Wyoming State Revolving Funds
Pine Bluffs Meter Project and Telemetry Business Cases
July 8, 2009

Green Reserve Project Type

The Town of Pine Bluffs will replace substantially malfunctioning water meters that are no longer used or work properly. This project qualifies as an energy and water efficiency project, as it will reduce unaccounted water losses and save electricity associated with pumping water that is lost.

Documents submitted and reviewed by the State:

The Wyoming State Revolving Funds has reviewed the following documents. These are attached:

1. Lidstone and Associates April 30, 2009 Memorandum Town of Pine Bluffs Green Project Reserve: Water Meter Replacement Project.
2. Town of Pine Bluffs Pumping Costs January 1, 2004 through May 31, 2009
3. Lidstone and Associates May 6, 2009 email and summary of meter status
4. *Does Your Water System have a Water Meter Program?* James Dailey
5. *Determining the Economical Optimum Life of Residential Water Meters When should you replace a water meter? A methodology for the calculation of this optimum age is presented.* Dr. Hans D. Allender, P.E.
6. *Residential Water Meter Replacement Economics.* S. E. Davis

List of eligible Green Project Reserve components:

1. The green components associated with this project are the water meters. The engineer's estimate is $738,715 for furnishing and installing the meters, which does not include design nor construction management. The remainder of the project includes radio equipment telemetry for automated reading of the meters.
2. Total project cost = $1,007,072
3. Total ARRA Loan/Grant Request = $1,007,072
4. Total project cost eligible for Green Project Reserve = $1,007,072

The following table highlights estimated project and green component costs.

Out of Service Meters, Lack of Meters		Estimated Replacement Costs	Total Replacement Costs[1]	Green Cost
Quantity[3]	Type			
6	Commercial Meters (Out of Service for an Extended Period of Time)	$2,435.00	$14,610.00	$14,610.00
22	Residential Meters (Out of Service for an Extended Period of Time)	$1,300.00	$28,600.00	$28,600.00

5	Trailer Park has one meter for 5 permanent residences and several seasonal / temporary residences	$1,300.00	$6,500.00	$6,500.00
8	Currently unmetered services	$1,300.00	$10,400.00	$10,400.00
404	Residential meters that have exceeded design life[2]	$1,300.00	$525,200.00	$525,200.00
63	Commercial meters that have exceeded design life[2]	$2,435.00	$153,405.00	$153,405.00
		Sub Total	**$738,715.00**	**$738,715.00**
Automated Radio Read	Radio read meter system	$268,357.00	$268,357.00	$268,357.00
		Total	**$1,007,072.00**	**$1,007,072.00**

Table 1. Town of Pine Bluffs Meter and Telemetry Project and Green Component Costs.

Green Reserve Project – Categorical Project:

This overwhelming majority of this meter project is not considered categorically green as defined by the USEPA guidance documents because it replaces substantially malfunctioning existing meters. There is a categorically defined green project portion for installation of new meters where no meters are currently provided. This totals $60,110 for 41 new meters.

The project also includes a radio based telemetry system that will reduce manpower and vehicle requirements to read 439 residential and 69 commercial meters. The telemetry system will also allow the system to identify and repair leaking lines in a timely fashion, reducing water loss, chemical costs to treat wasted water and electricity needed to pump wasted water. The total cost for the telemetry system is $268,357.

Green Reserve Project – Business Case Evaluation:

As stated in the USEPA March 2, 2009 Memorandum, for traditional projects that are not categorically green, for the project, or components of the project, to be counted towards the 20% requirement, the State project files must contain documentation that a clear business case for the project (or portion) investment includes achievement of identifiable and substantial benefits that qualify as Green Project benefits. The documentation should reference to a preliminary engineering or other planning document that makes clear that the basis upon which the project (or portion) was undertaken included identifiable and substantial benefits qualifying for the Green Project Reserve. The March 12, 2009 USEPA webcast slides 20 and 21 state that two components, the technical component and financial component, must be provided in the Business Case.

Green Project Reserve Type:

This project falls in the energy and water efficiency categories.

Technical Component Evaluation:
The Town of Pine Bluffs originally installed water meters in the late 1970's. It is difficult to find documentation that states the given life of meters that are thirty years old. Experts in the field generally agree that meters have a useful life of 10 to 20 years.[1] Today, meter manufacturers will warranty meters anywhere from 5 to 15 years (15 if the meters are repaired/rebuilt). The housings are sometimes warranted for 30 years, but this is the shell of the unit, and it is the mechanical and electronic components of meters that wear and fail.

As the meters age, they becoming increasingly less accurate and fail to read low flow conditions.[2] These low flow conditions are typical of residential connections, such as when a toilet is flushed. A manufacturer's representative has reported to a local Wyoming official that their meters lose about one percent accuracy per year, and recommended replacement every ten years.

The Town's meters have simply outlived their useful lives. The Town's engineer reports the meters are more than 30 years old, are not accurate, and cannot be repaired as parts are no longer available.[3] The Town does not use the meters to bill customers. This forces the Town to use a flat rate, rather than a use rate. This leads to excessive consumption as consumers are not billed more for greater use. Consumers pay the same whether they use 2,000 or 20,000 gallons per month. The Town's meters still may function in the sense they spin when water goes through them, but they do so with so much imprecision that they are inherently faulty. These meters are substantially malfunctioning and basically worthless. The only reason why they are still installed on the service lines is because it costs money to remove them.

The Town has compared flows based on their transmission meters compared to their distribution meters, i.e. the meters the Town will replace with this project. The Town estimates unaccounted lost water to be 25 percent.[4]

Financial Component Evaluation:
Unaccounted water losses are a reality all water systems face. USEPA cites a goal of 10 percent for unaccounted water losses.[5] It is difficult to predict what the actual savings of unaccounted water losses will be with the installation of the new meters and telemetry system. There will certainly be a savings associated with low flow meter slippage and inaccuracies. There will also be a savings associated with the determination of service line leakages losses after the meter pit.

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[1] *Residential Water Meter Replacement Economics.* S. E. Davis

[2] *Does Your Water System have a Water Meter Program?* James Dailey

[3] Lidstone and Associates April 30, 2009 Memorandum Town of Pine Bluffs Green Project Reserve: Water Meter Replacement Project.

[4] Ibid.

[5] Using Water Efficiently: Ideas for Communities. http://www.epa.gov/WaterSense/pubs/community.htm

The following table shows actual electrical demands for a period of five years and four months. The table also calculates the associated energy savings for various percent savings of reduced unaccounted water losses. The engineering report estimates that with the new and replacement meters, the system should realize a 15% energy savings and will meet the USEPA goal of 10% unaccounted water losses.

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Town of Pine Bluffs

Pumping Costs

January 1, 2004 through May 31, 2009

Well	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**TOTAL**
Water Treatment (Chlorine Tank)	2,047.80	2,047.76	1,329.47	1,863.74	2,253.41	1,376.60	10,918.78
Ball Park Well	31,873.99	21,690.02	34,494.55	25,994.74	23,297.09	12,861.63	150,212.02
Town Well Number 6 C	35,549.83	37,868.47	37,173.71	21,480.17	30,242.12	13,622.72	175,937.02
Water Well #1 Plant	17,154.06	3,548.69	4,980.78	6,041.66	4,647.83	999.88	37,372.90
Water Well #1	282.49	284.97	241.34	276.18	311.96	230.58	1,627.52
1279 1/2 North Main	12,712.51	12,775.30	12,852.58	8,609.12	29,763.38	16,935.77	93,648.66
East US Thirty	2,714.46	2,519.96	3,185.13	3,072.32	418.77	262.74	12,173.38
511 Butler Avenue	3,061.67	2,686.33	3,097.87	991.61	470.47	301.93	10,609.88
TOTAL	**$105,396.81**	**$83,421.50**	**$97,355.43**	**$68,329.54**	**$91,405.03**	**$46,591.85**	**$492,500.16**
Pumping cost savings if:							
5 % reduction in unaccounted water	$5,269.84	$4,171.08	$4,867.77	$3,416.48	$4,570.25	$2,329.59	**$24,625.01**
10 % reduction in unaccounted water	$10,539.68	$8,342.15	$9,735.54	$6,832.95	$9,140.50	$4,659.19	**$49,250.02**
15 % reduction in unaccounted water	$15,809.52	$12,513.23	$14,603.31	$10,249.43	$13,710.75	$6,988.78	**$73,875.02**
20 % reduction in unaccounted water	$21,079.36	$16,684.30	$19,471.09	$13,665.91	$18,281.01	$9,318.37	**$98,500.03**

Table 2. Summary of pumping costs and associated savings when unaccounted water losses are reduced at various percentages.

