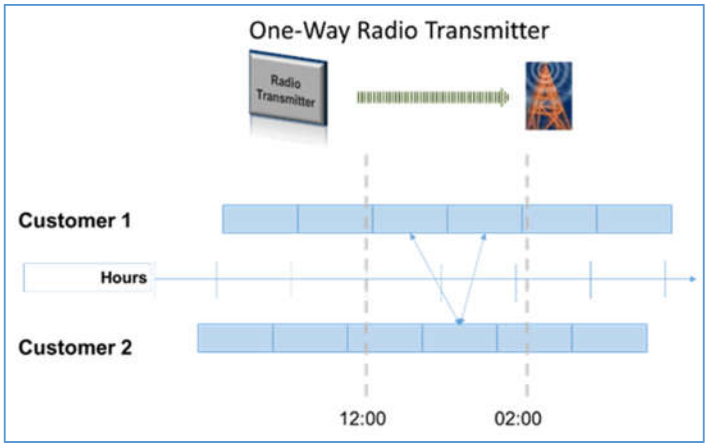


Figure 15

Given the same two customers, with the consumption over the same period being analyzed, a fixed base AMR system would suggest that Customer 1 had twice the consumption for the same one-hour period. This is due to the time readings were taken. The one thing a utility has to ask, is how often double the hourly consumption is actually going to change the analysis. Both types of systems will produce 24 hourly buckets. For a residential customer and an average daily consumption of 1,000 litres, this would mean approximately (1,000 liters / 24 hourly buckets) 41 liters in difference in some water buckets. Once you start to aggregate the number of customers you would want to do in district metering/dynamic water balancing, this difference does not really matter. If this is the only reason for requiring a two-way system, then it makes more sense to open up procurement to a fixed AMR/AMI system that collects hourly data and potentially give a few extra technical points for those systems that are two-way.

Remote Shut off Valves – Certain manufacturers are coming out with the ability to shut off water at a property from the office (eliminating truck rolls). A two-way system is required to perform this type of feature. If turning water off remotely is a business driver than a two-way AMI system should be specified.

Firmware Updates – Often one of the benefits that are promoted is the ability to push firmware updates to the radio transmitter. This is an important feature in the electric market due to some of the additional regulations and functionality an electric smart meter requires. Typically any additional functionality that is added to a water meter radio transmitter requires a new radio transmitter. It is very unlikely this functionality will benefit a water utility.

On-demand Read – A two-way AMI system will allow a utility to request a demand reading from the water meter anytime it is requested. This feature could be beneficial to a utility, if their billing agent is talking to a customer and wants to know the reading on the meter that very moment. That being said, most utilities are looking to obtain readings for final bills and a daily read pulled from the data collector would suffice. This can be accomplished by both a one-way and two-way system.

Future Abilities – Water utilities want to maximize their investment in the network by trying to expand what it is used for. Being able to send data from the office to a radio transmitter does appear to have a higher potential for other devices to be installed on them. AMR/AMI systems are not open, so innovation is limited to what the manufacturer develops or signs cross use agreements for. The other features that have been discussed include temperature and pressure gauges, scada system, remote hydrant flushing, and chlorine sampling. Some may require a two-way system, others could be achieved with a one-way system. These future abilities are still very much in development and differ by manufacturer. We would recommend during any procurement to provide additional technical points to systems that can perform these functions regardless of if it is a one-way or two-way system.

The biggest drawback of a fixed base AMI system is that there are fewer manufacturers that can provide it. Unless the benefits offered by an AMI system are critical to the utility's business case, then opening up the procurement specification to include either a fixed base AMR/AMI system will allow a larger number of manufacturers and products to participate. By doing this, it will increase the competitiveness of the bids the municipality can expect to receive.

3.2.3.2.5. Remote Shut off Valves

A two-way fixed base AMI system can allow a utility to install remote shut off valves for certain customers who have a history of non-payment or other bylaw violations. These valves would be able to reduce flow to a site or turn off completely without the need for someone to attend the property.

Installation of these devices may be more challenging, as they will likely require changes to the meter setting. Also, once a utility moves to device management, it is usually necessary to add a higher level of encryption to the system's radio transmissions which adds complexity and cost to the solution. It is unlikely a water utility would want to install these devices on 100% of the population due to the costs involved.

Some water meters are coming out with remote shut off capability within the standard water meter lay length, which would address some of the increased cost of installing this feature.

3.2.3.2.6. Acoustic Leak Detection

An optional addition to a fixed base AMR/AMI system is the installation of acoustic leak detection (ALD) devices across part or all of the utility's water system.

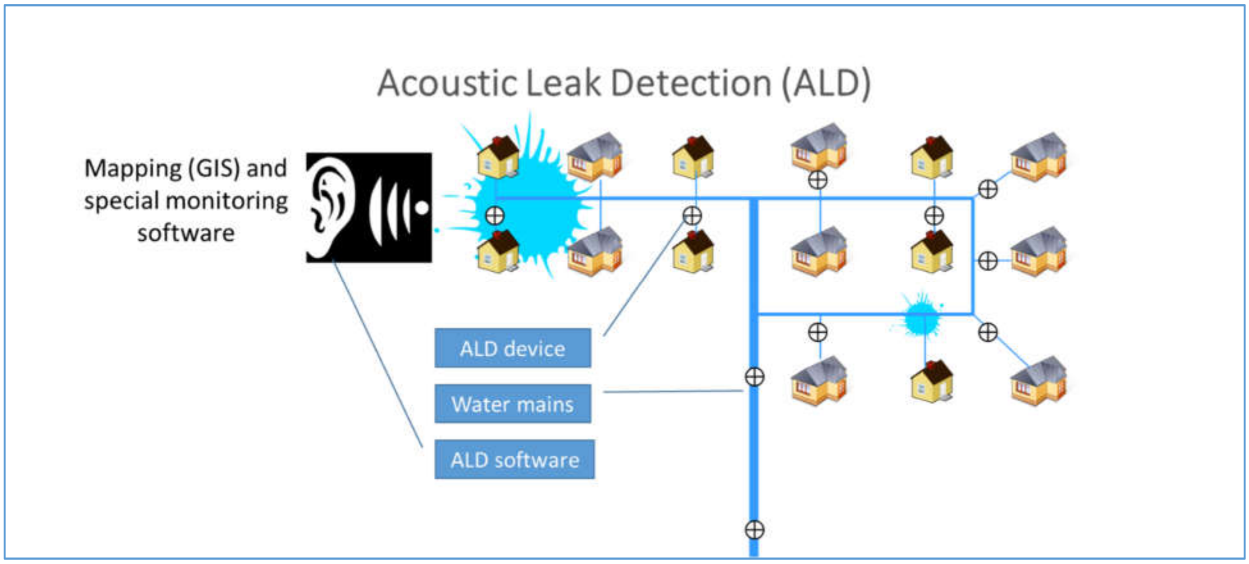


Figure 16

These devices measure the noise of the water flowing in the system and sends these acoustic readings through a number of 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.

3.2.3.2.7. Temperature and Pressure Gauges

Some water utilities have expressed some interest in having temperature or pressure gauges in place that send readings back to the head end software. These readings could be used to better manage the overall system. For example, a temperature reading could allow a utility to respond to a frozen water meter before the freezing does damage to or destroys the meter main case.

These devices are not widely available on all AMI systems, although it's expected that they will become much more common in the future.

3.2.4. Hybrid AMI/AMR Technology

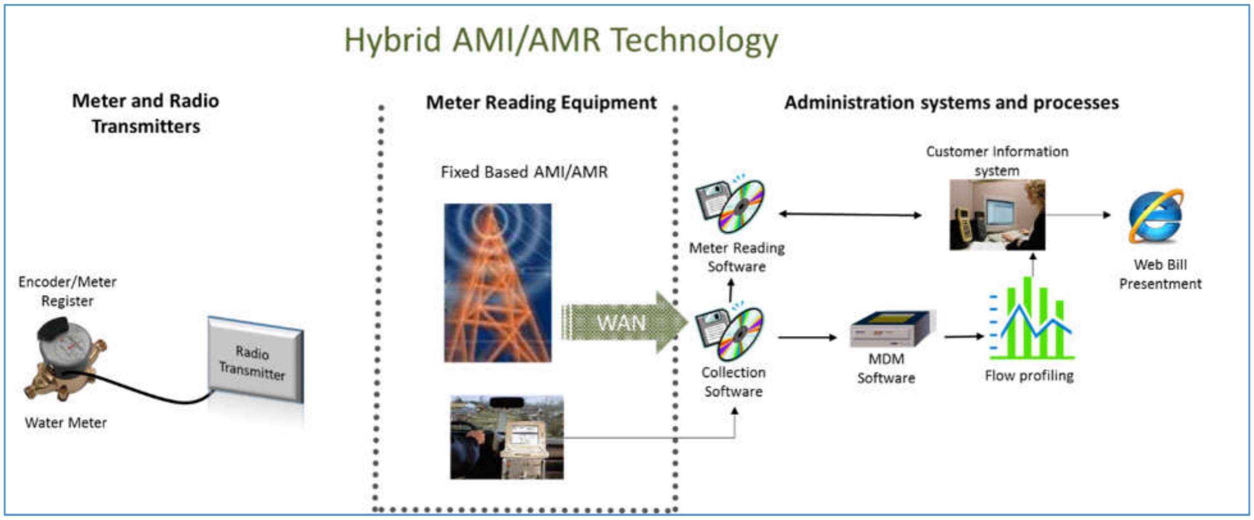


Figure 17

A Hybrid AMR/AMI technology solution would allow the utility to read radio transmitters using both fixed base collectors and mobile data collectors. This solution might work best for a utility where some parts of the system are too large and scarcely populated to justify the cost to install fixed area collectors. This hybrid solution would also allow the utility to gradually deploy an AMR/AMI network, only installing fixed network devices once all the meters in an area have been successfully converted.

