Asheville, NC – 10 years of Water Loss Control
... and Counting

M. Steve Cavanaugh, Jr., PE
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May 10, 2018
Agenda

National Water Loss Movement – Tools review
Audit to Action – Asheville Case Study
What’s next for your utility?
What's next for Pennsylvania?
Q&A
Problem has gone away...?

November 15, 2016

April 12, 2018

Source: US Drought Monitor
SAWS reveals 9 billion gallons of water wasted last year

by APRIL MOLINA | Wednesday, November 1st 2017

Problem has gone away...?
1991 - M36 1st Ed.
- AWWA adopts international standard, abandons Unaccounted For Water

1999 - M36 2nd Ed.
- Water Audits and Leak Detection

2003 - M36 3rd Ed.
- Applying worldwide BMPs in water loss control

2006 - M36 4th Ed.
- Water Audits and Loss Control Programs

2009 - M36 4th Ed.
- Water Audits and Loss Control Programs

2010 - M36 4th Ed.
- Water Audits and Loss Control Programs

2014 - M36 4th Ed.
- WRF study shows audit validity is a widespread challenge

2015 - M36 4th Ed.
- Validation method developed

2016 - M36 4th Ed.
- Performance Indicator Task Force WRF 4695-Effective WLC Planning

2017 - M36 4th Ed.
- WRF Real Loss Component Analysis Model

AWWA Audit Software v1
- AWWA Compiler developed for large audit sets
- (2,000 downloads)

AWWA Audit Software v4

AWWA Audit Software v5
- ~8,000 downloads to date of AWWA Audit Software v5

NORTH AMERICAN WATER LOSS 2015
- Georgia

NORTH AMERICAN WATER LOSS 2017
- California
No water loss reporting

Rudimentary water loss reporting

AWWA M36 terminology & metrics

AWWA M36 software

AWWA M36 software with validation (Level 1)

M36: State of the Art
Statewide Water Loss Management Program – Model Implementation

**Phase 1**

**Establish Annual M36 Water Auditing**
- Establish annual M36 Water Auditing for all utilities
- Educate Regulatory Community on M36 Method and appropriate use of performance indicators
- Establish Statewide Water Loss Control Committee
- Develop State Manual and Training Framework
- Provide extended, progressive training to utilities (funded)

**Phase 2**

**Achieve Minimum Standard of Audit Reliability**
- Develop and implement data management system
- Establish posting system and communication protocols
- Establish minimum standards of validation for quality assurance
- Determine by Agency or 3rd Party
- Establish validation program until certification program is in place
- Design and implement a Certified Water Audit program for sustained quality control
- Statewide Water Loss Control Committee provides support

**Phase 3**

**Manage Water Loss Performance for Long-Term Reduction**
- Suite of Performance and Process Measures
- System specific improvement over time in a cost-effective manner
- No universal targets
- Excessive thresholds established
- Annual audit submission threshold exceedances
- System specific progress review at designated regulatory touchpoints

**Statewide Water Loss**

- Year 1: Resource Management Grade C
- Year 2: Resource Management Grade B
- Year 3: Resource Management Grade C
- Year 4: Resource Management Grade B
- Year 5: Resource Management Grade A
- Year 6: Resource Management Grade B
- Year 7: Resource Management Grade A

**Statewide Data Validity**

- Year 1: Resource Management Grade C
- Year 2: Resource Management Grade B
- Year 3: Resource Management Grade C
- Year 4: Resource Management Grade B
- Year 5: Resource Management Grade A
- Year 6: Resource Management Grade B
- Year 7: Resource Management Grade A
IWA/AWWA Standard Water Balance

- **Own Sources**
  - Total System Input
  - Water Supplied (allow for known errors)

- **Water Imported**

- **Water Exported**
  - Water Supplied
  - Authorized Consumption
  - Billed Authorized Consumption
  - Unbilled Authorized Consumption

- **Water Losses**
  - Real Losses
  - Apparent Losses

- **Non-Revenue Water**
  - Unbilled Metered Consumption
  - Unbilled Unmetered Consumption
  - Unauthorized Consumption
  - Customer Metering Inaccuracies
  - Systematic Data Handling Errors
  - Leakage on Mains
  - Leakage on Service Lines
  - Leakage & Overflows at Storage

- **Revenue Water**
  - Billed Water Exported
  - Billed Metered Consumption
  - Billed Unmetered Consumption

- **Total System Input** (allow for known errors)
- Fire Dept Usage
- Operational Flushing
- Tools for control include efficient flushing practices and awareness campaigns

