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June 28, 2011

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Public Service Commission
211 Sower Boulevard
P.O. Box 615
Frankfort, KY 40602-0615

RE: Joint Applicants: Warren County Water District, Simpson County Water District and Butler County Water System, Inc.

This firm represents the Joint Applicants, Warren County Water District, Simpson County Water District and Butler County Water System, Inc. I enclose an original and eleven (11) additional copies of a Joint Application for your consideration. Please let me know of any additional information or corrections you may require.

Very truly yours,

COLE & MOORE, P.S.C.

Frank Hampton Moore, Jr.

FHMJR/cle
Enclsoures
cc: Mr. Alan Vilines

COMMONWEALTH OF KENTUCKY

BEFORE THE PUBLIC SERVICE COMMISSION

In the Matter of:

THE JOINT APPLICATION OF WARREN COUNTY WATER DISTRICT, SIMPSON COUNTY WATER DISTRICT AND BUTLER COUNTY WATER SYSTEM, INC. FOR A DEVIATION FROM APPROVED METER TESTING PROGRAM	)))))	CASE NO. _____

JOINT APPLICATION

1. In Case No. 1997-00434, the Public Service Commission ("Commission") authorized Warren County Water District, Simpson County Water District, and Butler County Water System, Inc. ("applicants"), to deviate from Administrative Regulation 807 KAR 5:066, Section 16(1), and to implement a meter testing and replacement program that permits 5/8 x 3/4-inch meters to remain in service without testing for 13 years. Administrative Regulation 807 KAR 5:066, Section 16(1), requires that a water utility periodically test 5/8 x 3/4-inch meters so that no meters remains in service without testing for 10 years.

2. On October 6, 2003, Applicants made a written request/application for permission to deviate from the approved program. In Case No. 2003-000391, the Commission approved the Applicants request to amend their approved meter testing and replacement program and permitted the Applicants to establish a sample group of SRII meters for each year of manufacture from 1990 to 1997 that would remain in service beyond 13 years of age with a report of the testing results provided to the Commission.

3. The Applicants incorporate the record contained in Case Numbers 1997-00434 and 2003-000391 as if here copied in full.

4. In this application, the Applicants now file their Revised Determination of Cost-Effective Meter Testing Frequency" dated May 16, 2011. Pursuant to KRS 278.210, Section 1(4), the Applicants demonstrate that no statistically significant number of its meters over-register above the limits set out in Subsection (3) of KRS 278.210. In fact, not a single one of the meters in the sample group tested registered above the limits set out in Subsection (3) of KRS 278.210.

5. Based upon established scientific, engineering, and economic methods, the Applicants have determined that the Cost-Effective Periodic Meter Testing Frequency for the subject utilities is 21 years. Consequently, it is petitioned that these utilities be permitted to implement the meter testing and replacement program outlined below:

Proposed Meter Testing and Replacement Program

a. No meters will remain in service past 21 years of age.

b. Meters will be removed after they have been in service for 21 years and replaced with new or rebuilt meters.

c. A random sample of meters that have been in service 21 years will be tested each year to determine if the actual meter accuracy of that group is statistically consistent with the cost-effective meter accuracy.

d. Meters removed at 21 years will be sold, if not rebuilt.

6. The Applicants incorporate herein, as if copied in full, the "Revised Determination of Cost-Effective Meter Testing Frequency" dated May 16, 2011 and attached hereto as an Exhibit.

WHEREFORE, the Applicants ask that the Public Service Commission of the Commonwealth of Kentucky make its Order authorizing Applicants, Warren County

Water District, Simpson County Water District, and Butler County Water System, Inc. to implement the meter testing and replacement program described in paragraph 4 a-d above.

DATED at Bowling Green, Kentucky, this 27th day of June, 2011.

Warren County Water District
523 U.S. Hwy 31-W Bypass
Bowling Green, KY 42101

Simpson County Water District
108 Morgantown Road
Franklin, KY 42134

Butler County Water System, Inc.
104 S. Tyler Street
Morgantown, KY 42261

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921 College Street - Phoenix Place
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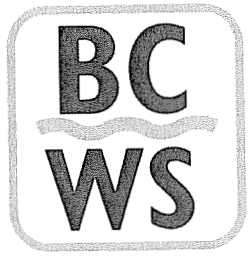
BY: _____
Frank Hampton Moore, Jr.
Attorney for the Applicants

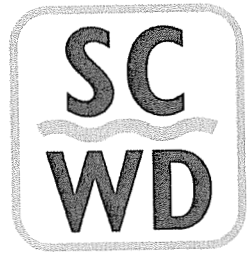
REVISED DETERMINATION OF COST-EFFECTIVE METER TESTING FREQUENCY

May 16, 2011

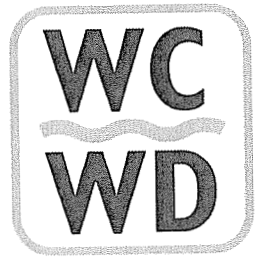
Butler County Water System, Inc.
Simpson County Water District
Warren County Water District



Butler County
Water System



Simpson County
Water District



Warren County
Water District

Prepared by:
Engineering Staff
Butler, Simpson, Warren Water Districts

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INTRODUCTION

On October 17, 1997 Butler County Water System, Inc., Simpson County Water District, and Warren County Water District (the systems), along with Grayson County Water District, filed a joint Application to the Kentucky Public Service Commission (PSC) regarding testing of 5/8 x 3/4-inch water meters. This Application proposed to deviate from the meter testing interval set forth in 807 KAR 5:066 Section 16(1). The Application was assigned Case No. 97-00434. On April 7, 1999 the systems filed a Supplemental Memorandum in Support of Joint Application and Request for Informal Conference. This filing contained a report titled *Determination of Cost-Effective Meter Testing Frequency,* dated February 1, 1999. In its Order dated April 28, 1999, The PSC granted a deviation from 807 KAR 5:066, Section 16(1) contingent on adherence to the Meter Testing and Replacement Program set forth in said report and outlined below:

Existing Meter Testing and Replacement Program

1. *No meters will remain in service past 13 years of age.*
2. *All meters in service in the water systems will be covered by the manufacturer's 15-year warranty.*
3. *Meters will be removed after they have been in service for 13 years and replaced with a new or rebuilt meter with a new 15-year warranty.*
4. *Meters removed at age 13 will be tested, but will not be returned to service.*

In October 2003 the systems filed an application with the PSC for a Deviation from Approved Meter Testing and Replacement Program. This Application was assigned Case No. 2003-00391. The Request stated that the analysis associated with the meter testing program approved in PSC Case No. 97-00434 was based on the Sensus (formerly Rockwell, then Sensus, then Invensys) Model SR meter. All meters purchased for the systems since 1986 were Sensus Model SRII meters. The SRII meter incorporates features which allows it to maintain higher accuracies for a longer period of time compared to the SR meter. The application proposed, in part, to allow a sample group of SRII meters to remain in service for up to 20 years, at which time the meters would be tested. This testing was to be conducted in 2010; the results of which would

allow the determination of a new cost-effective program for SRII meters. On January 31, 2005 the PSC issued an Order which granted approval for this portion of the application.