It's important to know that not all AMR/AMI systems have the ability to support a hybrid solution, as some radio transmitters can only be read by either a mobile or fixed network collector.

3.2.4.1. Functionality

The key to a hybrid system is the radio transmitter's ability to be heard by the walk-by, mobile or fixed base methods of data collection. This functionality is usually referred to as a system's ability to "migrate" to more advanced technologies.

Some systems allow the radio transmitter to transmit to a variety of different collection devices right out of the box, others require that the radio transmitter be purposefully reprogrammed. This reprogramming process usually changes the read and transmission frequency to provide more hourly data, while maintaining the battery life of the product. Different manufacturers have different processes for reprogramming transmitters: some require an on-site visit for individual manual reprogramming; others can be performed over-the-air using the mobile data collector. Solutions that require little to no effort to reprogram a transmitter for this purpose should be valued more highly than those that require an on-site visit.

3.2.4.2. Features

A hybrid system would have the same features discussed in the mobile and fixed base system sections. In addition, some systems are designed to allow the mobile data collector to act as a back up to read the radio transmitters in the event that the fixed base data collector goes down, without the need to re-program the transmitter.

3.2.5. Cellular Radio Transmitters

An emerging fixed base AMI technology eliminates the need for new data collectors to be installed. The radio transmitters transmit directly to the existing cellular network. As long as the property has cellular coverage, the radio transmitter can be heard and backhauls automatically to the Vendor's hosted headend software.

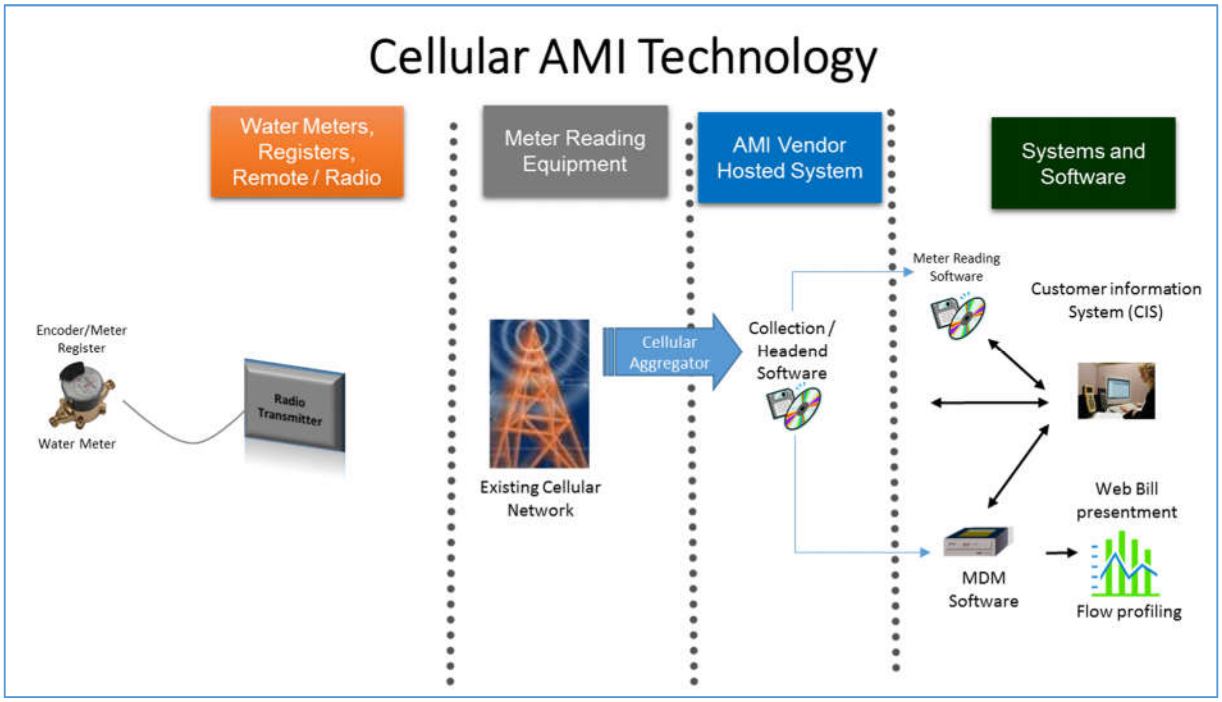


Figure 18

Not all AMR/AMI vendors have a cellular AMI system available for the water market. Most vendors are working on having cellular radio transmitter as an option in addition to a dedicated fixed network. There are some benefits to using a cellular network including not having to worry about maintaining a separate fixed network and no additional backhaul costs. There are some drawbacks that limit the applications you would want to use this technology for.

The main drawback of this technology is the radio transmitters have an expected life of about 10 to 12 years, with a limited warranty usually of about 10 years. This means the Utility would need to replace the radio transmitters well before the AMR or AMI radio transmitters discussed above. Also, the radio transmitter cost either includes the backhaul cost in the initial purchase or there is an on-going monthly fee based on the number of cellular radio transmitters a utility has deployed. If the backhaul costs are included in the initial purchase, the radio transmitter would likely cost more. With the cost of backhaul in the initial purchase, any radio transmitters replaced before the end of their useful life would not fully utilize the backhaul services included in the price resulting in higher maintenance cost for this type of system.

A risk with this technology depends on the type of cellular network the system is built around. Usually these radio transmitters transmit to an older type of cellular network (2 or 2.5G networks). Cellular providers are focusing on 4G and 5G type technologies and if they decided to not maintain the older cellular network in the future these radio transmitters may need to be replaced based on this decision that is outside the control of the utility.

3.2.5.1. Functionality

The AMI Vendor has an agreement in place with a cellular aggregator who provides cellular coverage across most major cellular networks. This allows for the ability that regardless of what cellular tower hears the radio transmitter, the data would be passed through the cellular aggregator to the AMI Vendors headend data collection software. The Utility would then need to access the software via a secured login and interface their CIS water billing system through a file transfer process. The utility would pay an on-going monthly software as a service fee to the AMI vendor that would include the backhaul costs.

3.2.5.2. Features

A cellular system would have the same features and functionality as the AMI radio transmitter. Utilizing cellular radio transmitters for 100% of the meters would not be economical. Strategically deploying a limited number of radio transmitters in areas that are not as densely populated, would allow the utility to have the same level of service across all their customers.

These radio transmitters could be deployed instead of having a portion of the meter population being read via mobile. This option should be explored during the procurement phase of the project.

3.3. State of the Market

The diagram below illustrates a number of Vendors products and systems that would likely show up within a procurement depending on the solution the utility is looking for.

	Register	Radio / Endpoint	Collection Equipment	Software
NEPTUNE TECHNOLOGY GROUP	• 9 Digits on Register • 8 Digits Encoded • Digital Display • Solar Powered • Programmable (Field & Factory)	• R900 – One Way • R450 – Two Way • Flags: Backflow / Leak / Days of No Flow / Tamper • 96 Days of Data Logging	• Trimble and Belt Clip – Walk by • MRX920 – Mobile • R900 Gateway – Fixed • R450 Gateway – Fixed • Cellular radio transmitters	• N_Sight – Walk by or Mobile • N_Sight Plus - Fixed Network • N_Sight IQ - Hosted
Badger Meter	• 9 Digits on Register • 9 Digits Encoded • Digital Display • Battery Powered • Programmable (Field & Factory)	• Orion CE / ME – One Way • Orion SE – Two Way • Flags: Backflow / Leak / Cut Wire / Reverse Flow / No Usage / Low Battery • 90 Days of Data Logging	• Trimble – Walk by • Mobile Transceiver – Mobile • Network Gateway – Fixed • Cellular radio transmitters	• Beacon AMA Field Application Suite - Hosted
SENSUS	• 9 Digits on Register • 8 Digits Encoded • Digital Display • Battery Powered • Programmable (Field & Factory)	• Smart Point – Two Way • Flags: Leak / Reverse Flow / Broken Pipe / Low Battery • 35 Days of Data Logging	• Field Logic Handheld – Walk by • Vehicle Gateway – Mobile • Base Station – Fixed	• Field Logic – Walk by or Mobile • Sensus Logic - Hosted
Itron	• N/A	• ERT 100W – Two Way • Flags: Leak / Reverse Flow / Tamper / Cut Cable / Low Battery • 40 Days of Data Logging	• FC300 – Walk by • MC3 - Mobile • Data Collector – Fixed	• MVRS – Walk by or Mobile • Choice Connect – Fixed Network
Mueller SYSTEMS	• 10 Digits on Register • 9 Digits Encoded • Digital Display • Battery Powered • Programmable (Factory)	• Hot Rod – One Way • Mi Node – Two Way • Flags: Leak / Reverse Flow / No Flow / Register Disconnect • 170 Days of Data Logging	• Psion Workabout Pro – Walk by • Street Machine 2 – Mobile • Mi. Hub - Fixed	• EZ Reader – Walk by or Mobile • Mi. Host - Hosted

Table 26

3.4. AMR/AMI Business Drivers

AMR/AMI technology has a number of financial and non-financial benefits, depending on the water utility's situation and what is important to them. Often some benefits of implementing AMR/AMI technology have both non-financial and financial implications, some benefits are too theoretical to calculate accurately and are therefore considered a non-financial benefit.

AMR/AMI technology will improve a water utility's operations in a number of areas, some can be easily calculated, while the majority will show a qualitative improvement in the respective area. AMR/AMI technology should be seen as a tool the utility can use to improve on how the utility operates. The areas of improvement often do not have a direct financial improvement but are critical to the utility achieving the broader goals of the organization. We have identified five areas where AMR/AMI technology can show benefits, they are:

Revenue Protection – Ability to identify areas of revenue improvement, reduce theft and tampering, quicker response to stopped meters and an improved ability to apply the right meter technology to customer applications.

Operational Efficiency – Improvements in response time to maintenance issues, reduced meter reading cost and hazards and a reduction in exceptions that cause more effort to bill or additional trips into the field to collect data.