Non-physical / revenue loss - slow meters, billing issues and theft
Cost impacts at ‘retail’ rate
Tools for control include data management, quality control policies/practices, & meter testing & repair

Physical loss - leakage
Cost impacts at ‘wholesale’ rate
Tools for control include leakage and pressure management
Water Loss as a Percentage of Supply is **not** an Indicator of Performance
AWWA Free Water Audit Software

Water Audit Report for:
Northern San Leandro Combined Water Sewer Storm Utility District (0007900)

Reporting Year: 2013

All volumes to be entered as: MILLION GALLONS (US) PER YEAR

Master Meter Error Adjustments

| Volume from own sources: | 825,000 | MG/Yr |
| Water imported: | 5,100,000 | MG/Yr |
| Water exported: | 1,000,000 | MG/Yr |

| WATER SUPPLIED: | 825,000 | MG/Yr |

Authorized Consumption

| Billed metered: | 700,000 | MG/Yr |
| Billed unmetered: | 50,000 | MG/Yr |
| Unbilled metered: | 10,313 | MG/Yr |
| Unbilled unmetered: | 1,000,000 | MG/Yr |

| AUTHORIZED CONSUMPTION: | 760,313 | MG/Yr |

WATER LOSSES (Water Supplied - Authorized Consumption)

| Unauthorized consumption: | 3,000 | MG/Yr |
| Customer metering inaccuracies: | 7,071 | MG/Yr |
| Systematic data handling errors: | 5,000 | MG/Yr |

| Apparent Losses: | 15,071 | MG/Yr |

| WATER LOSSES: | 64,688 | MG/Yr |

Non-Revenue Water

| NON-REVENUE WATER: | 75,000 | MG/Yr |

System Data

| Length of mains: | 100.0 | miles |
| Number of active AND inactive service connections: | 1,000 |
| Service connection density: | 100 | conn./mile main |
| Are customer meters typically located at the curbstop or property line? | Yes |
| Average length of customer service line: | 60.0 | psi |

Cost Data

| Total annual cost of operating water system: | $1,000,000 | $/Year |
| Customer retail unit cost (applied to Apparent Losses): | $3.50 | $/1,000 gallons (US) |
| Variable production cost (applied to Real Losses): | $3,000.00 | $/Million gallons |

| WATER AUDIT DATA VALIDITY SCORE: | 60 out of 100 |

Industry Standard (M36)
Free

~10 Volume Inputs
~7 System Data Inputs

awwa.org/waterlosscontrol
## Performance Indicators/Metrics

### AWWA Free Water Audit Software:
**System Attributes and Performance Indicators**

**Water Audit Report for:** City of Orem (UT4900332)
**Reporting Year:** 2015 - 7/2015 - 6/2016

**YOUR WATER AUDIT DATA VALIDITY SCORE IS: 55 out of 100 ***

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Losses</td>
<td>555.053 MGYr</td>
</tr>
<tr>
<td>Water Losses</td>
<td>772.682 MGYr</td>
</tr>
<tr>
<td>Unavoidable Annual Real Losses (UARL)</td>
<td>170.51 MGYr</td>
</tr>
<tr>
<td>Annual cost of Apparent Losses</td>
<td>$233,740</td>
</tr>
<tr>
<td>Annual cost of Real Losses</td>
<td>$213,979</td>
</tr>
<tr>
<td>Valued at: Variable Production Cost</td>
<td></td>
</tr>
</tbody>
</table>

### Performance Indicators:

#### Financial:
- Non-revenue water as percent by volume of Water Supplied: 14.8%
- Non-revenue water as percent by cost of operating system: 5.0%
- Real Losses valued at Variable Production Cost

#### Operational Efficiency:
- Apparent Losses per service connection per day: 26.11 gallons/connection/day
- Real Losses per service connection per day: 66.85 gallons/connection/day
- Real Losses per length of main per day*: N/A
- Real Losses per service connection per day per psi pressure: 0.77 gallons/connection/day/psi

From Above, Real Losses = Current Annual Real Losses (CARL): 555.65 million gallons/year

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure Leakage Index (ILI) [CARL/UARL]</td>
<td>3.26</td>
</tr>
</tbody>
</table>

* This performance indicator applies for systems with a low service connection density of less than 32 service connections/mile of pipeline
Statewide Water Loss Management Program – Model Implementation

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**Statewide Water Loss**
- Year 1
- Year 2
- Year 3
- Year 4
- Year 5
- Year 6
- Year 7

**Statewide Data Validity**
- Resource Management Grade C
- Resource Management Grade B
- Resource Management Grade A
AWWA Free Water Audit Software © (V5.0)

Data Grading for each Water Audit input (excerpt)

<table>
<thead>
<tr>
<th>Water Audit Report for:</th>
<th>&lt;&lt; Please enter system details and contact information on the Instructions tab &gt;&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reporting Year:</td>
<td></td>
</tr>
</tbody>
</table>

Please enter data in the white cells below. Where available, metered values should be used; if metered values are unavailable please estimate a value. Indicate your confidence in the accuracy of the input data by grading each component (n/a or 1-10) using the drop-down list to the left of the input cell. Hover the mouse over the cell to obtain a description of the grades.