The purpose of this report is to summarize the results of sample testing meters up to 20 years of age and recommend an ongoing, cost-effective meter testing and replacement program for 5/8 x 3/4-inch SRII meters.

SUMMARY AND CONCLUSIONS

This study is based on the provisions of KRS 278.210, Section 1(4), which states:

> *If a utility demonstrates through sample testing that no statistically significant number of its meters over-register above the limits set out in subsection (3) of this section, the meter testing frequency shall be that which is determined by the utility to be cost effective. This determination by the utility shall be based on established scientific, engineering, and economic methods and shall be documented in an application properly filed with the commission.*

A cost-effective program is one that is "economical in terms of tangible benefits produced by money spent".[1] Therefore, a meter testing program is cost-effective "when the increased return in revenue brought about by meter testing and replacement equals or exceeds the cost of testing and replacement".[2]

The data presented in this report shows that no statistically significant number of meters over-register. In fact, not a single one of the meters in the sample groups tested for this study registered above the limits set out in Subsection (3) of KRS 278.210.

Based on established scientific, engineering, and economic methods, this study has determined that the cost-effective periodic meter testing frequency for the subject utilities is 21 years. It is recommended that these utilities implement the meter testing and replacement program outlined below.

Proposed Meter Testing and Replacement Program

1. No meters will remain in service past 21 years of age.
2. Meters will be removed after they have been in service for 21 years and replaced with a new or rebuilt meter.
3. A random sample of meters that have been in service 21 years will be tested each year to determine if the actual meter accuracy of that group is statistically consistent with the cost-effective meter accuracy.
4. Meters removed at 21 years will be sold, if not rebuilt.

NO SIGNIFICANT OVER REGISTRATION

Subsection (4) of KRS 278.210, Section 1 includes a condition that must be met for a cost-effective program to be considered. The utility must demonstrate "through sample testing that no statistically significant number of its meters over-register above the limits set out in subsection (3)" of Section 1. The limits stated in Subsection (3) are "to the extent of more than two percent (2%) to the disadvantage of the patron."

Appendix A includes data from sample testing performed for this study. This data shows that none of the meters in any of the sample groups over-register above two percent to the disadvantage of the patron (meter accuracy greater than 102%). Therefore, it is clear that the meters in the subject water systems do comply with KRS 278.210, Section 1(4) in that the meters do not over-register above the limits in Subsection (3).

DETERMINATION OF COST-EFFECTIVE TESTING FREQUENCY

General

Because of "the relatively high costs of pulling, testing, repairing and replacing [residential meters], ... it is possible to spend too much on a meter maintenance program. Too frequent testing may result in spending more money on the meter maintenance program than is recovered in terms of the value of water formerly lost through inaccurate meters. On the other hand, spending too little on a meter maintenance program, and therefore testing meters too infrequently, can result in large revenue losses due to excessive under-registration of the meters in service."[3] "The time to restore meter efficiency is when the cost of meter repair or replacement is equal to

the loss in revenue from the under-registration if such work isn't done."[4] The objective of this study is to determine the meter age at which the costs for the maintenance program are offset by the water sales revenue increase achieved by the program. A program designed with this objective is said to be cost-effective.

Water Use Profile

Residential water customers use water within a range of flow rates from a fraction of a gallon per minute (gpm) to 15 gpm. This is an important fact because the accuracy of water meters can vary substantially within that range of flow rates. In order to estimate the percentage of the total volume of water consumed that actually registers on a meter, the portion of usage at low, medium, and high flow rates must be known. This consumption information is called the domestic water use profile.

To determine the water use profile for customers in the subject water systems special recording equipment was installed at 18 residences. This equipment (called a Meter Master) was installed at each location for approximately one week. Data collected by the Meter Master was downloaded to a PC and, using software provided with the equipment, water use profile data for each location was generated. These profiles are included as Appendix B. As shown on Table B-1, the mean values indicate that only 7.03 percent of total water consumption occurs at a low flow rate of 1/2 gpm or less. While a huge majority of consumption (87.06 percent) occurs at a medium flow rate between 1/2 and 6 gpm, only 5.91 percent of all water usage occurs at high flow rates above 6 gpm.

An extensive amount of work regarding water use profiles has been performed by the American Water Works Association (AWWA) Research Foundation and published in a 1993 report titled "Residential Water Use Patterns."[5] This research included collecting over 1,000 customer-weeks of field data in each of five cities across the United States. The work performed and the data compiled in this AWWA study was used to substantiate the data collected for the subject water systems. The water use profile determined from field measurements is determined to be statistically valid. The methodology for this determination is presented in *Determination of Cost-Effective*

Meter Testing Frequency from Case No. 1997-00434, and therefore that methodology will be used in calculations for this study. The water use profile is summarized in Table 1.

TABLE 1
Domestic Water Use Profile

Flow Rate Range (gpm)		Percentage of Total Volume Used
Low	0 – 1/2 gpm	7.03%
Medium	1/2 – 6 gpm	87.06%
High	Above 6 gpm	5.91%

Meter Accuracy Tests

In planning for this study, it was determined that with over 31,000 residential sized meters in service in the subject water systems, it would be advantageous to use a statistical sampling program. Such a program permits conclusions to be reached concerning an entire group of meters after actually testing only a small percentage of the total number in the group. Sample sizes were calculated for various age groups of meters to provide at least a 95 percent confidence level that the average meter accuracy determined in the study for each age group would be plus or minus 1 percent of the actual average accuracy of each respective group.

Eight sample groups, composed of meters that had reached 13, 14, 15, 16, 17, 18, 19, and 20 years of age were developed. The meters to be included in each sample group were selected at random from the meters which had been reserved from the existing 13-year meter test program. These meters were allowed to age such that this analysis would be possible (Reference Case No. 2003-00391). Water system personnel removed the selected meters from the various service locations and delivered them to the water systems' meter testing facility.

The meters in each group were tested at low, medium, and high flow rates in accordance with PSC regulations for "as-found tests." Tests were performed by

personnel and equipment certified by PSC. Data from these tests are listed by meter age group in Appendix A.

Results of Meter Testing

The information included in Appendix A provides details of the results of accuracy tests for each meter tested. The fifth column in each table is the Weighted Average Meter Accuracy (WAMA). The WAMA is computed as the sum of the products of a meter's low, medium, and high flow rate accuracies multiplied by the respective domestic water use profile percentage. For example, the WAMA for a meter with accuracies at low flow of 94.5 percent, medium flow of 100.5 percent and high flow of 99.8 percent would be computed as follows:

$$WAMA = \left[(94.5\% * 7.03\%) + (100.1\% * 87.06\%) + (99.7\% * 5.91\%)\right] = 99.7\%$$

The WAMA for a particular meter is not intended as a pass/fail indicator, but is a measure of the percentage of total volume of water passing through the meter that actually registers on the meter. This is very important in a cost-effective analysis because the WAMA subtracted from 100 percent is the percentage of water used, but not registering on the meters and not billed. Therefore, WAMA gives an indication of the potential revenue gain if a certain age group of meters is replaced.

The last column in the Appendix A tables is a note indicating if a meter meets PSC standards for repaired meters as identified in 807 KAR 5:066. Section 15. The accuracy results for all meters tested were compared to those standards and the word "no" placed in the last column of the table if the meter did not comply.