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

Improved Distribution System – Improvements in the utility's ability to manage their distribution system through district leak detection, dynamic water balance, system wide leak detection and more efficient by-law enforcement.

Societal Benefits – Improvements in water conservation and carbon emissions.

Within each area there are a number of very specific tasks the utility can perform, each of these tasks is considered a business driver. AMR/AMI technology functions differently and each provide different types of data allowing the utility to either fully achieve, partially achieve or in some cases cannot achieve specific business drivers. The table below describes the 24 business drivers and the technology's ability to achieve the goals of the driver.

Water AMI/AMR Goals					
Ref.	Goals/Drivers	AMS Technology Rating 0 - Not Achieves 1 - Partially Achieves 2 - Fully Achieves			Explanation
		Walk-by	Mobile	Fixed-base	
	1. Revenue Protection (RP)				
RP1	Move to monthly billing	0	2	2	**Mobile AMS** –supports monthly billing, it would also reduce staffing levels in the meter reading department.
					Fixed-base AMS – supports monthly billing and it eliminates the requirement for meter readers.
RP2	Detect meter tamper and water theft / Zero consumption	1	1	2	**Walk-by AMS –** Radio transmitters will have a stopped meter and cut wire tamper flag. These are *collected quarterly (some technology require monthly)* when meters are read, allowing staff to be alerted to an issue they need to attend to.
	Detect Stopped meters				**Mobile AMS** – Radio transmitters will havea stopped meter and cut wire tamper flag. These are collected *monthly* when meters are read, allowing staff to be alerted to an issue they need to attend to much quicker.
					Fixed-base AMS - Radio transmitters will have a stopped meter and cut wire tamper flag. These are collected several times *daily* when the meter issue is first detected, allowing staff to be alerted very quickly, reducing possible theft and resolving issue prior to readings being required for billing.
RP3	Detect mis-applied water meters	0	0	1	**Fixed-base AMS –** a customers water usage can be analyzed to determine high an low hourly flow rates helping a utility determine the best water meter for the applications. This will help detect some mis-applied meters.
RP4	Reduce Consumption Usage on Inactive Accounts	1	1	2	**Walk-by and Mobile AMR –** consumption on inactive accounts can

Water AMI/AMR Goals					
Ref.	Goals/Drivers	AMS Technology Rating 0 - Not Achieves 1 - Partially Achieves 2 - Fully Achieves Walk-by	Mobile	Fixed-base	Explanation
					be monitored with AMS technology on a quarterly or monthly frequency.
					Fixed-base AMS – this can be detected daily when the consumption starts. For detector check meters this can dramatically reduce water loss due to an un-authorized water use.
RP5	Reduce Uncollected Revenue Write-offs	0	0	2	**Fixed-base AMS –** allows the utility to prove when water was used. This level of data will help billing agents to stand their ground on high water complaints. With an on-line tool the utility can offer customer high water alerts that would allow the customer to be notified pro-actively, again giving the customer another tool to avoid these high water bills.
	Operational Efficiency				
OE1	Improve meter reader reliability	0	1	2	**Walk-by AMS –** still require meter readers to walk the meter reading route. This will continue to create issues if a meter reader is sick of the weather prevents the readings to be collected.
					Mobile AMS – eliminates most of the risk of meter readers walking to obtain meter readings. There is still some risk due to traffic and weather, but it is much lower than walk-by or manual meter reading methods.
					Fixed-base AMS – This eliminates all readers in the field. There may still be maintenance personnel attending the site due to no reads, but meter reading safety is ensured.

Water AMI/AMR Goals					
	Goals/Drivers	**AMS Technology**			**Explanation**
		Rating			
		0 - Not Achieves 1 - Partially Achieves 2 - Fully Achieves			
Ref.		**Walk-by**	**Mobile**	**Fixed-base**	
OE2	Reduce billing exception Processing	1	2	2	**Walk-by AMR -** meter reading exceptions will be reduced reduced reliance on manual entered readings. But some will manual entry will still be required. **Mobile AMR and Fixed Based AMR** - With all AMS technologies there will be a reduction in re-read requests, meter readings being fat fingered, or other reading associated with manually reading the meter or odometer remotes and keying them into a handheld.
OE3	Detect Register and wiring problems	0	1	2	**Walk-by AMR and Mobile AMR** – Wiring issues and flags will be picked up and repaired after the reading and billing process resulting in an estimated meter reading. **Fixed Based AMS –** Will allow register and wiring issues to be detected within 24 hours allows meter mainteance to performed right away, likely before the meter reader fails to pick up the reading. This will reduce the number of estimated readings.
OE5	Same day final and special reading	0	0	2	**Fixed-base AMI -** will allow the utility to retrieve the daily readings for all customers, eliminating the need to send meter readers out to perform a final reading on a specific day.
OE6	Remote Turn-off/Turn-on	0	1	2	**Mobile AMS** – need to drive past valve to operate. **Fixed-base AMS –** If a special valve/meter is installed in the customer properties, a two-way AMI or cellular AMI system will allow the utility to shut (or reduce flow) of the water from the office.

Water AMI/AMR Goals					
	Goals/Drivers	AMS Technology			Explanation
		Rating			
		0 - Not Achieves 1 - Partially Achieves 2 - Fully Achieves			
Ref.		Walk-by	Mobile	Fixed-base	
	Enhanced Customer Service				
CS1	Improve handling of high water bill complaints	1	1	2	**Mobile AMS** - will provide monthly readings
	Providing customers with information about their consumption will help them understand why their water bill was high.				**Fixed-base AMS** – will provide hourly readings as well as allowing monthly billing and online consumption profiling. Hourly data allows users to track exactly when and likely why their bill was high.
CS2	Customer Leak Detection Flags	1	1	2	**Mobile AMS –** the radio transmitter leak flags can be used to alert customers of *potential* leaks via a message on the water billing or customer web portal. These flags could be used by CSRs to resolve complaints. These flags require monthly reading which is why it would not be available on a walk-by AMS.
					Fixed-base AMS – potential leaks and irregular consumption patterns can be detected through the use of hourly consumption data. The utility and the customer can get access to these types of events through a reporting module within the MDM and customer portal. This can reduce high bill complaints can be reduced by sending alerts for consumption and leaks.
CS3	Customer Consumption Information	0	1	2	**Mobile AMR -** some mobile AMR system allows hourly consumption to be downloaded from the radio transmitter for the last 35 to 90 days. For a specific complaint this data could be obtained to provide the customer, but it take more effort to obtain it.

Water AMI/AMR Goals					
	Goals/Drivers	**AMS Technology Rating** **0 - Not Achieves** **1 - Partially Achieves** **2 - Fully Achieves**			**Explanation**
Ref.		**Walk-by**	**Mobile**	**Fixed-base**	
					Fixed-base AMS – CSRs are able to give more informed communications; proactive communication (e-mail) can be sent to customers.
CS4	On-line customer portal	0	0	2	**Mobile AMS** – only monthly reading information could be viewed online. There are some mobile AMSs that may be able to collect daily consumption information (not all systems allow this) **Fixed-base AMS** – will provide a customer with on-line hourly readings and customizable (high consumption warning, vacation consumption monitoring) alerts. These on-line tools allow the customer to better manage and monitor their consumption. There are alow some additional features that may be available relating to temperature monitoring - where an alert would be sent if the temperature at the meter drops below zero allow the customer avoid a frozen service.
	Customer controlled e-mail alerts	0	0	2	
	Improve Distribution System Performance				
DS1	District Metering	0	0	2	**Fixed-based AMI -** this technology allows a utility to setup district meters, group all customers within the district and compare water going into the system and water being billed. This type of anaylsis will allow a utility to determine water loss and prioritize those systems where infrastructure improvement is needed the most.

Water AMI/AMR Goals					
	Goals/Drivers	**AMS Technology Rating** **0 - Not Achieves** **1 - Partially Achieves** **2 - Fully Achieves**			**Explanation**
Ref.		**Walk-by**	**Mobile**	**Fixed-base**	
DS2	Dynamic water balance monitoring	0	0	2	**Fixed-based AMI -** Dynamic water balancing allows a utility to monitor their water balance (water produced - consumed = unaccounted for water) on a daily or weekly basis. A utility would be able to respond to changes in the unaccounted for water and start their investigation within a certain system prior to complaints being received. the end result would be a reduction in unaccounted for water.
DS3	Acoustic Leak Detection (ALD) - Hydrant monitoring	0	0	2	**Fixed-base AMS –** the utility could install accoustic listening devices on each fire hydrant in the distribution system raising an alert when someone is connected and using water from the hydrant. This will allow the utility to catch people stealing water from the hydrants.
DS4	Acoustic Leak Detection (ALD) - Reactive to leaks	0	0	2	**Fixed-base AMS –** the utility could install accoustic listening devices across the distribution system and locate leaks as they occur.
DS5	Acoustic Leak Detection (ALD) - Pro-active pipe replacement planning	0	0	2	**Fixed-base AMS –** The utility can use noise patters produced by the accoustic leak detection system to prioritize those parts of the distribution system where leakage is highest. This should allow the utility to focus infastructure dollars at system in the most need.
DS6	Detect backflow	0	1	2	**Mobile AMR -** by reviewing the negative flow flag reports and cross referencing these properties with those where a backflow device a mobile AMR system may highlight those customers that have a defective backflow detector. This may

Water AMI/AMR Goals					
	Goals/Drivers	**AMS Technology**			**Explanation**
		Rating			
		0 - Not Achieves **1 - Partially Achieves** **2 - Fully Achieves**			
Ref.		**Walk-by**	**Mobile**	**Fixed-base**	
					help monitoring the utility backflow program.
					Fixed-base AMR – by reviewing the negative flow reports and cross referencing these properties with those where a backflow device is installed the utility can flag those customers whose backflow device is faulty and exposing the water system to contamination risk.
DS7	By-law enforcement	0	0	2	**Fixed-base AMR** – monitoring customer consumption during the summer may shows those customer who are violating any water bans that are in place.
	Societal Benefit				
SB1	Less Vehicle Miles	0	1	2	**Fixed-base AMS -** Reduced CO2 and Vehicles on the Road – The elimination of manual meter reading will reduce vehicles and vehicle mileage, thus reducing CO2 emissions.
SB2	Water conservation – Peak Demand	0	0	2	**Fixed-base AMS -** water conservation programs has a positive impact on the enviroment. Being able to monitor how successfully a utilities conservation program is in reducing water consumption is a real benefit to a fixed base water system.
SB3	Water Conservation – Events Management	0	0	2	**Fixed-base AMS -** Comparing changes in consumption after a specfic event occurs (water meter is tested, mainteance performed, low flow devices are installed, tamper is detected, flushing is performed) can allow the utility to plan their resources to those events that may cause issues. Or

Water AMI/AMR Goals					
	Goals/Drivers	AMS Technology Rating 0 - Not Achieves 1 - Partially Achieves 2 - Fully Achieves			Explanation
Ref.		Walk-by	Mobile	Fixed-base	
					confirm that a certain event is resulting in increased consumption.