Green Reserve Project – Evaluation Conclusion:

The Wyoming State Revolving Fund Program has determined that this entire project qualifies as a green project. This is based on the following:

1) the meters are substantially malfunctioning at best,
2) the meters are not being used to charge customers, so the Town in essence is not metered, so there is no conservation benefits or results from the existing meters,
3) the Town charges a flat rate although it desires to go to a use rate after they install properly functioning meters,
4) the existing nonfunctional meters dissuade consumers from conserving water,
5) unaccounted water losses are estimated to be 25 percent,
6) the Town has to pump and treat all of its water,
7) the Town will realize an immediate 15 percent savings in pumping and treatment costs when they achieve the USEPA cited goal of having no more than 10 percent unaccounted water losses,
8) the Town will realize additional electrical and treatment savings as a user based rate will prevent consumers from wasting water, and
9) the Town will utilize the proposed telemetry system as a leak detection system,

For information on this Business Case, please contact the Wyoming State Revolving Funds Program, Wyoming Department of Environmental Quality, Herschler Building 4-W, Cheyenne, WY 82002, ATTN: Brian Mark, tel. 307 777 6371, email bmark@wyo.gov

MEMORANDUM

TO: **Brian Mark, Wyoming SRF**
Rob Tompkins, Wyoming State Lands

FROM: **Chris Lidstone, PG**
Erin Reed, PE

CC: **Town of Pine Bluffs**

DATE: **April 30, 2009**

SUBJECT: **Town of Pine Bluffs DWSRF Green Project Reserve: Water Meter Replacement Project**

On behalf of the Town of Pine Bluffs, Erin and I would like to take this opportunity to present further justification that the proposed Pine Bluffs Meter Replacement Project meets or exceeds the State of Wyoming's and U.S. Environmental Protection Agency's (EPA) guidance for "Green Project Reserve." In an effort to provide setting for the Town's "Green Project" and water conservation needs, it is important that the SRF and EPA understand not just the "green" portion of the proposed project, but also how important water conservation is to the Town of Pine Bluffs.

> *The water supply problems at Pine Bluffs are not only "real" but have placed the Town in a precarious position. Tom McDonough, the Pine Bluffs Utility Director, has approached each of the last two summers concerned with the Town water system's ability to supply municipal water to their 1,144 citizens. Since Lidstone and Associates, Inc. (LA) began providing engineering services to Pine Bluffs in 1992, the Town's municipal wells have experienced a 30 foot decline. Nearly 20 feet of this decline has occurred over the last 8 years. This water table decline is well documented in the Wyoming Water Development Commission (WWDC) funded Laramie County Aquifer Study (2008). During this same period in time, well production from the Town's principal well (Well No. 6) decreased from a sustainable yield ranging from 700-1000 gpm (2002) to less than 200 gpm in 2008. Overall and since 2002, the Town of Pine Bluffs has lost over 50% of their well production capacity and has completely lost two supply wells.*
>
> *In response to the water supply problems, the Town has implemented mandatory water conservation and has placed citizens on continuous water restrictions since 2006. Due to the inaccuracy of their distribution meter records, the Town's water conservation options are limited to alternating watering days and restricting hours for allowed lawn watering. The Town accurately believes that a use-based conservation water billing approach in addition to their existing water restrictions will be significantly more effective. Under the auspices of the WWDC, they have contracted with JR Engineering and LA to develop a use-based water conservation billing schedule. This schedule can not be implemented unless the Town can accurately measure residential water use. Based on the Town's efforts to rectify transmission line meters*

with their outdated distribution meters and unmetered public services, (i.e. the current metering system, which will be replaced under this project) may be off by as much as 25%. The EPA identifies a water industry goal for unaccounted water at less than 10%. The Town of Pine Bluffs' unaccounted water is significantly higher than the EPA goal. Until they are able to accurately account for the system's water use, the Town's water conservation efforts will continue to be severely hampered.

In an effort to maintain the EPA format, I would like to present my summary findings including our "Business Case" as follows:

Water Efficiency:

- Existing meters are over 30 years old and cannot be accurately read. Because they are neither accurate nor consistent, individual consumers cannot be charged on a "use basis." Because of the Town's severe water supply problems, ***water conservation*** is very important. Without funds to support a meter replacement program, the only enforceable water conservation alternative available to the Town is restricted "hours and days for allowable lawn watering."
- Approximately 80% of the Town's service line water meters are in the basements of homes or businesses and as such do not measure leaks in service lines. The Town estimates that between 2% and 4% of their water loss occurs along individual water service lines. This equates to a net loss of 12,000 gallons of treated water per day.
- In 2002, while replacing one single block of distribution line, the Town found that roughly 10% of the existing service lines were in "poor shape" or consisted of "outdated or unacceptable materials."
- Four major service line leaks were identified in the last 12 months, three of which were identified based on meter readings, where the meter and curb stop were in a position to identify and measure the leak:
    - 500,000 gallons at John Gross's house
    - 220,000 gallons at the Catholic Church
    - 120,000 gallons at Cliff Haukup's house
    - Unknown volume at Rich Gardner's house

  The size, nature and duration of these leaks is a reflection of the condition of individual service lines (which in many cases are over 40 years old), the need for an automated (versus manual) reporting of water use and a computer based alert system, as well as the need for a water conservation based billing system. The proposed project, if approved by the DWSRF program, would:
    - Replace all meters with a meter box located at the curbstop, where the distribution line meets the service line;
    - Replace all meters with an accurate, radio telemetry based system;
    - Allow the Town to implement a conservation based billing system;
    - Allow the consumers for a flat fee to replace their aging service line upon new meter connection;

Lidstone and Associates, Inc.
4025 Automation Way, Bldg. E —Fort Collins, CO 80525
(Phone) 970.223.4705 (FAX) 970.223.4706

- Move all meters to the street and thereby document all leaks on the service side of the connection.

Energy Efficiency

- A radio-based telemetry system for water meters will eliminate the manpower and vehicle requirements to read 535 residential and 85 commercial water meters each month. This will save both vehicle fuel and green house emissions associated with idling vehicles;
- A radio-based telemetry **(automated meter reading)** system will allow the Town to identify and fix leaks in a timely fashion. Effectively this will be a continuous and ongoing **leak detection program.** The software associated with the radio telemetry can be programmed to issue an "alert" should water usage at an individual service exceed a given amount or provide an unusual signature (such as continuous usage over a 24 hour period).
- The identification of leaks in a timely fashion will save energy for the Town both in pumping (kilowatt hours) energy, but also in treatment costs (including both pump energy and chemical costs). All chlorine is delivered to the Town and reducing the volume of chlorine by eliminating waste will reduce overall fuel and greenhouse emissions.

As mentioned previously, a WWDC Level I Study is currently underway which will evaluate long term water supply alternatives for the Town and complete a rate study. This study report, which is due for final completion in July, 2009, will provide the City Council several use-based rate schedule alternatives. However, it will be infeasible to implement any conservation based water use billing schedule if the Town cannot accurately measure residential water use. The Town of Pine Bluffs recognizes that an effective water conservation program begins with accurate water accounting and loss prevention. Given the regional decline in the Town's water supply, effective and immediate conservation is critical to the future of Pine Bluffs.

On behalf of the Town, we encourage DWSRF to view the Pine Bluffs Water Meter Replacement project as a "Green Project" or if not fundable under that category as a conventional project of similar importance as Pine Bluffs sewer replacement project. Pine Bluffs is a small town and if ARRA funding is not available, their remaining options are limited. Thank you for the opportunity to present you this memorandum.