It should be noted that the majority of the meters that failed to meet PSC Repaired Meter Standards failed in either the high flow or low flow ranges. **Only 13% of water use occurs in these ranges.** The WAMA and percentage within repaired meter standards, averaged for each age group, is presented in Table 2.

TABLE 2
Summary of Meter Testing Results

Meter Age (Years)	Weighted Average Meter Accuracy	Meters Meeting Repaired Meter Standards
13	99.8%	96.7%
14	99.9%	96.7%
15	100.3%	100.0%
16	99.6%	95.3%
17	99.8%	94.4%
18	99.5%	82.8%
19	99.4%	77.9%
20	98.8%	60.2%

Figures 1 and 2 also present the results given in Table 2 and show the "best fit" curve for each set of results. These graphs illustrate a clear relationship between meter age and accuracy. However, even at year 20, the WAMA is relatively high at 98.8 percent.

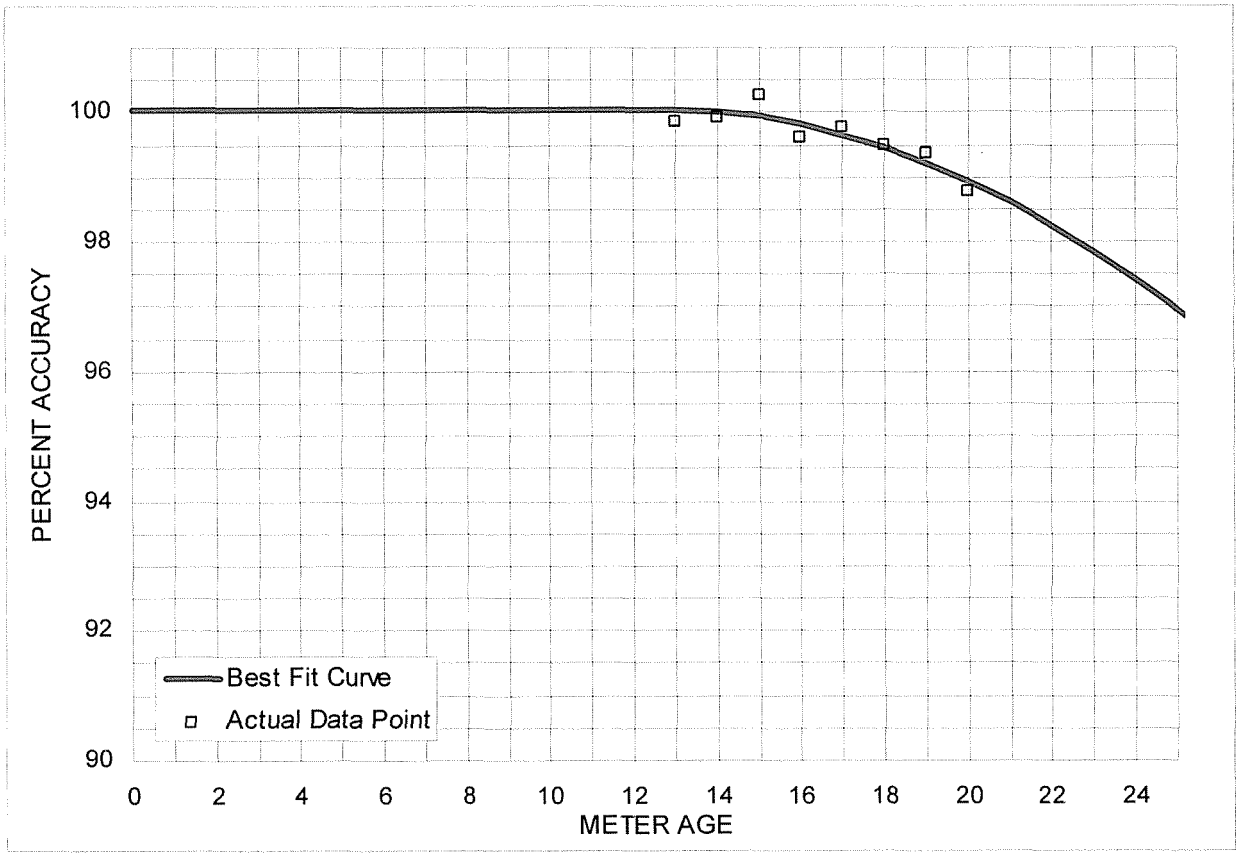

FIGURE 1: Weighted Average Meter Accuracy

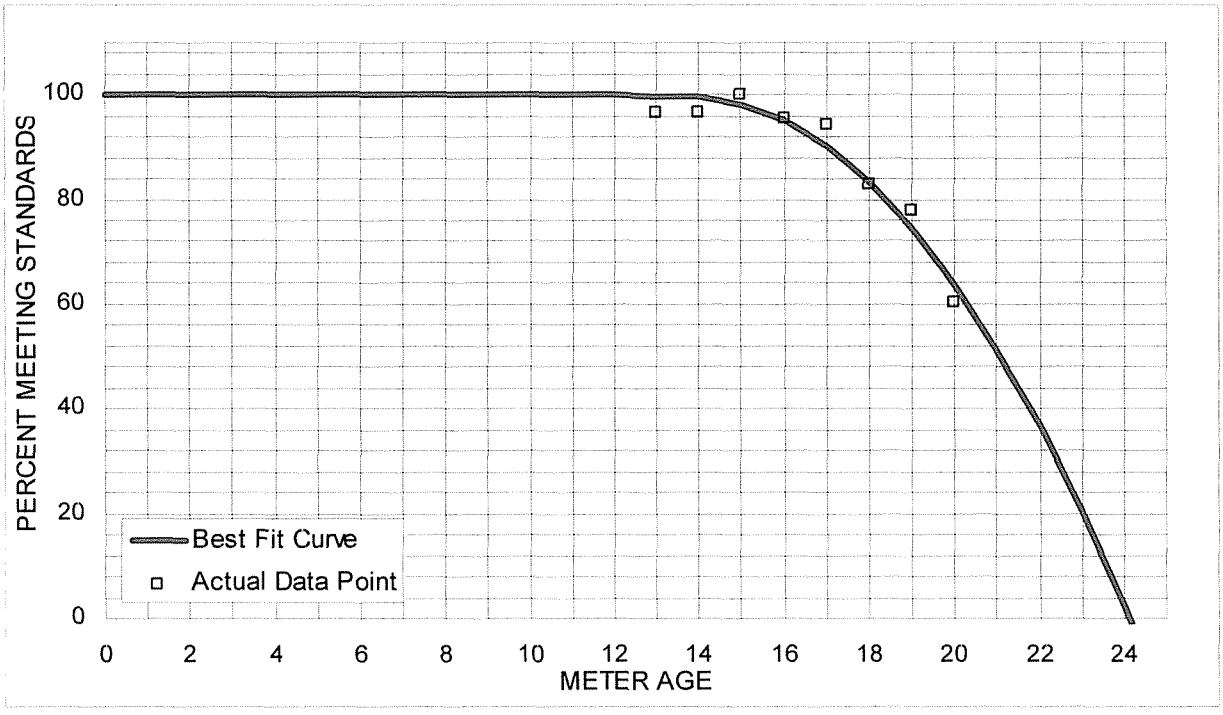

FIGURE 2: Meters Meeting PSC Repaired Meter Standards

Cost-Effective Analysis

As discussed earlier, the purpose of a cost-effective analysis is to determine the point at which the increase in revenue from a meter program equals or exceeds the cost of the program. Table 3 shows calculations required for the cost-effective determination.