Diameter Services reviewed each of the business drivers with CGS staff to determine which were important to them. We ranked each driver in the following manner:

> ***0 – Not important***, would not use the technology for this purpose.
> ***1 – Somewhat important***, may use the technology for this purpose.
> ***3 – Very important***, would use the technology for this purpose.

Just because a specific technology is able to perform a certain function does not mean the utility will get value out of it. In considering the type of technology that should be implemented, CGS focused on those drivers that were identified as *Somewhat Important* and *Very Important*.

The table below shows each business driver, how important each is to CGS and how the driver would benefit the utility. This table should influence the features and functionality specified in the future procurement document. It should also be used when implementing business process changes to ensure CGS uses the selected technology, as this business case has assumed.

Reference	Business Driver	Importance Assessment	How the Business Driver would benefit CGS
RP1	Move to monthly billing	Very Important	CGS billing service provider GSU is moving to monthly billing for electric. This is forcing CGS to also move to monthly billing, but moving to manually monthly readings was estimated to be $418,000 or .7% [2]increase to the customer. Implementation of both Mobile AMR and Fixed base AMI would

[2] Laplate, Lorraine, presentation on: Changes to Water Wastewater Billing, August 19, 2016, Option 1 annual cost for 2017.

Reference	Business Driver	Importance Assessment	How the Business Driver would benefit CGS
			allow monthly bills to be calculated based on actual readings.
RP2	Detect meter tamper and water theft / Zero consumption	Very Important	CGS has found approximately 10% of the meters they remove from service had signs of tampering, yet on average CGS meter staff have only been able to identify an average of 82 incidents per year of proven tampers. This technology will help CGS staff: • Reduce theft and tampering with the meter. • Respond quicker to zero consumption investigations.
RP3	Detect incorrectly applied water meters	Somewhat Important	Using hourly consumption analysis CGS meter staff could identify customers with incorrectly applied meters (too large or not properly applied). This may lead to reduced meter cost and potentially increased revenues.
RP4	Reduce Consumption Usage on Inactive Accounts	Somewhat Important	There were only a few situations in the last number of years where an inactive meter was found to be recording water. Technology may help catch these sooner.
RP5	Reduce Uncollected Revenue Write-offs	Not Important	Unpaid amounts go to taxes so this is not a big issue.
OE1	Improve meter reader reliability	Very Important	In 2015, there were 20,753 estimates (7.2% of all bills), most were due to meter readings not obtained for one reason or another. Technology would make meter reading and billing significantly more reliable.
OE2	Reduce billing exception Processing	Very Important	
OE3	Detect Register and wiring problems	Somewhat Important	Technology would help CGS meter shop respond to register and wiring issues well before they affect billing.
OE5	Same day final and special reading	Very Important	In 2015, GSU processed 3,836 final bills at a cost of $7.99 + the cost of travel to the far reaching systems. Technology would allow GSU to eliminate a manual reading for this purpose.
OE6	Remote Turn-off/Turn-on	Not Important	Not feasible for CGS due to concerns of discriminating against lower income customers.
CS1	Improve handling of high water bill complaints	Very Important	CGS and GSU staff would be able to better explain the reasons for the high

Reference	Business Driver	Importance Assessment	How the Business Driver would benefit CGS
CS2	Customer Leak Detection Flags	Very Important	water bill complaints. Technology could also send alerts to the customer directly to avoid a high water bills altogether.
CS3	Customer Consumption Information	Very Important	Providing customers with direct access to their consumption profile via an online web portal contributes to CGS tactical plan of providing more data and transparency to their customers.
CS4	On-line customer portal	Very Important	Would allow GSU existing customer portal to display real hourly consumption information.
DS1	District Metering	Very Important	With the ability to analyze hourly consumption, CGS would definitely start to move to district metering of some of the smaller and older parts of the distribution system. This will help reduce the unaccounted water.
DS2	Dynamic water balance monitoring	Somewhat Important	This would help CGS respond to changes in unaccounted for water improving reaction time to main breaks.
DS3	Acoustic Leak Detection (ALD) - Hydrant monitoring	Not Important	Not critical
DS4	Acoustic Leak Detection (ALD) - Reactive to leaks	Somewhat Important	CGS does contract some acoustic leak detection to identify leaks in their system. Depending on the cost they may use AMR /AMI technology to perform these studies but also may decide not to.
DS5	Acoustic Leak Detection (ALD) - Pro-active pipe replacement planning	Not Important	Not critical
DS6	Detect backflow	Very Important	CGS is implementing a backflow program, a technology to monitor this program would definitely be used.
DS7	By-law enforcement	Not Important	Not Critical
SB1	Less Vehicle Miles	Somewhat Important	Elimination of meter readers may have a positive impact on the environment, but this is not something CGS tracks.
SB2	Water conservation – Peak Demand	Not Important	Not critical due to the water systems have excess capacity and the year over year reduction in water demand.
SB3	Water Conservation – Events Management	Somewhat Important	May cross reference data AMR/AMI technology can provide with events

Reference	Business Driver	Importance Assessment	How the Business Driver would benefit CGS
			(meter testing, flushing) but it is not seen as critical.

Table 27

Reviewing the CGS business drivers that are important and comparing them to how well the different types of AMR/AMI technology, shows a strong correlation to a specific technology meeting the needs of CGS.

Of the 24 business drivers discussed, there were 17 rated as Somewhat Important (8 drivers) or Very Important (9 drivers). The tables below illustrates how well each type of technology being considered will achieve the drivers.

Walk-by AMR (Scenario 1)			
CGS Important Rating	**Fully Achieves**	**Partially Achieves**	**Cannot Achieve**
Somewhat Important	0	1	7
Very Important	0	4	5
Total	**0**	**5**	**12**
%	**0%**	**29%**	**71%**

Table 28

Implementing scenario 1 (Walk-by AMR) would only partially achieve 29% of the business drivers that were identified as Somewhat or Very Important to CGS.

Mobile AMR (Scenario 2)			
CGS Important Rating	**Fully Achieves**	**Partially Achieves**	**Cannot Achieve**
Somewhat Important	0	3	5
Very Important	2	5	2
Total	**2**	**8**	**7**
%	**12%**	**47%**	**41%**

Table 29

Implementing scenario 2 (Mobile AMR) would fully achieve 12% of the business drivers, and would partially achieve 47% of the business drivers that CGS identified as somewhat or Very Important to CGS.

Fixed Base AMI (Scenario 3 & 4)			
CGS Important Rating	**Fully Achieves**	**Partially Achieves**	**Cannot Achieve**
Somewhat Important	7	1	0
Very Important	9	0	0
Total	**16**	**1**	**0**
%	**94%**	**6%**	**0%**

Table 30

Implementing scenario 3 or 4 (fixed base AMI) would fully achieve 94% of the business drivers, and partially achieve the remaining 6% of the business drivers that CGS identified as Somewhat or Very Important to CGS.

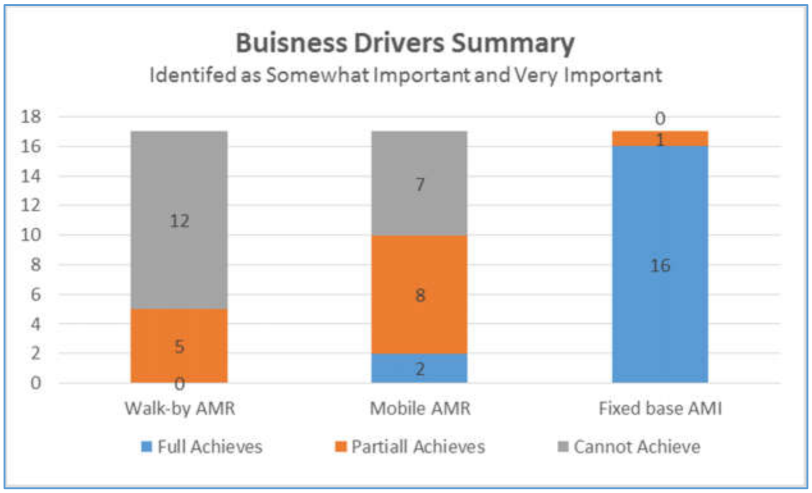
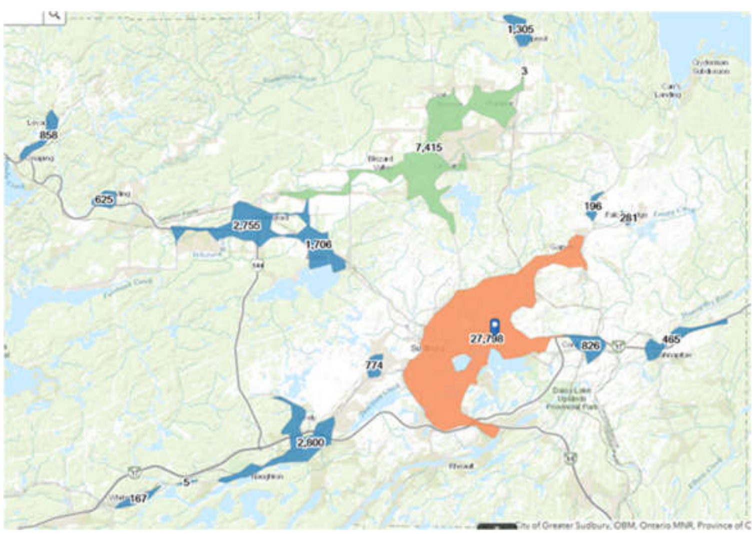


Figure 19

As a tool to help CGS improve Revenue protection, operational efficiency, customer service, distribution management and societal benefits, implementing a fixed AMI technology is strongly recommended.