Lidstone and Associates, Inc.
4025 Automation Way, Bldg. E — Fort Collins, CO 80525
(Phone) 970.223.4705 (FAX) 970.223.4706

Mark, Brian

From: Pinebluffs [pinebluffs@rtconnect.net]
Sent: Tuesday, June 09, 2009 10:51 PM
To: Mark, Brian
Cc: Chris Lidstone; Erin Reed
Subject: pumping costs
Attachments: Pumping Costs.xlsx

Brian,
As requested here are pumping costs for the Town of Pine Bluffs. If you need additional info please ask.
Thank you,
Cate Cundall

Town of Pine Bluffs
Pumping Costs
January 1, 2004 through May 31, 2009

Well	2004	2005	2006	2007	2008	2009	TOTAL
Water Treatment (Chlorine Tank)	2,047.80	2,047.76	1,329.47	1,863.74	2,253.41	1,376.60	10,918.78
Ball Park Well	31,873.99	21,690.02	34,494.55	25,994.74	23,297.09	12,861.63	150,212.02
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TOTAL	$105,396.81	$83,421.50	$97,355.43	$68,329.54	$91,405.03	$46,591.85	$492,500.16

Town of Pine Bluffs				
Water Meter Replacement Project				
Out of Service Meters, Lack of Meters		Estimated Replacement Costs	Total Replacement Costs[1]	Green Cost
Quantity[3]	Type			
6	Service for an Extended Period of Time)	$2,435.00	$14,610.00	$14,610.00
22	Residential Meters (Out of Service for an Extended Period of Time)	$1,300.00	$28,600.00	$28,600.00
5	Trailer Park has one meter for 5 permanent residences and several seasonal / temporary residences	$1,300.00	$6,500.00	$6,500.00
8	Currently unmetered services	$1,300.00	$10,400.00	$10,400.00
404	Residential meters that have exceeded design life[2]	$1,300.00	$525,200.00	$525,200.00
63	Commercial meters that have exceeded design life[2]	$2,435.00	$153,405.00	$153,405.00
		Sub Total	**$738,715.00**	**$738,715.00**
Automated Radio Read				
1	Radio read meter system	$268,357.00	$268,357.00	$268,357.00
		Total	**$1,007,072.00**	**$1,007,072.00**

Notes

[1] Replacement costs are for meter and pit only. Additional costs for

[2] Number of meters that have exceeded design life is based off the Town of Pine Bluffs' estimate that 80% of remaining meters were

[3] Quantities are based off best available information from the Town of Pine Bluffs' meter records and

Mark, Brian

From:	Erin Reed [elr@lidstone.com]
Sent:	Wednesday, May 06, 2009 4:01 PM
To:	Mark, Brian
Cc:	Chris Lidstone; Pinebluffs
Subject:	meters
Attachments:	WYPB106 Meter Information.xlsx

Brian,
Chris asked me to forward information to you regarding the number of Pine Bluffs water meters that are currently out of service or beyond their design life. I've attached a spreadsheet that quantifies unmetered services, broken meters, and meters that are past their design life as well as the related portion of replacement costs. The numbers are based on the best available information we have at this time. We can keep an updated tally during construction as well.
Please let me know if you need anything else.
Thanks,
Erin

Erin Reed, PE, CFM
Senior Engineer
Lidstone and Associates, Inc.
ph. 970.223.4705
fax 970.223.4706

Town of Pine Bluffs
Water Meter Replacement Project

Out of Service Meters, Lack of Meters		Estimated Replacement Costs	Total Replacement Costs[1]
Quantity[3]	Type		
6	Commercial Meters (Out of Service for an Extended Period of Time)	$2,435.00	$14,610.00
22	Residential Meters (Out of Service for an Extended Period of Time)	$1,300.00	$28,600.00
5	Trailer Park has one meter for 5 permanent residences and several seasonal / temporary residences	$1,300.00	$6,500.00
8	Currently unmetered services	$1,300.00	$10,400.00
404	Residential meters that have exceeded design life[2]	$1,300.00	$525,200.00
63	Commercial meters that have exceeded design life[2]	$2,435.00	$153,405.00
		Total	$738,715.00

Notes

[1] Replacement costs are for meter and pit only. Additional costs for radioequipment will be incurred.

[2] Number of meters that have exceeded design life is based off the Town of Pine Bluffs' estimate that 80% of remaining meters were installed in the late 1970s.

[3] Quantities are based off best available information from the Town of Pine Bluffs' meter records and maintenance experience

Does Your Water System have a Water Meter Program?
by: James Dailey

What is the purpose of a water meter? To measure and track the amount of water delivered through a distribution system. More importantly a water meter registers the amount of water delivered to a customer so an appropriate bill for that water can be charged. That charge determines the amount of revenue a system receives. The potential for revenue loss can be staggering if the system has a large number of meters significantly under-registering. Loss of revenue is more significant particularly for systems that have a high water production cost or high purchase water costs. Consideration must also be given for customer billing equity. Major differences is meter accuracy translates to unequal customer billing. A water system with a high unaccounted for water loss may have leaks or other distribution problems that must be addressed. Without accurate meters the degree of these problems cannot truly be known. The accuracy of a utilities water meters should be high priority and efforts made to maintain all meters at a high and uniform level of efficiency. An alert meter reader should be able to spot an under-registering meter by a quick comparison with past reading. Meter stoppages should be noted immediately at the time of the meter reading and scheduled replacement planned.

Why does the accuracy of a water meter diminish? A water meter like any mechanical device is subject to wear and deterioration over time. The deterioration would be accelerated by poor water quality such as corrosive or abrasive water. Water meters can register over register but this rarely occurs because wear on internal meter parts generally cause lower measurements. It can be assumed that after a certain age the inaccurracy of the meter due to deteriation becomes an economical liability.

When should a water meter be replaced? There is no study that can show or recommend the exact age when a water meters accuracy is diminished to such a degree that replacing is economical. How long water meters retain their overall accuracy depends on many factors, such as the quality of the water being passed through the meter, the rate of flow and the total quantity of water that has been measured. Various conditions that water meters are exposed to prevent any exact time frame for water meter decay due to differences in water chemical composition, temperature and humidity. Most studies do conclude residential meters should be repaired or replaced after 15 or 20 years. At this age the accuracy would have diminished to the point that the cost of meter replacement is less than loss of revenues with continued use of the meter. Residential meters the majority for any system generally cost between $30 and $40 which translates to less than $3 a year for a 15 year service period.

It is important that all water systems establish a meter program to insure that the system is able to track water production and distribution. There are essentially three levels or types of meter programs:

- A comprehensive meter testing program
- A meter testing and repair program
- A comprehensive meter replacement program

A meter testing program would consist of periodically testing meters within the system to determine their accuracy. The meter testing would be based on meter age, meter use, water quality, cost of testing and water revenue loss. Older meters and those carrying the largest volumes should be given the highest priority. Small meters should be tested once every five to ten years. Larger meters every one to five years. In theory new meter should be tested before installation although only a fraction of utilities perform such tests. Meters have an inherent variation of 2 to 3 percent in registration over the entire range of flows, except very low flows just above those that the meter will not register. Meters are to be considered to be satisfactory if measurements are 95% accurate at low flows and 98.5 % accurate during normal flows. Those meters that fall outside of these ranges should be serviced or replaced. Establishing a meter testing program is often difficult, as it involves repetitive testing and manpower. Obviously the only way to determine whether a specific meter is operating efficiently is to test it. Probably no phase of water utility operation has been handled in so many different ways as that of testing water meters. There have been no nationally recognized water meter testing procedures however accuracy requirements are contained in the various AWWA meter standards and these standards have been widely used as a basis for establishing individual testing methods.

Repairing meters is an option that may be economical for larger systems that have the equipment and expertise for such a program. Meter repair work is not considered acceptable if repaired meters do not register 90 percent on the test. Most modern meters have sealed registers and easily changed measuring chambers. These meters are usually maintained and repaired by the utility. Older style meter with heads that must be worked on should be returned to the manufacturer for maintenance and repair if they are not to be replaced.

A meter replacement program is generally the best and most cost effective method for smaller systems due to the lack of manpower, equipment and expertise. An initial service period must first be established. This period may be 20, 15 or even 10 years. Once the service period is reached the meters are replaced with new meters creating a reasonable economic balance between the cost of replacing the meter versus loss of revenue incurred with continued use of the old meter. It is obviously economical if the cost of the replacing a meter is less than the loss of revenue that would occur it the meters were to be used longer than there established service period. Essentially the meter program would more than pay for itself.

A comprehensive meter program not only benefits the system creating a more efficient operation but allows the system to maintain the lowest possible water rates.

Mark, Brian

From: Chuck Bartlett [chuck@saratogawyo.org]
Sent: Thursday, June 18, 2009 4:12 PM
To: Mark, Brian
Subject: Town of Saratoga

Sorry for the delay in getting this information to you.

From review of the water records for the past few months, the following is a tabulation of metered water usage with 20% water loss and Town unmetered usage, amount of water pumped and electric cost (total and per 1,000 gallons)

MONTH	WATER USAGE	WATER PUMPED	ELECTRIC COSTS TOTAL	PER 1000 GALLONS
JANUARY	4,605,600	6,272,952	2,950.37	.47
FEBRUARY	4,482,000	6,651,891	1,833.72	.275
MARCH	6,252,800	8,601,745	2,161.41	.251

Unaccounted for water, believed to be from meters, ranges from 26 to 32% of the total pumped water.