Column A in Table 3 is the meter age. Columns B and C are data from the "best fit" curves for WAMA and PSC repaired meter standards discussed previously. Column D is the cost per meter to retrieve a meter from its service location and the unit replacement cost is given in Column E. The proposed program calls for all meters retrieved due to age to be replaced with a new or rebuilt meter. Many utilities buy new residential meters rather than repair old meters.[4] For the subject systems it is usually more economical to replace with a new meter than a rebuilt meter. Column F is the total program cost per meter. This is the sum of the unit retrieval cost (Column D) and the unit replacement cost (Column E).

TABLE 3
Cost-Effective Determination

A	B	C	D	E	F	G	H	I	J
Meter Age	Weighted Average Meter Accuracy (WAMA)[1]	Percent Below Repaired Meter Standards[1]	Unit Retrieval Cost	Unit Replacement Cost	Total Program Cost Per Meter	Water Recovered (gals/yr)	Unit **Annual** Revenue Gain	Unit Present Value of Rev. Gain[2]	Net Present Value of Program per Meter
1	100.05%	0.00%	$13.38	$26.92	$40.30	0	$0.00	$0.00	-$40.30
2	100.05%	0.00%	13.38	26.92	40.30	0	0.00	0.00	-40.30
3	100.05%	0.00%	13.38	26.92	40.30	0	0.00	0.00	-40.30
4	100.05%	0.00%	13.38	26.92	40.30	0	0.00	0.00	-40.30
5	100.05%	0.00%	13.38	26.92	40.30	0	0.00	0.00	-40.30
6	100.05%	0.00%	13.38	26.92	40.30	0	0.00	0.00	-40.30
7	100.05%	0.00%	13.38	26.92	40.30	0	0.00	0.00	-40.30
8	100.05%	0.00%	13.38	26.92	40.30	0	0.00	0.00	-40.30
9	100.05%	0.00%	13.38	26.92	40.30	0	0.00	0.00	-40.30
10	100.05%	0.00%	13.38	26.92	40.30	0	0.00	0.00	-40.30
11	100.05%	0.00%	13.38	26.92	40.30	0	0.00	0.00	-40.30
12	100.05%	0.00%	13.38	26.92	40.30	0	0.00	0.00	-40.30
13	100.05%	0.25%	13.38	26.92	40.30	0	0.00	0.00	-40.30
14	100.01%	0.44%	13.38	26.92	40.30	0	0.00	0.00	-40.30
15	99.93%	1.69%	13.38	26.92	40.30	41	0.13	1.55	-38.75
16	99.82%	4.84%	13.38	26.92	40.30	114	0.35	4.40	-35.90
17	99.65%	9.86%	13.38	26.92	40.30	213	0.66	8.69	-31.61
18	99.45%	16.77%	13.38	26.92	40.30	337	1.04	14.30	-26.00
19	99.21%	25.57%	13.38	26.92	40.30	487	1.50	21.49	-18.81
20	98.93%	36.25%	13.38	26.92	40.30	661	2.04	30.35	-9.95
21	98.61%	48.82%	13.38	26.92	40.30	859	2.65	40.85	**0.55**
22	98.25%	63.27%	13.38	26.92	40.30	1,081	3.34	53.23	12.93
23	97.85%	79.61%	13.38	26.92	40.30	1,326	4.10	67.42	27.12
24	97.42%	97.83%	13.38	26.92	40.30	1,593	4.92	83.32	43.02
25	96.95%	100.00%	13.38	26.92	40.30	1,883	5.82	101.34	61.04

Unit Costs for District Operations:

Cost per Man-hour (Retrieval)	$17.97	
Cost per Man-hour (Admin.)	20.56	
Cost per Truck-hour	5.77	
Unit Retrieval Cost:		
Meters/hr.	1.80	
Unit Cost		$13.21
Unit Admin. Cost:		
Meters/hr.	120.00	
Unit Cost		$0.17
Total Unit Retrieval & Test Cost:		$13.38

Replacement Costs:

New Meter Cost	$31.88
Scrap Value	4.96
Net Cost	$26.92

Avg. Residential Usage = 61,764 Per Year

Incremental Water Rate = $3.09 per 1,000 gals.

[1] Best fit curve data.

[2] Unit Present Value of Rev. Gain (I) = Unit Annual Revenue Gain (H) * Present Value Factor @ 3.0%.

Column G is the volume of water that does not register on meters because of their inaccuracy, expressed as an annual average. This is calculated as:

$$[(1 - WAMA) * Avg.\ Consumption]^6$$

Column H is the average annual revenue gain, which is the incremental retail water rate multiplied by the water recovered. The present value of the revenue gain given in Column I is the annual revenue gain (Column H) multiplied by the present value factor.

The cost-effective determination is from the net present value (NPV) figures in Column J which represents the revenue of the program minus the costs of the program ($Column\ J = Column\ I - Column\ F$). Column J of Table 3 shows that through age 20, the NPV of the program is negative, meaning the costs exceed the revenue gained. However, beginning at age 21, the potential revenue gain of the program exceeds the costs. Therefore, a meter replacement program for the water systems included in this study is cost-effective if meters are allowed to remain in service until they reach 21 years of age.

A graphical depiction of the cost-effective determination is shown in Figure 3. The replacement cost per meter is indicated by the red line, and the present value of the revenue gain is indicated in by the green line. The blue line is the net present value of the program, which is the difference in the revenue gain and the replacement cost. The net present valve is negative, indicating a net program loss, prior to year 21. The net present value reaches the break-even point, indicated in yellow, at year 21.

DETAILS OF PROPOSED PROGRAM

No Meters Older Than 21 Years

There are normally no meters in place in the water systems that have been in service longer than 21 years. Under the proposed program this situation will be maintained as explained below.