3.5. AMI Vendor Network Coverage

The City of Greater Sudbury service area is quite large and spreads across both GSU and Hydro One's electric smart meter network. Working with CGS GIS group we established the total square of kilometers of the service area was 161.5km^2. The service areas with total estimate number of accounts is in the diagram below:



The number of water meters whose location corresponds to GSU and Hydro One is summarized in the table below.

Area Number	System Name	# of Meters	Area (Sq Km)	Electricity Provider
3	City of Sudbury	27798	73.79	GSU
6	Capreol	1305	2.90	GSU
11	Falconbridge	281	0.74	GSU
15	Coniston	826	3.57	GSU
1	Levack	858	2.79	Hydro One
2	Mikkola	2800	12.71	Hydro One
4	Val Caron/Val Therese/ Hanmer	7415	34.45	Hydro One
5	Chelmsford	2755	11.55	Hydro One
7	Azilda	1706	8.13	Hydro One
8	Dowling	625	1.94	Hydro One
9	Whitefish	167	1.71	Hydro One
10	Copper Cliff	774	1.81	Hydro One
12		3	0.10	Hydro One
13	Wahnaplilae	465	3.77	Hydro One
14	Old Skead Road	196	1.24	Hydro One
16		5	0.30	Hydro One
	Total	47,979	161.50	

Hydro Service Provider	# of Meters	%	Area (Sq Km)	%
Greater Sudbury Utilities:	30,210	63%	81.00	50%
Hydro One	17,769	37%	80.50	50%

3.5.1. GSU Existing Smart Meter Network

GSU has indicated a willingness in working with CGS to share the network and collection software system. We would anticipate there would be some savings in capital costs and potentially operating costs. The Sensus Flexnet system that GSU has deployed is capable of adding water meter readings to the existing system and software. But the existing GSU network of data collectors only covers 50% of the service territory and 63% of the water customers. To collect the remaining customers (17,769) CGS would have to add additional equipment.

CGS has been working on getting information on existing facilities across their whole service territory where additional data equipment could be installed.

3.5.2. Hydro One Existing Smart Meter Network

Hydro One smart metering AMI technology is manufactured by Trilliant Networks and appears to be an electric only network. This network does not appear to be capable to collection water meter readings.

This statement is not definitive because Hydro One was not responsive to phone enquiries made to them to discuss the possibility of using the existing network.

Diameter Services followed up four times and was unable to get a response from them on whether they would be interesting in discussing sharing their AMI network. The customer service representative we worked with did confirm that Hydro One has not shared their network with any water utility across Ontario.

So based on this discussion we do not recommend pursing this as an AMI option.

3.5.3. Other AMI Vendors

One part of this assessment was to determine how viable an AMI network was across the large CGS service territory. The capital cost of the network equipment was based on some broad based assumptions based on bids in City of Toronto and City of Baltimore. To get a better understanding of the viability we reached out to four AMI vendors and got responses on the number of data collectors and the estimated cost of the equipment. The below provides a summary of the responses we received. We left the name of each manufacturer off this report for confidentiality purposes.

AMI Vendor	Estimated # of collectors	Estimated Cost Range	Comment
Vendor 1	6 Existing collectors 2 to 4 New collectors	$80,000 to $160,000	
Vendor 2	50 to 60 collectors	$600,000 to $900,000	
Vendor 3	0 collectors (cellular)	$0	A cellular solution was offered but the radio transmitter only has a 10 year life.
Vendor 3	45 to 55 collectors	$225,000 to $275,000	
Vendor 4	10 to 15 collectors	$480,000	
Assumption in the Model	**75 collectors**	**$637,000** **+ cost of new poles**	

4. Financial Analysis

4.1. Key Assumptions and Variables

The financial model has a number of variables and assumptions. The scenarios may differ based on the type of technology being deployed. The variables and assumptions that were made in the financial model that remain constant are detailed in the table below:

Reference	Assumption	Assumption
3	Interest	2.000%
4	Inflation/Revenue Increases	0.000%
5	Growth	0.000%
6	Completion %	100%
9	Contingency Rate (of installation)	10%
10	Replacement Age - 15mm to 25mm	5 to 9 years
11	Replacement Age - 37mm to 50mm	Greater than 20 years
12	Replacement Age - 75mm and greater	Greater than 20 years
14	Plumbing Minor S&I - 15 to 20mm	0.00%
15	Plumbing Normal S&I - 15 to 20mm	0.00%
16	Plumbing Minor S&I - 15 to 20mm (Change Outs)	5.00%
17	Plumbing Normal S&I - 15 to 20mm (Change Outs)	4.00%
18	Plumbing Minor S&I - 25mm	0.00%
19	Plumbing Normal S&I - 25mm	0.00%
20	Plumbing Minor S&I - 25mm (Change Outs)	5.00%
21	Plumbing Normal S&I - 25mm (Change Outs)	4.00%
22	Plumbing Major S&I (WMI) - 15 to 25mm	2.00%
23	Plumbing Fitting S&I - 37mm	5.00%
24	Plumbing Fitting S&I - 50mm	5.00%
25	Plumbing Fitting S&I - 75mm	5.00%
26	Plumbing Fitting S&I - 100mm	5.00%
27	Plumbing Fitting S&I - 150mm	5.00%
28	Plumbing Major S&I (plumber) - 37mm and greater	10.00%
29	BCV Install S&I - 13 to 20mm	6.00%
30	BCV Install S&I - 13 to 20mm	6.00%
31	BCV Install S&I - 25mm	6.00%
32	BCV Install S&I - 25mm	6.00%
33	BCV Install S&I - 37mm	4.00%
34	BCV Install S&I - 50mm	4.00%
35	BCV Install S&I - 75mm	4.00%

Reference	Assumption	Assumption
36	BCV Install S&I - 100mm	4.00%
37	BCV Install S&I - 150mm	4.00%
38	Isolation Valve Install S&I - 13 to 20mm	0.00%
39	Isolation Valve Install S&I - 25mm	0.00%
40	Isolation Valve Install S&I - 37mm	4.00%
41	Isolation Valve Install S&I - 50mm	4.00%
42	Isolation Valve Install S&I - 75mm	4.00%
43	Isolation Valve Install S&I - 100mm	4.00%
44	Isolation Valve Install S&I - 150mm	4.00%
45	Kornerhorn - KH2 S&I 15X20mm	0.00%
46	Kornerhorn - KH3 S&I 20mm	0.00%
47	Resetter - 15mm to 15X20mm	0.50%
48	Resetter - 20mm	0.50%
49	Resetter - 25mm	0.50%
50	Small System Premium (total Number	-
51	Crawl Space	1.00%
52	Confined Space	2.00%
53	Residential Wire run to the Outside	15.00%
54	Commercial Wire run to the Outside	1000.00%
55	Carpentry Minor	6.00%
56	Carpentry Normal with Box	0.00%
57	Contingency	10.00%
58	% of Compound	65.00%
59	% Turbine	35.00%
101	GSU Customer Service Hourly Rate	$50.00
102	GSU Billing Rate	$50.00

Table 31

The following assumptions differed based on the scenario being reviewed.

Reference	Assumption	Unit	Scenario 1 AMR Walk-by	Scenario 2 - AMR Mobile	Scenario 3 - AMI Fixed Alone	Scenario 4 AMI Fixed GSU
62	Handhelds - Meter Reading	# of devices	7.00	2.00	-	-
63	Cradle - Meter Reading	# of devices	7.00	2.00	-	-
64	Handhelds - Maintenance	# of devices	5.00	5.00	5.00	5.00
65	Cradle - Maintenance	# of devices	5.00	5.00	5.00	5.00
66	Mobile lite	# of devices	-	-	-	-

Reference	Assumption	Unit	Scenario 1 AMR Walk-by	Scenario 2 - AMR Mobile	Scenario 3 - AMI Fixed Alone	Scenario 4 AMI Fixed GSU
67	Full Mobile	# of devices	-	2.00	-	-
68	Multi-handheld cradle	# of devices	2.00	1.00	1.00	1.00
69	Data Collectors - Supply	# of devices	-	-	75.00	4.00
70	Data Collectors Deployment - Installation	# of devices	-	-	75.00	4.00
71	Data Collectors Deployment - Supply and Install Poles	# of devices			20.00	-
72	Data Collectors Deployment - Management/Approval	# of devices			50.00	25.00
73	Software Implementation and Daily Rate	Per Day $	$1,600.00	$1,600.00	$1,600.00	$1,600.00
74	Meter Reading Software - Initial License	# of Licenses	1.00	1.00	1.00	1.00
75	Meter Reading Software - Implementation (in days)	# of days	6.00	6.00	6.00	6.00
76	Meter Reading Software - User Training (in days)	# of days	6.00	6.00	6.00	6.00
77	Collection Software - Initial License	$ of License	-	-	$150,000.00	
78	Collection Software - Implementation (in days)	# of days	-	-	60.00	30.00
79	Collection Software - User Training	# of days			20.00	10.00
80	Collection Software - Servers/Hardware	# of system environments			1.00	-
81	Collection Software - Operating & DB Licenses	# of Licenses			1.00	
82	MDM Software - Initial License	# of Licenses			1.00	1.00