Mark, Brian

From:	Gary Steele [gary@pmpc-eng.com]
Sent:	Thursday, April 30, 2009 3:11 PM
To:	Mark, Brian
Subject:	RE: green project resrve business case

Brian: I apologize for the delay in getting back to you on this issue but I have been waiting for information from the Town. Based upon the information provided by the Town the meters were installed in the mid 1970's and have outlived their useful life. The meters do no measure the water accurately and they are so old that it is difficult to find parts to fix or replace the existing meters. As the meters get older they tend to loose their accuracy in measuring low flows.

Last January the Town switched from treated surface water to a groundwater supply with wells and a transmission line. The water treatment plant had a master meter that utilized an orifice plate for measuring the amount of water produced from the plant. Shortly after the wells were put on line we evaluated the water usage and compared it to the information from the meter at the water treatment plant and determined that the Town is utilizing approximately 34% more water than what was being recorded with the old meter.

In 2006 the Town was having difficulty with their water treatment plant and the residences were under water restriction to reduce water consumption to a level that could be maintained by the plant. During that time the Town identified that approximately 9,000,000 gallons of water could not be accounted for in the system. The Town also believes that during a given year they are loosing 20% to 25% of their water because meters are not reading usage correctly.

In regards to your question about the water rates included 7,000 gallons of water in their base rate I spoke with the Town Engineer and did some research. The Town indicated that the 7,000 gallons has been included in their base rate for many years, but that they are looking at it and discussing the possibility of reducing it. I also looked at my use for the summer of last year and for the months of June, July and August I used 11,000, 15,000 and 23,000 gallons respectively. I have an average size yard and so during the irrigation season people are seeing higher bills thus paying more.

The green aspect to the project is that through an accurate metering system the town will be able to track water usage accurately and thus bill for the actual amount of water used which will in turn cause people to use less so their monthly bills are less. The system will also give the Town the ability to compare the amount of water supplied to the system with the amount billed to customers so system leakages can be identified. The newer meters can also help identify system leaks in the service lines after the meter.

Accurately measuring water will create conservation through higher costs to the user and earlier leak detection conserves considerable water loss to the system. Reduced water loss and reduced usage through conservation means less costs for pumping from the wells and less water taken from the environment.

I hope this helps and if you need anything else please let me know.

Gary Steele

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Determining the Economical Optimum Life of Residential Water Meters

Terms & Conditions of Use

Detection

When should you replace a water meter? A methodology for the calculation of this optimum age is presented.

- Dr. Hans D. Allender, P.E.

When should you replace a water meter? This question has become an evasive one for many Utilities that have to make this decision. On the basis of these meter readings, Utilities assess their water and wastewater customers with the corresponding consumption fees. Therefore, these fees, dictated by the meter's recordings, become the main source of income for the majority of Utilities.

The assumption that aging makes water meters become less accurate, leads to the hypothesis that revenues are lost because the consumption of water is not completely recorded. However, replacing water meters that are still providing accurate recordings is a waste of resources and an additional economic burden for the Utilities. Between these two economically opposing tendencies, there is a point that economically justifies the cost of meter replacement. The central objective of this article is to provide a methodology for the calculation of the economic optimum age for meter replacement.

This study concentrates in finding the economic optimum replacement time of non-commercial water meters. Data in this study applies to Anne Arundel County (Maryland) and is presented as an example. However, the methodology used can be adapted to any other Agency. In addition, as a secondary objective and in order to find the optimum, this study proves the assumption that water meters actually decay with age, losing their recording capabilities.

After reviewing the latest literature on water meter replacement, it was concluded that no current study recommends the proper age for water meter replacement. Water meter life expectancy, as given by manufacturers, only offers the estimated time the water meter can function (mostly for guarantee purposes). However, it does not offer any analysis of the progressive decay of the meter's recording capabilities. Other studies point out the tremendous variations of conditions that water meters are exposed to in different parts of the country. These multiple conditions, ranging from chemical composition of the water, to variation of temperature and humidity, prevent any universal study on the decay of water meter recording capability to be successful. Therefore, the analysis has to focus on zones or districts with identical conditions.

Sample

The first step in the process aimed at producing a sample, for statistical analysis, of the local water meters. The analysis will yield a correlation of the misreading factor with age. Given the number of meters in the zone under analysis and to minimize sampling size while obtaining representative groups, the following experiment was designed. Eight (8) water meters per age group and four (4) age groups were tested by qualified technicians in the Norman Test Bench at the Meter Shop. The four age groups specified were 15, 20, 25 and 30 years-old. With the total sample size being 32 meters (eight water meters in four age groups), each water meter was tested at three levels of flow intensity: low flow (1/4 gallon per minute); intermediate flow (2 gallons per minute); and fast flow (10 gallons per minute). The results assess the fraction (%) recorded by the water meter when compared to the real amount of flow forced through it. For example, a reading of 60 percent means that the water meter did not register 40 percent of the water going through; it is only 60 percent accurate. The results from this experiment are assembled in Table 1.

The test results consistently prove that the water meter's recording capability diminishes over time. This finding is accentuated when the meter operates at a low intensity flow. The results of the test show that not only the age of water meters diminishes their recording capability, but also the way customers use water affects the readings (i.e., less accuracy at low flow v. better accuracy at high flow). This additional finding complicated the study and compelled an investigation into the way customers use water.

According to the agency's statistics, a typical household is composed of four persons and consumes about 108,000 gallons of water per year. To determine the pattern of water consumption in the area under investigation, three average four-person households were sampled. In this test, we wanted to estimate the portion of water that is consumed at low flow, intermediate flow, and high flow. At the selected households, measures of flow were taken at different outlets including instances of double or multiple simultaneous use. Table 2 shows the results of the sampling.

The different water flow for the outlets in the sample is normally distributed around a mean value. Calculation of the mean and standard deviation produced the values:

$\mu = 0.89$ GPM and $s = 0.58$ GPM

The results of the sample indicate that the average water flow consumption is 0.89 GPM with a standard deviation of 0.58 GPM. With these two parameters known, the normal distribution curve for flow intensity can be easily constructed. The graph on page 20 shows the pattern of this water consumption.

In order to cover the complete range of flow intensities, the ranges will be defined as follows:

Low Flow 0 to 0.25 GPM

Intermediate Flow 0.25 to 2 GPM

High Flow Above 2 GPM

With these parameters, the corresponding areas under the Normal curve can be calculated using the Normal Distribution Tables. These values represent the proportions of water flowing through the meters at low flow, intermediate flow, and high flow, which provides an interpretation of how the water is consumed in terms of flow intensity.

They are:

Low Flow 0 .12

Intermediate Flow 0.86

High Flow 0.02

This means that 12 percent of the water that flows through the meter flows at low speed, 86 percent at intermediate speed, and 2 percent at high speed. Combining in a single formula the pattern of water use, and the pattern of water meter reading capabilities produced by aging, it is now possible to calculate the real accuracy of the meters.

The formula is:

Real Meter Accuracy (RMA) =

MRL(pul) + MRI(pui) + MRH(puh)

Where:

MRL - Meter Reading at Low Flow as Affected by Age

MRI - Meter Reading at Intermediate Flow as Affected by Age

MRH - Meter Reading at High Flow as Affected by Age

pul - Pattern of Use at Low Flow

pui - Pattern of Use at Inter. Flow

puh - Pattern of Use at High Flow

Armed with this formula, The Real Meter Accuracy for each age group is calculated at:

Meters 15 Years Old

RAM = [(0.95)(0.12) + (1.00)(0.86) + (1.00)(0.02)] = 0.994

Meters 20 Years Old

RAM = [(0.93)(0.12) + (1.00)(0.86) + (1.00)(0.02)] = 0.990

Meters 25 Years Old

RAM = [(0.87)(0.12) + (0.97)(0.86) + (0.98)(0.02)] = 0.958

Meters 30 Years Old

RAM = [(0.35)(0.12) + (0.90)(0.86) + (0.96)(0.02)] = 0.816

A typical household uses on the average about 9,000 gallons of water per month, this according to historical data and considering the summer peak consumption. Knowing the accuracy of meters calculated previously, the gallons of water going through the meters without being recorded can be calculated by subtracting from the average consumption the result of the multiplication of the RAM (the Real Accuracy of Meters) and the average consumption.