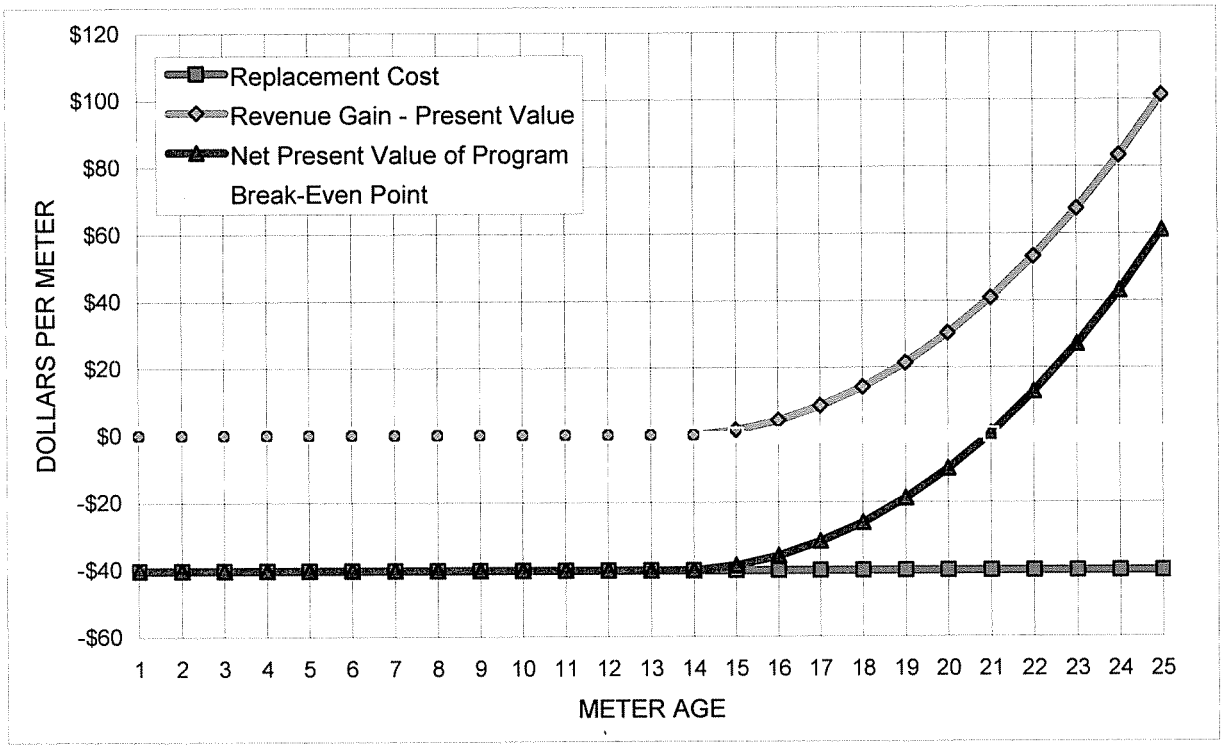

FIGURE 3: Cost Effective Determination

All Meters Replaced Every 21 Years

Each year the total population of meters that have reached the age of 21 years will be removed from service. The meters will be replaced at each customer location with a new or rebuilt meter. Either will be supplied with certified test results and meet PSC standards.

Meter Testing of Sample Group Each Year

To confirm that future meter accuracy trends conform to the data obtained in this study, a random sample of 21-year old meters will be tested each year. As with the current sample testing, the size of the sample will be calculated to provide a 95 percent confidence level that the average meter accuracy determined for the sample group would be plus or minus 1 percent of the actual average accuracy of all 21 year old meters. The results of these annual sample tests will be submitted to the PSC.

Disposition of 21 Year Old Meters

Since it has been determined that the 21-year old meters which are retired each year will be permanently removed from service, they may be sold for scrap. This scrap value will help to offset the cost of new, replacement meters. However if market conditions change in the future it could become more economical to rebuild the old meters and return them to service in-like new condition.

OTHER CONSIDERATIONS

General

The information and discussion in this report is related only to the 5/8 x 3/4-inch positive displacement meters in service in the three subject water systems. The water systems propose to continue testing all other meters in accordance with the regulations contained in 807 KAR 5:066, Section 16. The three systems are operated and maintained under similar operating policies and procedures. System design, construction practices, and water quality are also very similar in the three systems.

Existing Meter Program

The water systems currently conduct a meter testing and replacement program in accordance with the deviation approved by the PSC in its Order dated April 28, 1999 (Case No. 97-00434). The testing and replacement interval specified for 5/8 x 3/4-inch meters is 13 years. For the reasons detailed in this report, in accordance with KRS 278.210, the water systems have determined that this interval should be extended to 21 years.

Table 2 and Appendix A show results of tests on a sample group of 13-year old meters. This sample indicates that 96.7 percent of the meters that have been in service for 13 years operate within PSC accuracy limits. Therefore, if the entire population of 10-year old meters were tested, more than 96.7 percent of the meters would be returned to service with virtually no benefit derived from the testing program.

If the water systems continue the current testing and replacement program, a tremendous unnecessary expense will be placed on its customers. It is estimated the 13-year interval would cause the program cost to be approximately $19,400 per year higher than the proposed cost-effective program, this represents a 48 percent increase in program costs.

In addition to periodic meter replacement, the water systems use two other procedures to routinely monitor meter accuracy. The first procedure involves "zero consumption" detection. After a meter reader enters a new reading into his electronic data collector, an audible alarm is issued if there has been zero consumption at this location since the last reading. The second procedure is analysis of a 50 percent consumption report. This report is routinely generated from billing records. Any account that displays consumption that is less than one-half of that observed in the prior 12 months is flagged.

Both of the above procedures prompt operating personnel to determine whether there is a problem with the meter or there was actually a change in consumption. By using these methods meter failures are caught early and billing inequities are minimized.

Fairness

One of the primary purposes of a meter testing and replacement program is to ensure equitable charges to each of the utilities' customers. More frequent testing results in a water system with smaller differences between the most accurate and the least accurate meters. However, for the three systems studied, the difference in the range of accuracies is very small. After 21 years in service the meters still have a weighted accuracy of about 98.6 percent. This amounts to a maximum difference of $2.65 per year out of a total annual bill of $243.60, or less than 1.1 percent, for the average domestic water user.

Fairness is also incorporated in this proposal by all customers being treated the same regarding meter replacement. Under the proposed testing and replacement program, all customers, over time, will have equal experience with both new and old meters.

Therefore, the inherent range of accuracy over time is reflected in each customer's water bill. Also, the operational cost savings of the 21-year program will be seen in lower water rates to all customers.

REFERENCES:

[1] Cost-effective - Definition and More from the Free Merriam-Webster Dictionary, Merriam-Webster, Inc, 2011, <www.merriam-webster.com/dictionary/cost-effective>.

[2] Barker, Gene R., *Water Meter Testing Used to Raise Revenues*, Opflow, American Water Works Association, (Vol. 13, No. 12, December 1987)

[3] R. Richard Noss, et.al., *Optimal Testing Frequency for Domestic Wafer Meters*, Journal of Water Resources Planning and Management, Vol. 113, No. 1, January 1987.

[4] Mercer, Ken, *How Often Should Residential Water Meters be Replaced*, Opflow, American Water Works Association, (Vol. 37, No. 2, February 2011)

[5] Paul To. Bowen, et.al., *Residential Water Use Patterns*, American Water Works Association Research Foundation, Denver, CO, 1993.

[6] *Calculating the Optimal Meter Testing Frequency*, Bennett & Williams, Inc., Columbus, OH, 1989.