Reference	Assumption	Unit	Scenario 1 AMR Walk-by	Scenario 2 - AMR Mobile	Scenario 3 - AMI Fixed Alone	Scenario 4 AMI Fixed GSU
83	MDM Software - Implementation	# of days			60.00	60.00
84	MDM Software - User Training	# of days			20.00	20.00
85	MDM Software - Servers/Hardware	# of system environments			1.00	1.00
86	MDM Software - Operating & DB Licenses	# of Licenses			1.00	1.00
87	Interface Daily Rate	$ per day	$1,600.00	$1,600.00	$1,600.00	$1,600.00
88	Interfaces (days of programming)	# of days	20.00	20.00	60.00	40.00
89	Contingency					
90	Procurement	Yes=1, No=0	1.00	1.00	1.00	1.00
91	Project Support	Yes=1, No=0	1.00	1.00	1.00	1.00
92	Disbursements	Yes=1, No=0	1.00	1.00	1.00	1.00
93	Project Manager	% of FTE	50%	50 %	50 %	50%
94	IT Support - Hardware (days)	# of days	-	-	20.00	10.00
95	IT Support - AMS Champion	% of FTE	-	-	50 %	50 %
96	CIS Support - Validation Review (days per month)	# of days per month	10.00	10.00	10.00	10.00
97	Field Supervisors (days per month)	# of days per month	10.00	10.00	10.00	10.00
98	Inspector	# of days per month	20.00	20.00	20.00	20.00

Table 32

4.2. Meter Accuracy Improvements

One of the ways to improve revenues is to replace aging meters. As meters become older, like any mechanical device, the parts begin to wear down and the meter becomes less accurate over time. Using the Neptune SEER® Program and the information provided from CGS database, the chart below was derived.

Meter Accuracy	5/8"	3/4"	1"	1.5"	2"	3"	4"	6"	8"
Less than 5 Years	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
5-9 Years	98.5%	98.5%	98.5%	98.0%	96.0%	97.0%	96.0%	96.0%	96.0%
10-14 Years	96.5%	96.5%	97.0%	96.5%	94.0%	95.0%	94.0%	94.0%	94.0%
15-19 Years	95.0%	95.0%	95.0%	95.0%	92.0%	93.5%	92.0%	92.0%	92.0%
20+ Years	93.0%	93.0%	93.0%	92.7%	90.0%	92.0%	90.0%	90.0%	90.0%

Table 33

The chart represents an average meter accuracy across age category and meter size.

Neptune's SEER® (Statistical Evaluation for the Enhancement of Revenue) analysis tool is specifically designed to identify Non-Revenue Water at the water meter level[3]. SEER Model can determine meter accuracy within a 95% confidence interval.

Within the information, CGS also provided 2015 consumption revenue for both Water and Sewer on a per account basis. The chart below represents the combined water and sewer consumption revenue of by age category and meter size. The revenues un-relating to consumption were not included below.

Consumption Revenue - Water + Sewer	15x20mm	20mm	25mm	37mm	50mm	75mm	100mm	150mm	200mm	(blank)	Grand Total
Less than 5 Years	$ 2,349,653	$ -	$ 1,193,185	$ 1,590,890	$ 3,367,889	$ 700,384	$ 510,703	$ 826,073	$ 26,644	$ 9,057	$ 10,574,478
5 to 9 Years	$ 1,973,938	$ 8,309	$ 618,147	$ 481,368	$ 892,441	$ 131,562	$ 46,656	$ 231,508	$ -	$ 12,861	$ 4,396,791
10 to 14 Years	$ 2,016,273	$ -	$ 273,538	$ 29,625	$ 126,418	$ 46,819	$ 42,226	$ 79,827	$ -	$ 525,142	$ 3,139,868
15 to 19 years	$ 10,296,740	$ -	$ 18,675	$ -	$ 6,679	$ -	$ -	$ -	$ -	$ -	$ 10,322,094
Greater than 20 years	$ 6,804,924	$ -	$ 130,069	$ 5,723	$ 125,730	$ -	$ 20,312	$ -	$ -	$ -	$ 7,086,758
(blank)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 171,713	$ 171,713
Grand Total	**$ 23,441,529**	**$ 8,309**	**$ 2,233,614**	**$ 2,107,606**	**$ 4,519,157**	**$ 878,765**	**$ 619,897**	**$ 1,137,408**	**$ 26,644**	**$ 718,773**	**$ 35,691,703**

Table 34

Using the meter accuracy and the combined consumption revenue tables we can estimate the revenue loss for each age category and meter size as seen in the chart below. The formula we used for each cell within the matrix is as follows:

*Revenue Loss = (100% - Meter Accuracy) * Consumption Revenue*

Revenue Loss	15x20mm	20mm	25mm	37mm	50mm	75mm	100mm	150mm	200mm	Total
Less than 5 Years	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
5 to 9 Years	$ 29,609	$ 125	$ 9,272	$ 9,627	$ 35,698	$ 3,947	$ 1,866	$ 9,260	$ -	$ 99,404
10 to 14 Years	$ 70,570	$ -	$ 8,206	$ 1,037	$ 7,585	$ 2,341	$ 2,534	$ 4,790	$ -	$ 97,062
15 to 19 years	$ 514,837	$ -	$ 934	$ -	$ 534	$ -	$ -	$ -	$ -	$ 516,305
Greater than 20 years	$ 476,345	$ -	$ 9,105	$ 418	$ 12,573	$ -	$ 2,031	$ -	$ -	$ 500,472
Grand Total	**$1,091,360**	**$ 125**	**$ 27,517**	**$ 11,082**	**$ 56,390**	**$ 6,288**	**$ 6,431**	**$ 14,050**	**$ -**	**$ 1,213,243**

Table 35

[3] https://www.neptunetg.com/products/water-meters/metering-system/seer/

The estimated revenue lost shown in this table can only be realized if the water meters are going to be replaced. The City reviewed the best options and decided the following change out criteria would be used. This will adjust the revenue loss estimate to include only those meters that will be replaced.

Reference	Assumption	Assumption
10	Replacement Age - 15mm to 25mm	5 to 9 Years
11	Replacement Age - 37mm to 50mm	Greater than 20 years
12	Replacement Age - 75mm and greater	Greater than 20 years

Table 36

These assumptions reduced the total annual revenue loss to be $1,119,000.

4.3. Operational Improvements

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

The project team reviewed and calculated the savings each specific technology are expected to deliver. The assumed change and the overall financial impact of these changes are summarized by function: meter reading, customer service and water billing, and meter maintenance. These changes should be compared to the Project Assessment section of this report.

We also included the cost impact that the different technologies would have on distribution system management and IT Support costs. As well as provided some estimates on the financial improvements to the distribution system management.

4.3.1. Meter Reading

As discussed in the Project Assessment (2.3.2) the total meter reading costs are summarized below:

Meter Reading Cost	Extended
Olameter – Reading costs	$ 250,983
Olameter – Other Services	$ 21,167
Meter Reader Coordinator	$ 75,000
CGS re-read costs	$ 44,100
Total	**$391,251**

Table 37

The affect the different types of technology will have on the detailed meter read functions are detailed in the table below.

Read Rates	**Scenario 1 AMR Walk-by** Readings bi-monthly	**Scenario 2 - AMR Mobile** Readings monthly	**Scenario 3 - AMI Fixed Alone** Readings monthly	**Scenario 4 AMI Fixed GSU** Readings monthly
Meter Reading Service Provider Costs				
Residential Inside	Rate: reduced by 25% ($.41/ read) Freq: no change	Rate: reduced by 75% ($.136/ read) Freq: increased to 12 reads per year per customer	Rate: Reduced by 100% Frequency: Reduced by 100% (collecting hourly readings)	
Residential Outside	Rate: same as residential read Freq: no change	Rate: same as residential inside read Freq: read with residential meters 12 reads per year per customer	Rate: same as residential inside read Frequency: Reduced by 100% (collecting hourly readings)	
Residential Freezing				
Commercial	Rate: reduced by 25% ($1.48 / read)			

<table>
<tr><th>Read Rates</th><th>Scenario 1 AMR Walk-by
Readings bi-monthly</th><th>Scenario 2 - AMR Mobile
Readings monthly</th><th>Scenario 3 - AMI Fixed Alone
Readings monthly</th><th>Scenario 4 AMI Fixed GSU
Readings monthly</th></tr>
<tr><td></td><td>Freq: no change</td><td></td><td colspan="2"></td></tr>
<tr><td>Special Reading at $3.06</td><td>No change</td><td>No change</td><td colspan="2" rowspan="2">Rate: reduced by 100%
Frequency: reduced by 100%</td></tr>
<tr><td>Special Reading at $7.99</td><td>No change</td><td>No change</td></tr>
<tr><td>Initial Call</td><td colspan="4" rowspan="5">Rate: No change
Frequency: No change</td></tr>
<tr><td>Turn-Off of Water Service</td></tr>
<tr><td>Turn-On of Water Service</td></tr>
<tr><td>Negotiation of Payment</td></tr>
<tr><td>No. Customer Contact Required</td></tr>
<tr><td colspan="5">Project Coordinator costs</td></tr>
<tr><td>Coordination Costs</td><td>No change
($75,000)</td><td>Rate: reduced by 50%
($37,500)</td><td colspan="2">Rate: reduced by 100%
(%0)</td></tr>
<tr><td colspan="5">CGS Meter Reading Maintenance costs</td></tr>
<tr><td>Re-read Cost</td><td colspan="4">Rate: No change
($35/ re-read investigation)
Frequency: Reduced by 75%</td></tr>
</table>

Table 38

The above changes reduced the total expected meter reading costs from the current $391,251 per year.