The quantity of gallons of water that water meters do not record per month, per age group will be:

Meters 15 Years Old

9,000 Gallons - (9,000)(0.994) =

54 Gallons per month

Meters 20 Years Old

9,000 Gallons - (9,000)(0.990) =

90 Gallons per month

Meters 25 Years Old

9,000 Gallons - (9,000)(0.958) =

378 Gallons per month

Meters 30 Years Old

9,000 Gallons - (9,000)(0.816) =

1,656 Gallons per month

We can now find out the cost of these misreadings. The vast majority of customers in Anne Arundel County use both, water and wastewater services. The payment schedule in Anne Arundel County is:

First 5,000 gallons $8.82 (water) $11.58 (wastewater)

Every 1,000 gallons $1.38 (water) $2.57 (wastewater)

The combined rate for residential users is $3.95, which is the rate for water/wastewater consumption above the 5,000 gallons. Since the average household consumes well above the initial 5,000 gallons, the calculation will deal only with the rate ($3.95) that applies to every 1,000 Gallons after the initial 5,000 gallons are consumed.

The annual losses in revenue due to maintaining aging water meters are calculated for each age group at:

Meters 15 Years Old

12 x 54/1000 x $3.95 = $2.56

Meters 20 Years Old

12 x 90/1000 x $3.95 = $4.26

Meters 25 Years Old

12 x 398/1000 x $3.95 = $17.92

Meters 30 Years Old

12 x 1656/1000 x $3.95 = $78.64

These values (when assembled as a graphic of time vs. cost) produce a curve that resembles an exponential distribution but of unknown parameters. The cumulative cost of not replacing water meters can be obtained empirically from the curve for different years. For purpose of simplification, it is assumed that the misreading factor for the first 10 years of the meter's life is negligible, and from there the cost increases linearly between the values of 10 to 15 years, 15 to 20, 20 to 25, and 25 to 30 years.It is known that the cost of replacing a residential water meter in Anne Arundel County is $39.00. This cost is broken down into $34.00 for the new meter, and $5.00 for the installation cost.

Given these facts, Table 3 shows the annual cost of water meters. Under the column "Cost of Use" the annual cost due to meter inaccuracy is shown. Observe that this cost is zero the first 10 years. The column headed "Accumulated Cost" adds the "Meter Cost" ($39) and the "Cost of Use" up to that year. The last column presents the "Average Cost Per Year" and results from the quotient of the accumulated cost and the years in service.

Optimum

Finding the economically optimum year for replacement can be identified as a typical "replacement due to decreasing efficiency" problem. This methodology's objective locates the minimum average annual cost. It is based on the annual distribution of both costs (meter replacement and decreasing efficiency). In the table, developed for a span of 30 years, under the column "Average Cost Per Year" you will be able to pick the minimum annual cost and with it the year at which the meter should be replaced. Replacement at the end of year 16 will guarantee a minimum annual cost under the conditions specified in the presentation.

Despite the fact that the accuracy of a 16 year-old water meter is estimated at 0.992, replacement at this age is economically justifiable. The justification for replacement lingers on the prevention of further losses and to meter the water flow the Agency incurs in the cost of buying and installing water meters. This cost, as shown in Table 3, reaches the minimum balance with the misreading cost at the end of the 16th year. Management should decide to replace these meters at the end of year 16 (under these conditions). A significant variation in the meter installation cost or price of water, will render the numerical answer (16th year) obsolete and will demand a recalculation of the optimum life.

The value of this study rests in its methodology and not in the actual results. Even working with approximations, management can benefit from a similar study in their utility, For example, if calculations show the optimum replacement to be at the 16th year, they can decide to only replace meters older than 20 years. In the case of Anne Arundel County, it was found that by just replacing meters older than 30 years, additional revenue lost was calculated at over $201,800 per year. When comparing the potential increase in revenues and the cost of doing a similar water meter cost analysis, the keen manager will discover that the exercise presented in this paper is worth pursuing.

About the Author:

Dr. Hans D. Allender is president of "The ProducBoxTM Institute," a firm that furnishes training and management consulting services to diverse clients. As a management consultant, Dr. Allender specializes in reengineering, productivity and quality improvements under the TQM umbrella.

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Residential Water Meter Replacement Economics

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Keywords: Meter accuracy; Replacement; Economics

Abstract

This paper analyzes an important apparent water loss component of the IWA water audit methodology; namely, losses in revenue due to customer meter inaccuracy. There has been an ongoing water utility debate over which criterion to use as a guideline for small residential water meter replacement in public and private water utilities. The primary criterion has been length of field service of the water meter. Nominally, most water utilities have used a range of service between 10 and 20 years for meter replacement due to the perception of decreasing meter accuracy with length of service. Recently, meter manufacturers have included age of meter, as well as cumulative water registered by the meter, as joint criteria for their national warranty for new and repaired meter accuracy. Obviously, meter manufacturers recognize the relationship between cumulative flow through the meter and meter accuracy deterioration with wear on meter measurement components and have quantified cumulative volume warranty for new meter and repaired meter accuracy for different meter sizes. Meter manufacturer warranty is likened to a new car warranty such as the ten years or 100,000-mile power train coverage offered by competing foreign auto manufacturers.

Additionally of note, more utilities are recognizing that low initial bid should not be the sole criterion for selection of small, domestic water meters. Some utilities have adopted multiple selection criteria, including life cycle cost, where lost revenue due to meter inaccuracy is considered as accuracy reduces over the "life" of a water meter. Due to national issues of population and water demand growth, drought, increasing costs for new water supplies, increasing operational costs to achieve higher water quality standards, increasing costs to replace aging infrastructure, and the emphasis on the utility being a good steward of its water resource as an example to its customers, water meter accuracy and reduction of non-revenue water are becoming more important to water utility management and their customers.

The purpose of this paper is to present the results of multiple accuracy tests of 5/8-inch by 3/4-inch domestic residential water meters, all having the same age of field service but varying amounts of cumulative water flow through the meter. The relationship between accuracy and cumulative flow will be presented and discussed for AWWA low, medium, and high flow regimes. The economics of water meter replacement will be discussed relative to the accuracy-flow relations for the three flow test ranges, and the process for determining the economic optimum cumulative volume through the meter will be described. For the Arizona utility from which the meters tested were derived, the recommended replacement timeframe will be presented utilizing the specific average annual residential water use and water rate structure in effect. The optimum replacement volume for different utilities will vary based on water meter environment and water use. To determine optimal meter replacement based on cumulative flow, a methodology has been developed that is defensible for all water utilities which collect the required meter accuracy data and apply their own unique economic and water usage circumstances. Results for the Arizona utility are presented and described herein for the low, medium, and high accuracy test flow ranges and the resultant optimum replacement volume.

Introduction

Many water utilities face multiple challenges throughout the world, and the issue of water loss accountability and subsequent revenue recovery through meter accuracy are no exception. Water losses affect water utilities in terms of resource impacts and economic impacts. Both can be quantified through a comprehensive utility water audit, such as that sanctioned by the International Water Association (IWA) and adopted by the AWWA. This audit methodology categorizes water losses as either real or apparent. Water losses through meter inaccuracies are in the apparent water loss category. Quantifying and reducing water losses, real or apparent, are significant undertakings for many water utilities. The subject of this paper primarily deals with apparent water losses through small, residential meter inaccuracies which increase over time and cumulative volume. This paper documents the findings, conclusions, and recommendations of a multi-year data collection and domestic water meter accuracy testing process by the Metropolitan Domestic Water Improvement District Northwest of Tucson, Arizona to determine the optimum meter replacement time based on cumulative volume registered through the meter. This study focuses on results from accuracy testing of small, single-manufacturer residential water meters (5/8-inch by 3/4-inch positive displacement type) having a nominal field service life of ten years.

The Metropolitan Domestic Water Improvement District is a sole service water provider serving approximately 16,000 customers representing a population of 45,000. The District encompasses approximately 25 square miles of service area and is primarily residential with some multi-unit housing. Ninety-five percent of District meters serve residential customers. The only potable water source at this time is groundwater pumped through multiple wells.