APPENDIX A

Details of Meter Accuracy Tests

TABLE A-1
METER TESTS - 13 YEAR OLD METERS

	-------- Test Results --------				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
52144498	90	99	100	98.0	
52144541	96	99	99	98.8	
52144582	98	101	100	100.7	
52144590	98	101	100	100.7	
52144620	100	101	100	100.9	
52144629	96	100	100	99.7	
52144638	99	100	100	99.9	
52144656	98	101	100	100.7	
52428523	98	100	100	99.9	
52428524	93	99	100	98.6	
52428534	99	101	100	100.8	
52428541	96	101	100	100.6	
52428542	97	101	100	100.7	
52428577	97	101	100	100.6	
52428621	96	100	100	99.7	
52428634	99	100	100	99.9	
52652713	100	101	100	100.9	
52652731	92	96	99	95.9	no
52877953	97	100	100	99.8	
52878001	97	100	100	99.8	
52878002	98	101	100	100.7	
52878027	96	101	100	100.6	
52878063	97	100	100	99.8	
53078860	97	100	100	99.8	
53078865	97	99	100	98.9	
53078877	97	101	100	100.7	
53078892	96	99	100	98.8	
53078905	96	100	99	99.7	
53078987	98	101	100	100.7	
53078994	98	99	100	99.0	
AVERAGES	96.9	100.1	100.0	**99.8**	
MIN	90.0	96.0	99.3		
MAX	100.0	101.0	100.3		

% Meeting PSC Repaired Meter Stds. **96.70%**

MIN	95.9
MAX	100.9
STD	1.1
Total Pop. Size	1,127
Acceptable Error	0.010
Std. Deviation	0.011
Samp. Size (95% Conf. Level)	30
Actual Error	0.004

TABLE A-2
METER TESTS - 14 YEAR OLD METERS

	-------- Test Results --------				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
50796298	99	101	100	100.8	
50796307	93	100	100	99.5	
50796360	99	101	100	100.8	
50796367	97	100	100	99.8	
50796398	97	100	100	99.8	
50796418	97	99	100	98.9	
50796421	97	101	100	100.7	
50983402	97	99	100	98.9	
50983540	94	101	100	100.4	
51059764	85	99	98	98.0	no
51059781	98	101	100	100.7	
51059871	96	101	100	100.6	
51059880	96	100	100	99.7	
51059890	93	100	101	99.6	
51182097	98	100	100	99.9	
51182110	100	100	100	100.0	
51182167	98	99	99	98.9	
51182176	96	101	100	100.6	
51182216	95	101	100	100.5	
51334155	99	99	100	99.1	
51335696	93	99	99	98.6	
51335705	97	101	100	100.6	
51335761	98	100	100	99.8	
51335794	96	100	100	99.7	
51488629	97	100	100	99.8	
51556612	97	101	100	100.7	
51698422	98	100	100	99.9	
51939470	99	101	101	100.8	
51939489	98	101	100	100.7	
52025472	97	100	100	99.8	
AVERAGES	96.5	100.2	99.9	**99.9**	
MIN	85.0	99.0	98.2		
MAX	100.0	101.0	101.0		

% Meeting PSC Repaired Meter Stds. **96.70%**

MIN	98.0
MAX	100.8
STD	0.7
Total Pop. Size	1,887
Acceptable Error	0.010
Std. Deviation	0.007
Samp. Size (95% Conf. Level)	30
Actual Error	0.003

TABLE A-3
METER TESTS - 15 YEAR OLD METERS

	-------- Test Results --------				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
49620277	99	101	100	100.8	
49620280	97	101	100	100.7	
49620282	99	100	100	99.9	
49620299	99	101	100	100.8	
49620319	98	101	100	100.7	
49620323	93	100	100	99.5	
49620326	95	101	100	100.5	
49620340	100	101	100	100.9	
49620406	98	100	99	99.8	
49632216	98	100	100	99.9	
49743552	98	100	100	99.8	
50018889	98	100	100	99.8	
50018921	97	101	100	100.6	
50019007	98	100	100	99.9	
50020419	101	101	101	101.0	
50020460	96	100	99	99.7	
50020490	92	100	100	99.4	
50020506	99	101	100	100.8	
50020511	100	101	99	100.8	
50245946	99	101	100	100.8	
50245955	96	100	100	99.7	
50246065	98	100	100	99.8	
50336535	98	100	100	99.9	
50336543	99	101	100	100.8	
50336549	99	101	100	100.8	
50336579	98	100	100	99.8	
50336625	98	100	99	99.8	
50336672	99	100	101	100.0	
50336673	100	100	100	100.0	
50399705	98	100	100	99.9	
50614653	97	101	100	100.7	
50614667	100	101	100	100.9	
50614694	96	100	100	99.7	

	-------- Test Results --------				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
50614699	99	101	101	100.8	
AVERAGES	97.9	100.5	99.9	**100.3**	
MIN	92.0	100.0	99.1		
MAX	101.0	101.0	100.7		
% Meeting PSC Repaired Meter Stds.					**100.00%**
MIN				99.4	
MAX				101.0	
STD				0.5	
Total Pop. Size				1,258	
Acceptable Error				0.010	
Std. Deviation				0.005	
Samp. Size (95% Conf. Level)				34	
Actual Error				0.002	

TABLE A-4
METER TESTS - 16 YEAR OLD METERS

	-------- Test Results --------				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
48292342	96	101	100	100.6	
48292346	0	100	100	93.0	no
48292365	97	100	100	99.8	
48292372	99	101	100	100.8	
48292424	99	100	100	99.9	
48292453	97	100	100	99.8	
48292456	98	101	100	100.7	
48292558	96	101	100	100.6	
48292559	97	100	100	99.8	
48292596	99	100	100	99.9	
48292598	98	100	100	99.8	
48292608	98	100	100	99.8	
48292637	97	100	100	99.8	
48292741	97	100	100	99.8	
48758977	95	99	100	98.7	
48759014	100	100	100	100.0	
48759017	96	100	100	99.7	
48759090	97	100	99	99.8	
48759107	97	100	100	99.8	
48761844	96	99	100	98.8	
48761880	90	100	100	99.3	
48809770	99	101	100	100.8	
48809782	95	100	100	99.6	
48809801	96	99	100	98.8	
48809897	94	99	100	98.7	
49074152	98	101	100	100.7	
49074223	97	99	99	98.9	
49074290	95	99	100	98.8	
49074327	97	100	99	99.7	
49146236	98	101	100	100.8	
49146269	98	101	100	100.7	
49146300	100	101	101	100.9	
49146305	98	101	100	100.7	
49146306	97	101	100	100.7	
49146341	97	100	100	99.8	
49146343	99	100	100	99.9	
49291226	98	101	100	100.7	

	-------- Test Results --------				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
49291240	99	101	100	100.8	
49291259	97	90	100	91.1	no
49291275	99	101	100	100.8	
49291277	100	100	101	100.0	
49291333	97	100	100	99.8	
49291335	98	101	100	100.7	
AVERAGES	95.0	100.0	99.9	**99.6**	
MIN	0.0	90.0	99.3		
MAX	100.0	101.0	100.6		

% Meeting PSC Repaired Meter Stds. **95.30%**

MIN	91.1
MAX	100.9
STD	1.8
Total Pop. Size	1,349
Acceptable Error	0.010
Std. Deviation	0.018
Samp. Size (95% Conf. Level)	43
Actual Error	0.005