Table 39

Meter Reading Cost	Existing	**Scenario 1 AMR Walk-by** Readings bi-monthly	**Scenario 2 - AMR Mobile** Readings monthly	**Scenario 3 - AMI Fixed Alone** Readings monthly	**Scenario 4 AMI Fixed GSU** Readings monthly
Olameter – Reading costs	$ 250,983	$193,167	$127,192	$0	$0
Olameter – Other Services	$ 21,167	$ 21,167	$ 21,167	$ 21,167	$ 21,167
Meter Reader Coordinator	$ 75,000	$75,000	$37,500	$0	$0
CGS re-read costs	$ 44,100	$11,025	$11,025	$11,025	$11,025
Total	**$391,251**	**$300,360**	**$196,885**	**$32,192**	**$32,192**
Annual Savings	**$0**	**$90,891**	**$194,366**	**$359,058**	**$359,058**

4.3.2. Customer Service and Water Billing

As discussed in the project assessment section of the report there were three areas we felt could be positively affected by the application of AMI technology, improvement in water bill estimates, ability to better manage high/low consumption service calls and improved customer service to both residential and commercial customers.

Improvement	Current Level	Scenario 1 AMR Walk-by Readings bi-monthly	Scenario 2 - AMR Mobile Readings monthly	Scenario 3 - AMI Fixed Alone Readings monthly	Scenario 4 AMI Fixed GSU Readings monthly
Water Bill Estimates High / Low Consumption Calls Improved Customer Service	Qty = 20,753 Admin time = 10min / estimate	Qty = 15,564 (25% reduction) Admin time = 10 min / estimate Reduction in customer interaction = No change On-line access reducing calls by = no change	Qty = 10,375 50% reduction Admin time = 10 min / estimate Reduction in customer interaction = 25% improvement* On-line access reducing calls by = 25%[1]	Qty = 5,188 75% reduction Admin time = 10 min / estimate Reduction in customer interaction = 35% improvement* On-line access reducing calls by = 35%[1]	

Table 40

1 Improvements in complaints and call volumes comes from other water utilities and may not translate into reduced fees by GSU.

Some in GSU have concerns moving water customers to hourly reading will lead to increases in required customer service staffing. These improvements in customer service are estimated to create some efficiencies in the customer service and water billing and improve overall customer service.

Meter Reading Cost	Existing	Scenario 1 AMR Walk-by Readings bi-monthly	Scenario 2 - AMR Mobile Readings monthly	Scenario 3 - AMI Fixed Alone Readings monthly	Scenario 4 AMI Fixed GSU Readings monthly
Water Bill Estimate	$ 172,941	$129,706	$86,470	$43,235	$43,235
High / Low Consumption Calls	$ 120,472	$ 120,472	$ 90,354	$ 78,307	$ 78,307
Improved Customer Service	$ 13,553	$13,553	$9,035	$3,011	$3,011
Total Expenses	**$306,967**	**$263,731**	**$185,860**	**$124,554**	**$124,554**
Annual Savings	$ 0	$43,235	$121,106	$182,412	$182,412

Table 41

4.3.3. Water Meter Maintenance

Applying technology to the City's meter maintenance group affects a number of tasks the department is responsible for. First, there are a number of high/low consumption investigations that result in a field visit. The combination of hourly consumption history (with AMI technology) and being able to respond quickly to potential tampers, will reduce the number of onsite visits required over time.

As a part of scenario 3 and 4 we have recommended testing some temperature gauges installed at properties whose water services are shallow and susceptible to freezing. Receiving these temperature flags will help CGS inform customers of the risk of pipes freezing. Due to this, we would expect to see a reduction in the number of total frozen meters and minimize the number of required replacements.

The third factor that we would expect to see improvements in relates to ensuring the correct application of the water meter type and size are installed. With hourly consumption information that an AMI system would provide the City would be able to determine mis-applied meters, resulting in increased meter accuracy.

Lastly, with the addition of a radio transmitter, the meter shop will need to perform additional maintenance. We have allowed for an increase in the amount of time servicing the radio transmitters as well as additional radio transmitters required due to lost or damaged devices.

Improvement	**Current Level**	**Scenario 1 AMR Walk-by** (per year)	**Scenario 2 - AMR Mobile** (per year)	**Scenario 3 - AMI Fixed Alone** (per year)	**Scenario 4 AMI Fixed GSU** (per year)
Radio Transmitter Maintenance	None	Qty = 240	Qty=240	Qty 240	
High / Low Consumption Calls	Qty= 1,084	Qty 1,084	Qty = 725	Qty= 240	
Frozen Meters	Qty = 80	Qty=80	Qty=80	Qty=60	
Misapplied meters	$ improvement = 0	$ improvement = 0	$ improvement = 0	$ improvement = $10,500 / year	

Table 42

The financial impact each technology will have on the meter maintenance department is summarized below.

Meter Reading Cost	Existing	Scenario 1 AMR Walk-by Readings bi-monthly	Scenario 2 - AMR Mobile Readings monthly	Scenario 3 - AMI Fixed Alone Readings monthly	Scenario 4 AMI Fixed GSU Readings monthly
Radio Transmitter Maintenance	$ 0	$38,551	$38,551	$38,551	$38,551
High / Low Consumption Calls	$ 74,137	$ 74,137	$49,425	$16,475	$16,475
Frozen Meters	$14,270	$14,270	$10,700	$3,567	$3,567
Expenses	88,407	$126,958	$98,676	$58,593	$58,593
Change in Expenses	**$0**	**$38,551**	**$10,269**	**$29,814**	**$(29,814)**
Misapplied meters	$ 0	$ 0	$ 0	$-10,500	$-10,500
Annual Savings	**$0**	**$(38,551)**	**$(10,269)**	**$40,314**	**$40,314**

Table 43

Negative savings are considered an increase in expenses.

4.3.4. Distribution System Management

Technology can be used in other parts of the CGS organization to improve the Utilities ability to manage the water distribution systems. Consumption data that an AMR/AMI system can provide will allow CGS to focus resources and capital improvement to the system that is in most need. We have provided a financial estimate of the improved system management, by comparing the affect each type of technology will have on unaccounted for water estimate (currently at 27%). We calculated the cost of this unaccounted for water by totaling the variable distribution and treatment costs. The table below provide a current estimate of unaccounted for water:

2015 Water Production Costs				
	Treatment	Distribution	Total	Total
Costs	Actual	Actual	Actual	Variable Cost
Salaries	$923,729	$1,156,819	**$2,080,548**	
Materials	1,283,026	486,210	**1,769,236**	1,769,236
Purchased Services	325,899	994,407	**1,320,306**	
Energy	1,895,152	658	**1,895,810**	1,895,810
	$4,427,806	$2,638,094	**$7,065,900**	3,665,046
Unaccounted for Water			**27%**	$ 989,562.42

Table 44

Each technology will show different levels of improvement to the unaccounted for water percentage. AMR Mobile reducing this to an estimated 25%; we estimated AMI fixed network technology would improve this to 20%.

These improvements would be associated across the entire CGS system as well as the Vermilion water system. Improvements in unaccounted for water in Vermillion will have a direct improvement to expenses due to CGS purchasing water for $.416 per cubic meter rate. The cost of unaccounted for water and the savings produced for reducing it is detailed in the table below:

Description	Extended
Vermillion Flow (M3 in 2015)	1,650,308
Vermillion Flow (paid at $.416)	$ 0.416
Total Cost of Water Vermillion	$ 686,528
Unaccounted for Water - Vermillion (%)	20%
Unaccounted for Water - Vermillion ($) at 20%	$ 137,305
Unaccounted for Water – Vermillion ($) at 15%	$102,979
Savings per year	$34,326

Table 45

The second area of distribution management improvement relates to reduction of water meter tampering. CGS meter shop consistently uncovers customers whose water meter has been damaged or tampered with, which has a direct impact on the total water consumption being recorded. These are usually uncovered due to dramatic changes in water consumption over a long period of time (60 days). CGS meter installers found approximately 10% of the meters they replaced in the last couple years had evidence of tampering, so it is likely CGS is not detecting all tampering that currently occurring. AMR and AMI technology can improve CGS ability to detect and monitor tampering and react quicker to changes in consumption behavior that may indicate that tampering is occurring.

The financial improvements CGS should expect are estimated in the table below:

Meter Reading Cost	Existing	**Scenario 1 AMR Walk-by** Readings bi-monthly	**Scenario 2 - AMR Mobile** Readings monthly	**Scenario 3 - AMI Fixed Alone** Readings monthly	**Scenario 4 AMI Fixed GSU** Readings monthly
Unaccounted for Water System-wide	$ 989,560	$ 989,560	$ 916,260	$ 733,000	$ 733,000
Unaccounted for Water Vermillion system	$ 137,305	$ 137,305	$123,575	$102,980	$102,980
Expenses	$1,126,865	$1,126,865	$1,039,835	$835,980	$835,980
Change	**$0**	**$0**	**$87,030**	**$290,885**	**$290,885**
Revenue Recovery from Tampering (Consumption + Admin fees)	$95,437	$95,437	$ 116,386	$232,773	$232,773
Change	**$0**	**$0**	**$20,949**	**$137,336**	**$137,336**
Annual savings	**$0**	**$0**	**$107,979**	**$428,221**	**$428,221**

Table 46

4.3.5. IT Support Costs

Meter reading software and equipment currently in place require very little IT support to operate. The current contract with GSU and Olameter (through GSU) include all require IT support for the existing meter reading equipment and software. Introduction of AMI/AMR technology and having CGS directly manage the meter reading contract, will require and increase in IT support. Fixed network AMI technology requires significantly more IT support than a mobile AMR technology, due to the amount of data that would be collected.

The table below summarizes the IT support assumptions we made.