By 1999, the District realized that unaccounted for water losses (non revenue water) were increasing annually and exceeding 10% per year, the Arizona regulatory limit. The District was faced with determining where the water losses were occurring and recognized an opportunity to potentially recover lost revenues via a meter replacement program. Since the majority of existing water mains are buried an average of 36 inches deep, real losses attributable to water main leaks typically surface and are easily detectable 90% of the time. The District was determined to focus efforts on apparent water losses, since there had never been a meter replacement program. The initial effort was to replace all small meters that were ten years of age and older, which represented approximately 50% of the existing meters in the system. These meters were identified and replaced during a period of two and one-half years. Thereafter, all 5/8 x 3/4-inch meters were anticipated to be replaced on a 10% replacement schedule, replacing a tenth of the meters per year over a ten-year period.

A primary indicator that meter replacement could be beneficial was the generation of random test results on a series of meters that had been known to be in the system longer than ten years. Those results showed dramatic inaccuracies in the water meters at multiple flow ranges. Since the inception of the meter replacement program, over 9,800 meters have been replaced through 2004, representing over 60% of the total 5/8 x 3/4-inch meters. Subsequent water measurement and revenue recovery through greater meter accuracy indicate that the program is successful. Water losses for calendar years 2003 and 2004 were reduced to 5.6% and 5.2% of total water delivery, respectively. Budget considerations for an aggressive meter replacement program must be balanced against revenue savings.

The District determined that it currently costs $45 to replace a 5/8 x 3/4-inch meter. Therefore, the District was tasked with determining the economic breakpoint at which the cumulative losses due to meter inaccuracy would economically equal the cost of the replacement program. In its initial meter replacement effort, the District recognized that ten-year-old meters had a variance of cumulative usage ranging from 300,000 to 3,000,000 gallons based on individual water use patterns. To allow the District to be more effective in its replacement program, it was felt that a cumulative flow-based meter replacement program would be more economically prudent and efficient.

Purpose of this Paper

The purpose of this paper is to document the procedures used for determining the optimum time for residential water meter replacement based on cumulative flow through the meter during service in the field, rather than length of time that the meter is in service. To determine optimal meter replacement based on cumulative flow, a methodology is developed that is defensible not only for the District, but also for all other water utilities having interest in collecting the required data, applying their own unique economic and water usage circumstances, and determining their specific optimum meter replacement volume.

Using the methodology developed in this paper, lost revenue per year specific to the District and the cumulative dollar loss from the decreased accuracy resulting from cumulative flow volume through the meter are calculated. The cumulative loss in revenue is compared with the cost of meter replacement to determine optimum meter life in terms of cumulative flow and average length of service.

Background

Water meters serve as both yardsticks and cash registers for water-conscious modern water utilities. Not only do they provide information on water usage and help to determine potential losses in the system, but water usage as recorded through meters is the basis for water user fees and the majority of a utility's recurring revenue. The District relies heavily on accurate monthly water usage as measured by its small residential water meters. Inaccuracies in water meter readings mean a loss of revenue for the District. Meter inaccuracy also results in apparent losses affecting total Non-Revenue Water (NRW) calculation in a standard water audit and reported total losses to the Arizona Department of Water Resources (ADWR) in the required annual report. Higher utility water loss affects customer confidence in the utility and credibility during times of drought and requests for individual customer water conservation. Many states, including Arizona, are legislating audit requirements and setting limits on allowable Non-Revenue Water. Meter accuracy is, therefore, an ongoing concern of many water utilities, and strategically replacing meters to optimize revenue is of key importance.

For many years, utilities and water professional researchers have been trying to determine the optimum time for meter replacement with no conclusive answer. The evaluation described herein proposes meter replacement when the cumulative revenue lost due to meter inaccuracy exceeds the amount it costs to replace the meter. Cumulative revenue loss depends on change in meter accuracy over the service life of a meter. Factors such as water quality and specific meter characteristics contribute to the degradation and loss of accuracy of the water meter over time in service. Many of the studies and articles previously published attempting to determine the optimum life of a residential water meter focus primarily on a direct correlation between the loss of accuracy and time.

The evaluation described herein seeks to statistically correlate meter accuracy and cumulative volume through the meter as the determinant of the optimum meter replacement criterion. If, in fact, it is cumulative flow rather than time that affects meter accuracy, then this would explain why there is no definitive utility standard time for meter replacement. Each utility has a unique set of water usage patterns, water quality, and environmental conditions which impact the degradation and accuracy of their various water meters. Armed with this hypothesis, the District conducted tests and provided multiple meter accuracy data sets and results from time-of-day residential meter flow readings for in-depth analyses. This study demonstrates that cumulative flow rather than time is the primary factor affecting residential water meter accuracy. The cumulative flow method accounts for the specific water use conditions for various utilities and can be utilized by any water utility collecting the relevant data.

Study Assumptions and Criteria

The following assumptions and criteria provide the basis for the technical portion of this study:

- All meters tested were 5/8"x 3/4" positive displacement residential water meters.
- Accuracy at zero cumulative flow is assumed to be 100% at low, medium, and high test flow rates.
- Trend lines (linear best data fit) are used to statistically normalize meter accuracy versus cumulative flow test data for each test flow rate.
- Meter test accuracies measuring below 10% and above 102% were assumed to be "bad data" and were purged from the database.
- Meter accuracy testing was conducted by a limited number of trained District staff using its own in-house designed, constructed, calibrated, and operated testing bench.
- Cumulative flow was assumed as measured in actual field service by the individual water meters.
- Time in service is based on the dates the meter was installed and subsequently removed from the field. For the single meter manufacturer analyzed in this study, the meter number depicts the year of manufacture.
- The average service life of the meters tested for accuracy in the large-sized database, which serves as the primary database, is ten years.
- The meter life for the meters tested used for the smaller-sized databases, for trending only, varies between two and eleven years.

Data Collection

Multiple data types are required for this evaluation, including: meter accuracy tests with low, medium, and high flows for meters with the same nominal service life; meter accuracy tests with low, medium, and high flows for meters removed from system service regardless of service life; percentage of time residential customers use water at the low, medium, and high flow rates by season; nominal residential meter replacement cost; annual average residential water use per customer; and residential water rates.

A large-sized database of water meter accuracy tests was provided by District staff to Malcolm Pirnie for analysis in Microsoft Excel format. The large database consisted of typical 5/8-inch by 3/4-inch meters manufactured by a single manufacturer and placed in service in 1993. One thousand five hundred sixteen (1,516) meters were removed from the District water system over a three-year period and tested for accuracy.

The average nominal service life for these meters is ten years. The meters were tested within several days of their removal by a limited number of trained District staff using its own in-house designed, constructed, calibrated, and operated testing bench. Accuracy tests were conducted at low, medium, and high flows as established by AWWA Water Meter testing standards for this size meter. Test flows are defined as shown in Table 1 below.

Table 1: AWWA 5/8-inch by 3/4-inch Water Meter Testing Standards

Flow	Defined Flow Range	Test Flow Rate
Low	0 – 0.25 gpm	0.25 gpm
Medium	0.25 – 2 gpm	2 gpm
High	2 – 15 gpm	15 gpm

A meter accuracy results database was set up, and data were recorded. Recorded data included the date the meter was removed from the system, meter number, cumulative flow as recorded on the meter, meter size, and the tested accuracy at low, medium, and high flows. An additional element of data collection and analysis involved evaluating the percentage of time meters within the system operate at the various flow ranges. This data is relevant, since meter accuracy changes with flow rate through the meter. District staff installed seven-day flow recorders on selected residences during each of the four seasons as defined in the table below. A summary of the "Meter-Master" time-of day flow range results can be found in Table 2 below, entitled *Percentage of Residential Flow by Season*. This summary shows the average percentage of time that selected households operate at the various low, medium, and high flow ranges by season. Also included is the number of meters measured for each season. The Meter-Master database includes 132 customers with measured flow at the low, medium, and high flow rates. Water use by residential customers in the three flow ranges varies by season, but the low flow usage varies the least of the three ranges. Higher flow variation exists in the medium and high flow ranges.

Table 2: Percentage of Residential Flow by Season

Seasons	Percentage of Time				Total Percentage	Number of Meters Counted
	Low Flow	Med Flow	High Flow			
	0 - 0.25 gpm	0.25 - 2 gpm	2-15+ gpm			
Spring	13.9	19.0	67.1		100.0	27
Summer	10.5	16.0	73.4		100.0	48
Fall	11.5	25.3	63.3		100.0	30
Winter	7.8	33.6	58.6		100.0	27
Annual Weighted Average	10.87	22.31	66.81		100.0	132

Figure 1, Percent Variation in Water Use by Season, shows a graphical representation of this seasonal data. But, more importantly, the annual weighted average at which the sampled residential customers use water within a given flow range is an essential factor in estimating meter replacement.