TABLE A-5
METER TESTS - 17 YEAR OLD METERS

	-------- Test Results --------				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
46995929	99	101	100	100.8	
46995986	98	100	100	99.9	
46996017	97	100	99	99.8	
46996082	99	100	100	99.9	
46996111	96	100	100	99.7	
46996119	99	101	99	100.8	
47097073	97	95	100	95.4	no
47097240	96	99	99	98.8	
47155415	98	101	100	100.7	
47155485	98	101	100	100.7	
47155508	97	100	100	99.8	
47155521	95	100	100	99.6	
47155546	93	100	100	99.5	
47155548	98	101	101	100.8	
47221777	92	100	99	99.4	
47221788	97	101	100	100.7	
47221845	99	100	99	99.9	
47221854	96	100	100	99.7	
47221858	97	100	100	99.8	
47221923	96	101	100	100.6	
47221956	95	100	100	99.7	
47221967	97	101	100	100.6	
47221979	93	99	100	98.6	
47406935	99	100	100	99.9	
47406945	97	100	100	99.8	
47406985	97	100	100	99.8	
47407052	98	101	101	100.8	
47407055	94	101	100	100.5	
47407124	99	99.5	100	99.5	
47705211	97	100	99	99.7	
47705221	92	100	100	99.5	
47705232	99	100	100	99.9	
47705237	95	96	100	96.2	no
47705266	100	101	100	100.9	
47705296	100	100	100	100.0	
47705347	96	100	100	99.7	
47705386	99	101	100	100.8	
47705400	97	100	100	99.8	

Meter No.	Test Results Low	Medium	High	WAMA	Meets PSC Repaired Meter Stds.
47758549	98	100	99	99.8	
47758555	99	99	100	99.0	
47758575	91	99	99	98.4	
47758660	99	101	100	100.8	
47758661	98	100	100	99.8	
47758671	97	100	100	99.8	
47758683	95	100	100	99.6	
47758696	100	101	100	100.8	
47758697	98	97	100	97.2	no
47758711	96	100	99	99.7	
47758721	95	100	99	99.6	
47758727	98	101	100	100.7	
47991272	100	100	100	100.0	
47991341	99	100	100	99.9	
47991367	99	101	100	100.8	
47991439	96	100	99	99.7	
AVERAGES	97.0	100.0	99.7	**99.8**	
MIN	91.0	95.0	98.9		
MAX	100.0	101.0	100.5		

% Meeting PSC Repaired Meter Stds. **94.40%**

MIN	95.4
MAX	100.9
STD	1.0
Total Pop. Size	1,907
Acceptable Error	0.010
Std. Deviation	0.010
Samp. Size (95% Conf. Level)	54
Actual Error	0.003

TABLE A-6
METER TESTS - 18 YEAR OLD METERS

	-------- Test Results --------				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
45974799	99	101	101	100.8	
45974824	97	100	99	99.7	
46044751	97	100	100	99.8	
46044778	93	100	100	99.5	
46044798	98	100	100	99.9	
46044800	98	100	100	99.8	
46044849	98	101	100	100.8	
46044940	85	98	98	97.1	no
46044943	88	99	98	98.2	no
46045091	98	100	100	99.8	
46045126	96	101	100	100.6	
46045140	92	100	99	99.4	
46045146	85	99	98	98.0	no
46045148	97	98	98	97.9	no
46045155	97	99	100	98.9	
46045186	88	99	98	98.2	no
46057924	91	98	97	97.5	no
46057931	92	99	99	98.5	
46182000	99	101	100	100.8	
46182067	96	101	100	100.6	
46182113	98	100	100	99.9	
46182123	99	101	100	100.8	
46182138	63	100	99	97.4	no
46182147	98	101	100	100.7	
46252867	9	100	100	93.7	no
46252890	98	101	100	100.7	
46252893	98	101	100	100.8	
46291748	99	101	100	100.8	
46291758	97	100	100	99.8	
46291761	98	101	101	100.8	
46291763	98	100	100	99.9	
46291853	99	100	100	99.9	
46291892	96	100	100	99.7	
46291927	99	101	100	100.8	
46553919	98	96	100	96.3	no
46553925	98	100	100	99.9	
46553927	98	100	100	99.8	
46553956	97	99	101	98.9	

	-------- Test Results --------				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
46656698	97	100	100	99.8	
46656700	97	99	100	98.9	
46656740	99	100	101	100.0	
46656794	99	100	101	100.0	
46656816	96	100	100	99.7	
46656819	99	101	100	100.8	
46690806	94	100	100	99.6	
46690810	93	101	99	100.3	
46690843	95	99	100	98.8	
46690862	96	96	100	96.2	no
46690863	95	100	100	99.7	
46690865	96	100	100	99.7	
46692291	98	101	100	100.7	
46692298	95	99	99	98.7	
46692313	96	101	100	100.6	
46692321	96	99	100	98.8	
46692335	95	101	100	100.5	
46692336	94	95	100	95.2	no
46692344	99	100	100	99.9	
46692347	98	100	100	99.8	
46692348	99	101	100	100.8	
46692356	96	101	100	100.6	
46692359	98	100	100	99.8	
46692386	98	101	100	100.7	
46692419	98	101	100	100.7	
46692424	98	101	101	100.8	
AVERAGES	94.3	99.9	99.7	**99.5**	
MIN	9.0	95.0	97.3		
MAX	99.0	101.0	100.6		

% Meeting PSC Repaired Meter Stds. **82.80%**

MIN	93.7
MAX	100.8
STD	1.4
Total Pop. Size	1,569
Acceptable Error	0.010
Std. Deviation	0.014
Samp. Size (95% Conf. Level)	64
Actual Error	0.003

TABLE A-7
METER TESTS - 19 YEAR OLD METERS

	-------- Test Results --------				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
44894643	94	100	100	99.6	
44894646	92	99	99	98.5	
44894654	98	101	100	100.7	
44894658	96	101	100	100.6	
44894668	92	99	99	98.5	
44894694	97	101	100	100.7	
44894705	93	99	99	98.6	
44894714	98	101	100	100.8	
44894718	96	100	100	99.7	
44894723	92	100	98	99.3	no
44894724	96	101	100	100.6	
44894735	95	90	99	90.9	no
44894737	96	99	99	98.8	
44894742	91	99	99	98.5	
44894745	97	101	100	100.7	
44894754	98	100	100	99.9	
44894764	99	101	100	100.8	
44894769	99	100	101	100.0	
44894787	94	100	99	99.5	
44894796	96	100	100	99.7	
44894811	93	100	100	99.5	
44904035	92	100	99	99.4	
44904037	97	101	100	100.7	
44904045	96	101	100	100.6	
44983752	88	99	99	98.2	no
44983756	93	100	99	99.5	
44983799	87	99	99	98.1	no
44983806	91	100	99	99.3	
44983807	92	99	99	98.5	
44983825	96	100	100	99.7	
44983828	78	97	98	95.7	no
44983872	98	100	100	99.9	
44983904	96	100	99	99.7	
44992193	94	100	100	99.6	
44992226	97	101	100	100.7	
44992248	98	101	100	100.7	
44992259	79	99	99	97.6	no
44992299	91	99	99	98.4	