Assumption	**Current Level**	**Scenario 1 AMR Walk-by** (per year)	**Scenario 2 - AMR Mobile** (per year)	**Scenario 3 - AMI Fixed Alone** (per year)	**Scenario 4 AMI Fixed GSU** (per year)
Meter Reading software	None, included in Olameter contract	1 software license	1 software license	1 software license	1 software license
Collection Software	Not required	Not required	Not required	1 software license	Included in fees with GSU
Meter Data Management	Not required	Not required	Not required	1 software license	1 software license
RF license	Not required	Not required (or included in software cost)	Not required (or included in software cost)	Not required (or included in software cost)	Included in fees with GSU
Handheld Support (reading & Maintenance)	Not required	Handhelds= 12 Support $=15% of capital cost	Handhelds= 7 Support $=15% of capital cost	Handhelds= 5 Support $=15% of capital cost	Handhelds= 5 Support $=15% of capital cost
Mobile Data Collector Support	Not required	Not required	Mobile units= 2 Support $=15% of capital cost	Not required	Not required
Fixed network Data collectors	Not required	Not required	Not required	Data collectors = 10 to 75 collectors (depends on manufacturer) Support $=15%	Use of existing network + 3-4 data collectors Support $=15%
Wide Area Network Costs	Not required	Not required	Not required	75 cellular data plans @ $600 / year	Included in fees with GSU
AMI Data Anaylst	Not required	Not required	Not required	50% of FTE	50% FTE
IT Hardward support	Not required	Not required	Not required	Included in existing CGS IT infrastructure	Included in existing CGS IT infrastructure

Assumption	Current Level	Scenario 1 AMR Walk-by (per year)	Scenario 2 - AMR Mobile (per year)	Scenario 3 - AMI Fixed Alone (per year)	Scenario 4 AMI Fixed GSU (per year)
GSU System Sharing fee	Not required	Not required	Not required	Not required	Network+ $58,800 Licenses=$3/ customer/ year

Table 47

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

Meter Reading Cost	Existing	Scenario 1 AMR Walk-by Readings bi-monthly	Scenario 2 - AMR Mobile Readings monthly	Scenario 3 - AMI Fixed Alone Readings monthly	Scenario 4 AMI Fixed GSU Readings monthly
Meter Reading Software	$ -	$ 2,000	$ 2,000	$ 2,000	$ 2,000
Collection Software	$ -	$ -	$ -	$30,000	$ -
Meter Data Management	$ -	$ -	$ -	$30,000	$ 30,000
RF Licence					$ -
Handheld Support Cost	$ -	$ 12,900	$ 9,488	$ 2,401	$ 377
Mobile Unit Support Cost		$ -	$ 10,125	$ 4,125	$ 0
FN Data Collector Support		$ -	$ -	$67,500	$ 24,000
WAN (Assuming cellular)			$ -	$45,000	$ -
Data Anaylst				$65,000	$ 65,000
IT Hardware - Support					
GSU System Sharing Fee					$ 204,803
	$ -	**$ 14,900**	**$ 21,613**	**$ 246,026**	**$ 326,181**
	$ -	**$(14,900.00)**	**$(21,612.50)**	**$(246,025.90)**	**$(326,180.65)**

Table 48

4.4. Capital Costs

4.4.1. Project Scope

With any water meter project there are always complications that can prevent the replacement or radio transmitter installation from happening. These issues usually include water meter enclosed behind a finished wall, valves not operational, or plumbing fittings that would need to be replaced to complete the work. One part of having a successfully project is to convert as close to 100% of the water meters to the new technology as possible. To achieve this level of completion, the Utility needs to allow the installation contractor to overcome most of the above issues. Allowing carpentry, plumbing, and valve replacement will allow the project to achieve over 97% complete. Although this extra work is not usually performed by the City meter shop it is vital for this to occur (as a one-time event). Not including this work in the project would likely reduce the conversion to below 90%.

The project will include performing either a meter change out where the old water meter is removed, a new meter and AMR/AMI radio transmitter is installed; or a retrofit where a radio transmitter is installed on existing water meters.

There was an option to upgrade existing water meter with a high resolution water meter registers to allow for some of the enhanced AMI/AMR features to all customers. The additional cost of this optional project scope is approximate $450,000 (~6300 @ $70 / register).

The customers can be broken into two categories small meter (SM – meters 15mm to 20mm) and large meters (LM – meters 25mm and greater). The table below summarizes how many meters in each category and their assumed work type (change out, retrofits).

Category\ Work Type	Change out	Retrofit	Total
Small Meter	41,339	529	**41,868**
Large Meter	4,712	1,609	**6,321**
Total	**46,051**	**2,138**	**48,189**

Table 49

The following cost summaries are based on the above quantities.

4.4.2. Installation Cost

Category	Scenario 1 Walk-by AMR	Scenario 2 AMR Mobile	Scenario 3 AMI Fixed (alone)	Scenario 4 AMI fixed with GSU
SM - C/O	$3,634,975	$ 3,634,975	$ 3,634,975	$3,634,975
SM Extra Work	$ 799,659	$799,659	$799,659	$799,659
LM - C/O	$ 181,185	$181,185	$181,185	$181,185
LM Extra Work	$ 80,945	$ 80,348	$ 80,348	$ 80,348
Total Installation Cost	**$4,696,764**	**$ 4,696,167**	**$ 4,696,167**	**$4,696,167**

Table 50

The SM - C/O and LM – C/O includes the installation portion of the changes out and retrofit work.
The Extra work where required (based on assumptions) for valve replacement, plumbing, wire replacement, carpentry, freezing pipe in lieu of curb stop operation, confined and crawl space entry.

4.4.3. AMI/AMR Supply Cost

The AMI/AMR project costs are summarized below by category.

Category	Scenario 1 Walk-by AMR	Scenario 2 AMR Mobile	Scenario 3 AMI Fixed (alone)	Scenario 4 AMI fixed with GSU
SM - Radio	$ 4,225,500	$4,225,500	$4,225,500	$4,225,500
LM - Radio	$ 180,000	$180,000	$180,000	$180,000
ALL – Temperature Gauges	$ -	$250,000	$-	$-
FN Collectors	$ -	$-	$797,500	$200,000
Handheld Devices	$ 86,000	$ 49,750	$ 33,250	$ 36,250
Mobile Devices	$ -	$ 40,000	$-	$-
Software Implementation	$ 9,600	$ 9,600	$196,800	$148,800
Northstar Interfaces	$ 32,000	$-	$ 96,000	$ 64,000
Server Hardware	$ -	$-	$ 50,000	$ 25,000
License (OS & DB)	$ -	$-	$ 50,000	$ 25,000
Meter Reading, data collection and MDM Software licenses	$ 10,000	$ 10,000	$310,000	$160,000
System Training	$ 9,600	$ 9,600	$ 73,600	$ 57,600
Contingency	$ 91,054	$ 95,489	$120,253	$102,443
AMR Supply	**$ 4,643,754**	**$4,869,939**	**$6,132,903**	**$5,224,593**

Table 51

The temperature gauge cost assumes approximate 300 temperature gauges that will transmit water temperature to be installed at service addresses that have shallow services.

4.4.4. Meter Supply Cost

The meter supply costs are summarized below:

Category	Scenario 1 Walk-by AMR	Scenario 2 AMR Mobile	Scenario 3 AMI Fixed (alone)	Scenario 4 AMI fixed with GSU
SM	$ 3,653,273	$3,653,273	$3,653,273	$3,653,273
LM	$ 41,575	$ 41,575	$ 42,025	$ 42,025
Meter Supply	**$ 3,694,848**	**$3,694,848**	**$3,695,298**	**$3,695,298**

Table 52

4.4.5. Consulting Support

The AMI/AMR subject matter expert consulting services costs are summarized below:

Category	Scenario 1 Walk-by AMR	Scenario 2 AMR Mobile	Scenario 3 AMI Fixed (alone)	Scenario 4 AMI fixed with GSU
Procurement	$85,000	$85,000	$85,000	$85,000
Project Support (3 years)	$700,000	$700,000	$700,000	$700,000
Consulting	**$785,000**	**$785,000**	**$785,000**	**$785,000**

Table 53

4.4.6. Internal Project Support

Category	Scenario 1 Walk-by AMR	Scenario 2 AMR Mobile	Scenario 3 AMI Fixed (alone)	Scenario 4 AMI fixed with GSU
PM	$ 127,637	$127,637	$127,637	$127,637
CIS (GSU) Support	$ 140,000	$140,000	$140,000	$140,000
Field Support	$ 364,000	$364,000	$364,000	$364,000
IT Support	$ -	$-	$127,637	$127,637
Project Support	**$ 631,637**	**$631,637**	**$759,273**	**$759,273**

Table 54

4.4.7. Contingency

Category	Scenario 1 Walk-by AMR	Scenario 2 AMR Mobile	Scenario 3 AMI Fixed (alone)	Scenario 4 AMI fixed with GSU
Contingency -0.1	**$ 469,677**	**$469,617**	**$469,617**	**$469,617**

Table 55

Glossary

1. AMI – Advanced Metering Infrastructure, a two-way communication network for meter reading and other functions
2. AMR – Automated Meter Reading, a one-way communication network or mobile data collection system used for meter reading
3. CIS – Customer Information System, a software application used to store information about customers; often includes billing functionality
4. FAN or FN – Fixed Area Network, a radio communications network that typically uses a matrix of data collectors
5. GPS – Geographical Positioning System, a method of determining location from satellites
6. ICI – Industrial, Commercial and Industrial, usually the largest customers, sometimes referred to as "commercial" customers
7. IT – Information Technology
8. KPI – Key Performance Indicator, a measurement used to manage performance
9. MDM – Meter Data Management System, the data repository for an advanced metering infrastructure system
10. QA – Quality Assurance, in IT, a QA system is used to test software prior to deployment in Production
11. RSR – Read Success Rate, the percentage of expected meter readings captured in the meter data management system or data repository; it is the key performance indicator of an AMI system