For this database, 10.87 percent of the total measured flow was used at the low flow range, 22.31 percent was used at the medium flow range, and 66.81 percent was used at the high flow range. It is important to note that typical District residential customers use most water at the medium and high flow rates, for which water meters typically have higher accuracy. As will be shown below in the analysis section of this paper, it is the low flow percentage that drives lost revenue due to meter inaccuracy and, thus, the optimum meter replacement criterion.

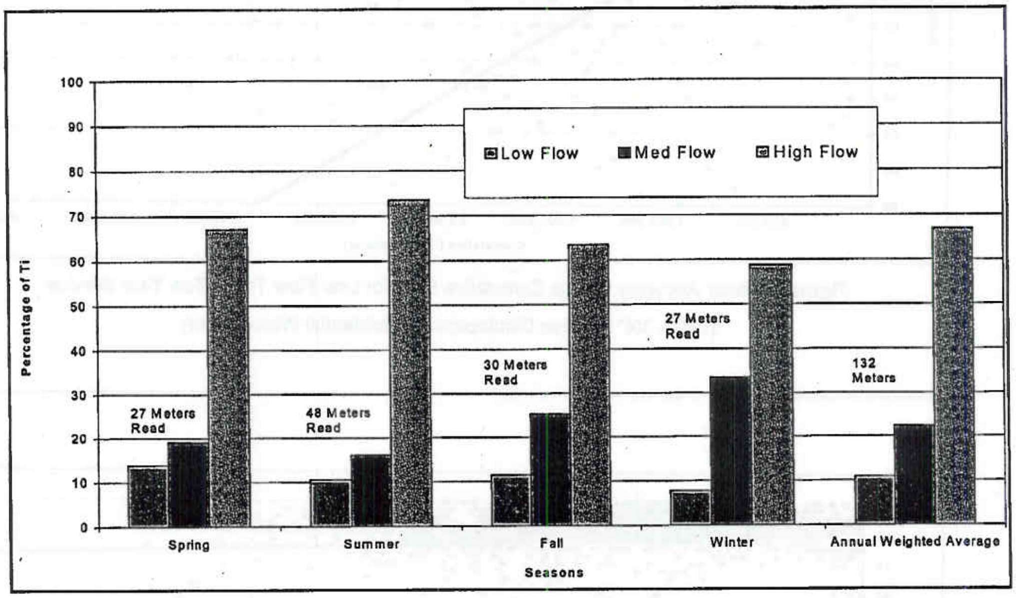

Figure 1: Percent Variation in Water Use by Season (Percentage of Time versus Seasons)

Analysis of Meter Accuracy Tests

The single manufacturer database was analyzed for completeness and reasonableness of accuracy test results. With the ten-year average service life data collected in one large database, the data were reviewed and screened. Accuracy tests not having all test ranges were eliminated. All accuracy test readings below ten percent and above one hundred two percent were assumed faulty readings and were purged from the database, leaving a total of one thousand two hundred ninety-seven (1,297) data points for each of the low, medium, and high flow test ranges.

Once the database was screened, a data plot of cumulative flow versus accuracy for each of the low, medium, and high flows was produced. Figures 2, 3, and 4 indicate data results of accuracy versus cumulative flow for the large database at low, medium, and high test flow rates, respectively. Data indicates higher scatter for the low flow test, as expected, and lesser scatter for the medium and high flow test rates. Also indicated on the plots are Microsoft Excel-calculated trend lines indicating best linear fit. The slope of the trend line was used as the normalized indicator of the decrease in meter accuracy for a specific flow range with increasing cumulative flow volume measured by the meters.

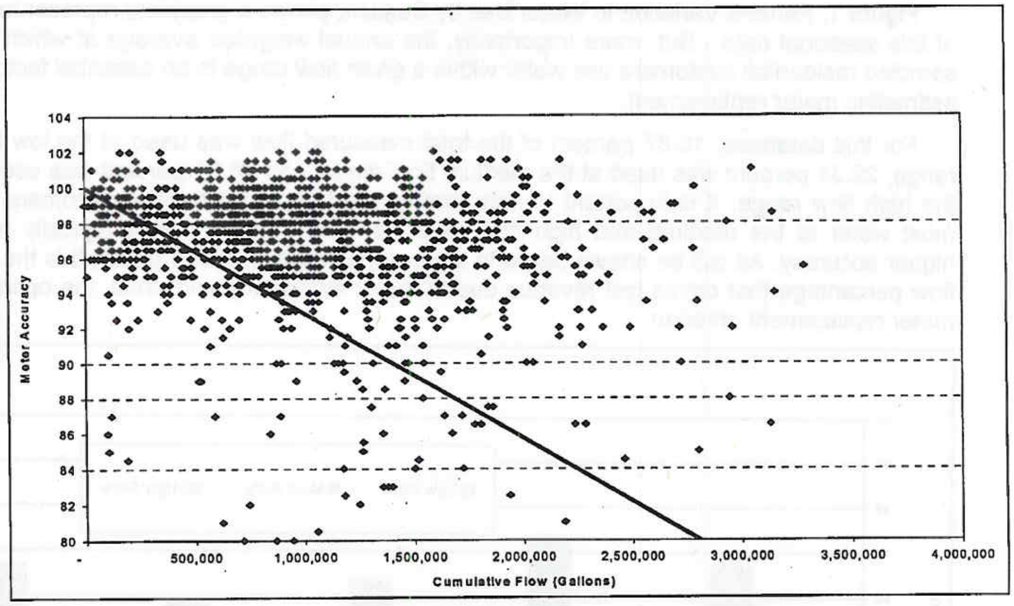

Figure 2: Meter Accuracy versus Cumulative Flow for Low Flow Tests -Ten Year Service (5/8" x 3/4" Positive Displacement Residential Water Meter)

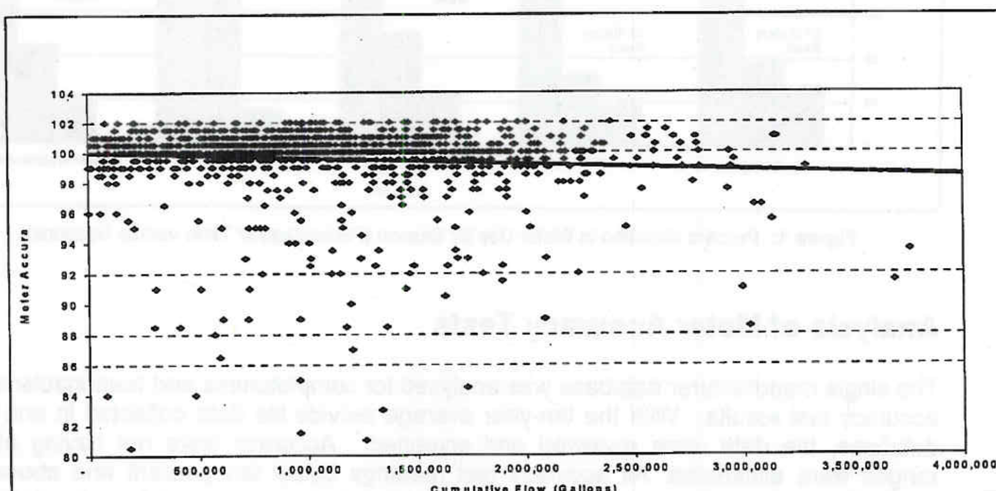

Figure 3: Meter Accuracy versus Cumulative Flow for Medium Flow Tests-Ten Year Service (5/8" x 3/4" Positive Displacement Residential Water Meter)