	Test Results				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
44992300	98	101	100	100.7	
44992314	89	99	99	98.3	no
45221876	90	99	99	98.4	
45221883	99	100	101	100.0	
45221903	99	101	100	100.8	
45221914	97	101	101	100.7	
45221925	83	98	98	97.0	no
45221930	98	101	100	100.7	
45221934	92	100	99	99.4	
45221961	97	101	100	100.7	
45221975	98	101	100	100.7	
45221992	93	100	99	99.5	
45222002	97	101	100	100.6	
45222013	97	101	100	100.7	
45304352	88	99	99	98.2	no
45304355	96	99	100	98.8	
45415293	88	99	99	98.3	no
45415384	96	100	100	99.7	
45415416	89	99	98	98.3	no
45415428	99	101	100	100.8	
45415452	88	98	99	97.3	no
45415483	99	101	100	100.8	
45468897	95	100	99	99.6	
45468910	89	99	99	98.3	no
45468916	97	101	100	100.6	
45468967	92	99	99	98.5	
45468983	91	100	98	99.3	no
45468993	93	101	56	97.8	no
45469045	84	98	98	97.0	no
45469049	98	101	100	100.7	
45469119	97	101	100	100.7	
45469126	81	99	99	97.7	no
45469131	97	101	100	100.6	
45469138	95	101	100	100.5	
45469211	98	101	100	100.7	
45469668	96	101	100	100.6	
45469682	94	100	99	99.5	
45613350	90	99	100	98.4	

	-------- Test Results --------				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
45613352	91	99	99	98.4	
AVERAGES	93.7	99.9	98.9	**99.4**	
MIN	78.0	90.0	55.9		
MAX	99.0	101.0	100.7		
% Meeting PSC Repaired Meter Stds.					**77.90%**
MIN				90.9	
MAX				100.8	
STD				1.5	
Total Pop. Size				1,569	
Acceptable Error				0.010	
Std. Deviation				0.015	
Samp. Size (95% Conf. Level)				77	
Actual Error				0.003	

TABLE A-8
METER TESTS - 20 YEAR OLD METERS

	-------- Test Results --------				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
43504555	87	98	98	97.2	no
43504560	82	98	98	96.9	no
43520287	98	101	101	100.8	
43520292	95	99	99	98.7	
43520294	88	99	98	98.2	no
43520302	84	98	98	97.0	no
43520438	81	98	98	96.8	no
43520443	98	101	100	100.7	
43520449	80	97	97	95.8	no
43520458	93	101	99	100.3	
43520467	89	98	98	97.4	no
43520477	97	101	100	100.6	
43520490	77	97	98	95.7	no
43520494	82	97	98	96.0	no
43851272	91	99	98	98.4	no
43851275	99	101	100	100.8	
43851279	81	98	98	96.8	no
43851295	83	98	98	96.9	no
43851296	97	101	100	100.7	
43851318	99	101	100	100.8	
43851319	70	97	97	95.1	no
43851346	95	101	100	100.5	
43851348	94	101	100	100.4	
43851349	96	100	100	99.7	
43851351	95	100	99	99.6	
43851368	95	101	99	100.5	
43851379	97	101	100	100.6	
44099705	98	100	99	99.8	
44099712	88	98	98	97.3	no
44099719	99	101	101	100.8	
44099725	99	101	100	100.8	
44179861	93	100	99	99.5	
44179865	91	99	99	98.4	
44179874	95	100	99	99.6	
44179907	100	101	101	100.9	
44179912	97	100	99	99.8	
44179918	92	99	99	98.5	
44179929	99	101	100	100.8	

	Test Results				Meets PSC
Meter No.	Low	Medium	High	WAMA	Repaired Meter Stds.
44179930	87	98	98	97.2	no
44179951	87	100	98	99.0	no
44179954	98	100	100	99.9	
44344098	87	99	98	98.1	no
44344111	83	98	98	96.9	no
44344113	85	98	97	97.0	no
44344127	93	100	100	99.5	
44344129	86	99	99	98.1	no
44344130	98	101	101	100.8	
44344131	91	100	99	99.3	
44344132	96	101	100	100.6	
44344137	92	99	99	98.5	
44344156	89	98	98	97.4	no
44344157	79	96	97	94.9	no
44344184	86	97	98	96.3	no
44344185	93	99	99	98.6	
44344216	99	101	100	100.8	
44344240	93	100	99	99.4	
44344307	91	99	99	98.4	
44344330	89	99	98	98.3	no
44364080	96	100	99	99.7	
44364083	96	100	99	99.7	
44364098	96	100	99	99.7	
44364104	87	99	98	98.1	no
44364115	97	101	100	100.7	
44364120	80	97	98	95.8	no
44364141	95	100	99	99.6	
44364146	92	99	99	98.5	
44364178	82	98	98	96.9	no
44364183	90	99	98	98.3	no
44364197	54	98	99	94.9	no
44661101	100	100.5	100	100.4	
44661126	96	100	99	99.7	
44661128	93	100	100	99.5	
44661139	97	101	100	100.6	
44661148	97	100	100	99.8	
44661204	98	100	100	99.8	
44661209	97	101	100	100.7	
44661213	86	98	98	97.2	no
44661219	89	99	99	98.3	no
44661222	98	100	100	99.8	

Meter No.	Test Results Low	Medium	High	WAMA	Meets PSC Repaired Meter Stds.
44712748	97	101	100	100.7	
44712750	96	100	100	99.7	
44712760	89	98	99	97.4	no
44712763	81	97	98	95.9	no
44712769	88	98	98	97.3	no
44712782	91	100	99	99.3	
44712796	89	99	99	98.3	no
44712822	90	100	99	99.3	
44712830	93	100	99	99.5	
44712834	98	100	100	99.9	
44712839	94	100	99	99.5	
44712854	90	99	99	98.4	
44712859	88	98	98	97.3	no
44712868	88	99	99	98.2	no
AVERAGES	91.0	99.4	99.0	**98.8**	
MIN	54.0	96.0	96.9		
MAX	100.0	101.0	100.5		

% Meeting PSC Repaired Meter Stds. **60.20%**

MIN	94.9
MAX	100.9
STD	1.6
Total Pop. Size	1,328
Acceptable Error	0.010
Std. Deviation	0.016
Samp. Size (95% Conf. Level)	93
Actual Error	0.003

APPENDIX B

Water Use Profile Testing

TABLE B-1
WATER USE PROFILE TESTING

Meter Number	Low Flow	Medium Flow	High Flow
BN88-008	12.6%	87.4%	0.0%
1W18-302	8.2%	82.2%	9.6%
2W14-014	9.3%	87.9%	2.8%
1W18-309	6.2%	80.6%	13.2%
BN74-009	5.5%	75.5%	19.0%
2N10-010	7.1%	86.8%	6.0%
2N07-012	14.3%	85.2%	0.6%
1N03-113	7.6%	85.8%	6.6%
1N21-012	11.5%	87.1%	1.4%
1W02-563	8.6%	82.7%	8.7%
1324-150	2.4%	94.9%	2.7%
1214-73	2.3%	91.8%	5.9%
2114-35	3.2%	96.1%	0.7%
2212-17	9.9%	73.4%	16.7%
2312-134	7.2%	91.2%	1.6%
3208-91	1.6%	96.0%	2.3%
8L03-001	1.8%	89.7%	8.4%
1S01-001	7.1%	92.9%	0.0%
Average	7.03%	87.06%	5.91%