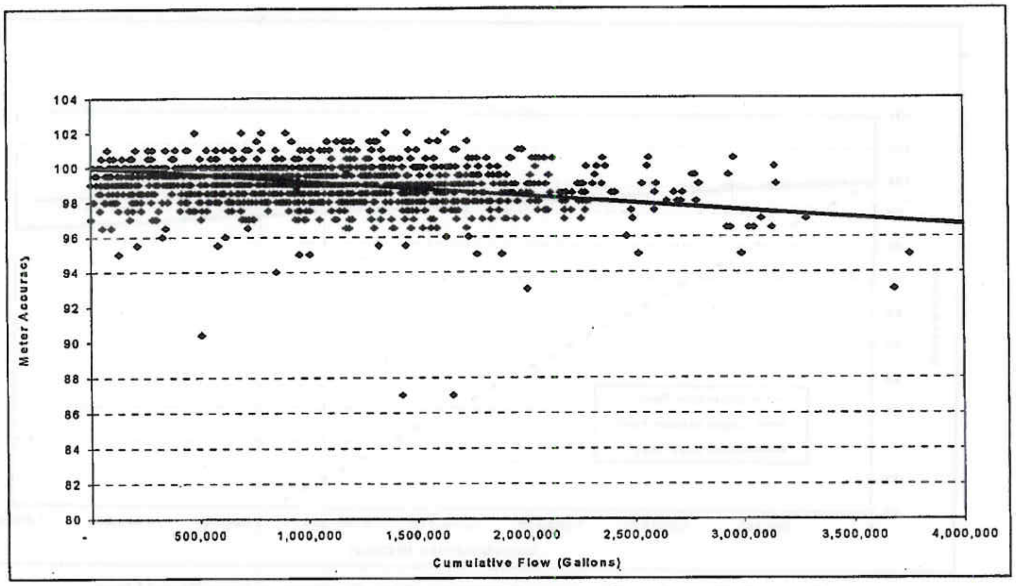

Figure 4: Meter Accuracy versus Cumulative Flow for High Flow Tests-Ten Year Service (5/8" x 3/4" Positive Displacement Residential Water Meter

Figure 5, *Meter Accuracy versus Cumulative Flow-Summary of Trend Lines,* indicates comparative plotted results for the three test flow ranges. With service life of the meter held constant at ten years to remove age as a variable, Figure 5 clearly reveals that, as total cumulative flow volume increases, the meter accuracy decreases. This is not an unusual concept, since it is documented in water meter manufacturer warranties, and AWWA publications state that "*Registration curves of water meters show that meters in good operating condition follow a general pattern of registration. Above the very low flows that the meter will not register there is an intermediate point of maximum registration. Above and below this point, lower registration is obtained*". Figure 5 shows that the maximum "registration curve" or "the least decrease" of accuracy with the accumulation of flow volume is the medium flow range. What is noteworthy with this analysis is the impact that the low flow water use rates have on meter accuracy as cumulative flow volume increases. This substantial decrease in accuracy with increasing cumulative volume appears to be the primary factor that ultimately drives the need for meter replacement.

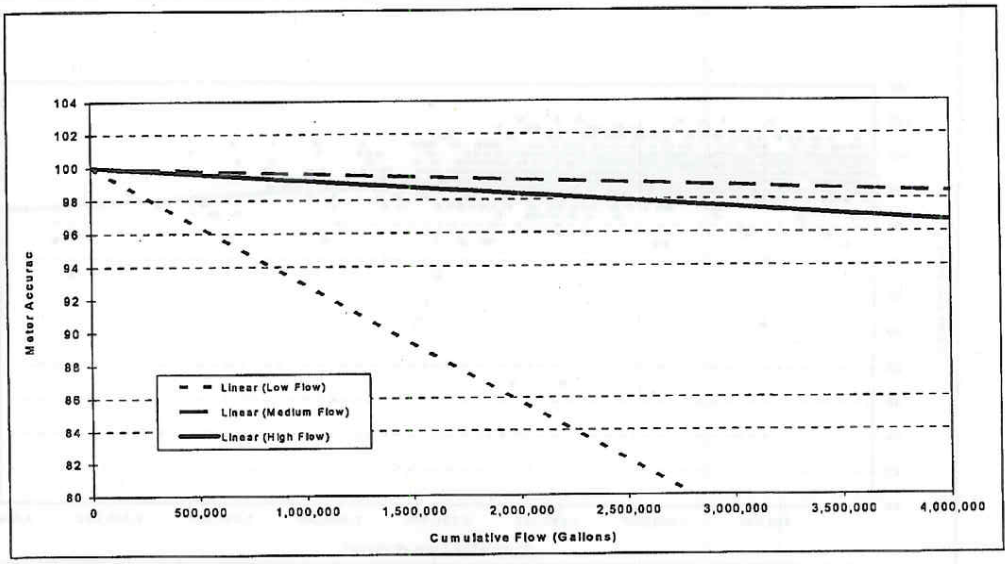

Figure 5: Meter Accuracy versus Cumulative Flow-Summary of Data Trend Lines (Ten Year Average Service - Low/Medium/High Flow)

Revenue Lost Due to Meter Inaccuracy

The average residential water use per customer for the Metropolitan Domestic Water Improvement District system is 130,000 gallons per year. Using this average, the total number of years to accumulate metered volumes in 500,000-gallon increments was calculated. The average accuracies at each of the cumulative flow volumes (in increments of 500,000 gallons) are calculated from the trend lines for the low, medium, and high flow test ranges as shown in Figure 5. The average annual weighted average for the percentage of time the average residential customer uses water at the low, medium and high flow rates combined with the current District average residential water bill of $33.56 per month were used to calculate the dollars lost per year due to increasing meter inaccuracy.

By plotting the total dollars lost per year versus the total number of calculated years, as calculated from total cumulative volume, and summing the area under the curve, the total cumulative lost revenue is calculated, as indicated on Figure 6, *Lost Revenue versus Cumulative Flow*. With the District's existing cost of meter replacement, the optimum cumulative volume for meter replacement for the District was calculated at 1,420,000 gallons.

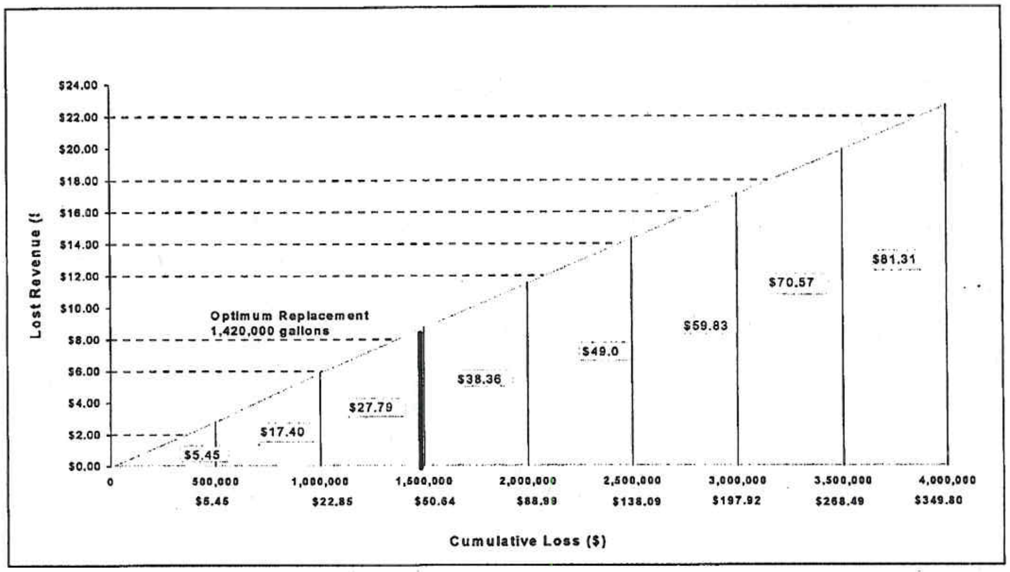

Figure 6: Lost Revenue versus Cumulative Flow

(5/8" x 3/4" Positive Displacement Residential Water Meter)

Summary of Approach

The following steps present a simplified approach for determining optimal meter replacement based on cumulative flow through a typical 5/8 x 3/4-inch residential water meter:

1. Collect time-of-day instantaneous flow measurements for a representative sample of residential water customers to determine average percentage of flow used at the low, medium, and high flow ranges.
2. Conduct meter accuracy testing of 5/8 X 3/4- inch meters pulled from the utility system at the low, medium, and high flow test ranges noting cumulative volume and length of time in service.
3. Plot meter accuracy versus cumulative volume for individual low, medium, and high test flow rates. Determine the best linear fit of the data.
4. Based on Step 1 and Step 3 results, calculate the weighted meter accuracy versus cumulative volume.
5. Based on Step 4 results, calculate lost revenue per year versus cumulative volume.
6. Sum lost revenue versus cumulative volume and compare with utility's economic cost to replace the water meter. The amount where cost and value of lost revenue are equivalent indicates the optimum cumulative volume for meter replacement.

This paper clearly demonstrates that cumulative flow volume of the meter combined with the percentage of average water used by residential customers at low flow levels within the District is the driving factor for meter replacement. Prior to this study, the District was replacing meters every ten years independent of volume, but has now officially adopted a cumulative volume-based program of 1.42 MG for all small meters.