Please choose reporting units from the instructions sheet before entering data.

**WATER SUPPLIED**

Volume from own sources: [ ]
Water imported: [ ]
Water exported: [ ]

**WATER SUPPLIED**

**AUTHORIZED CONSUMPTION**

Billed metered: [ ]
Billed unmetered: [ ]
Unbilled metered: [ ]
Unbilled unmetered: [ ]

Enter a positive value, otherwise a default percentage of 1.25% (of billed metered).

**AUTHORIZED CONSUMPTION**

**WATER LOSSES (Water Supplied - Authorized Consumption)**

0.000

<table>
<thead>
<tr>
<th>Apparent Losses</th>
<th>Pctn:</th>
<th>Value:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unauthorized consumption:</td>
<td>0.25%</td>
<td></td>
</tr>
<tr>
<td>Default option selected for unauthorized consumption - a grading of 5 is applied but not displayed</td>
<td>1.00%</td>
<td></td>
</tr>
<tr>
<td>Customer metering inaccuracies:</td>
<td>0.25%</td>
<td></td>
</tr>
<tr>
<td>Systematic data handling errors:</td>
<td>0.25%</td>
<td></td>
</tr>
</tbody>
</table>

Master Meter Error Adjustments

1. Less than 25% of water production sources are metered, remaining sources are estimated. No regular meter accuracy testing or electronic calibration conducted.
2. 25% - 50% of treated water production sources are metered; other sources estimated. No regular meter accuracy testing or electronic calibration conducted.
3. Conditions between 2 and 4
4. 50% - 75% of treated water production sources are metered, other sources estimated. Occasional meter accuracy testing or electronic calibration conducted.
5. Conditions between 4 and 6
6. At least 75% of treated water production sources are metered, or at least 90% of the source flow is derived from metered sources. Meter accuracy testing and/or electronic calibration of related instrumentation is conducted annually. Less than 25% of tested meters are found outside of +/- 6% accuracy.
7. Conditions between 6 and 8
8. 100% of treated water production sources are metered, meter accuracy testing and electronic calibration of related instrumentation is conducted annually, less than 10% of meters are found outside of +/- 6% accuracy.
9. Conditions between 8 and 10
10. 100% of treated water production sources are metered, meter accuracy testing and electronic calibration of related instrumentation is conducted semi-annually, with less than 10% found outside of +/- 3% accuracy. Procedures are reviewed by a third party knowledgeable in the M36 methodology.
Accuracy in the Water Balance

8” Propeller Meter
Check Valve
Well Pump

Accuracy results from MFR test bench: 99.5%
Accuracy results from in-situ test: 142.2%

Courtesy MESCO
Statewide Water Loss Management Program – Model Implementation

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- Year 1
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- Year 4
- Year 5
- Year 6
- Year 7

**Statewide Data Validity**
- Resource Management Grade C
- Resource Management Grade B
- Resource Management Grade A
Wisconsin Pilot
6 systems, 6 months

Washington Pilot
10 systems, 9 months

Colorado Pilot
50 systems, 3 months

Wisconsin Pilot
6 systems, 6 months

Utah Pilot
20 systems, 6 months

California Full Scale
460 systems, 2 years

North & South Carolina Pilot
18 systems, 1 year

Hawaii Full Scale
100 systems, 4 years

New Mexico Full Scale
134 systems, 1 year

Georgia Full Scale
230 systems, 5 years (and counting)

Arizona Pilot
6 systems, 6 months

Hawaii Full Scale
100 systems, 4 years

New Mexico Full Scale
134 systems, 1 year

Georgia Full Scale
230 systems, 5 years (and counting)
The Big Picture: Economic Intervention

Annual Water Balance
- Annual M36 water audit
- Apparent & Real Loss volumes
- Level 1 validation

Loss Profiling
- Validation
  - Level 2 Analytics
  - Level 3 Field Study
- Analyze sources of Apparent Loss
- Analyze 3 types of Real Loss

Cost-Benefit & Targets
- Costs of losses
  - by subcomponent
  - in aggregate
- Costs of intervention strategies
- Program design
- System-specific

Intervention
- Leakage Management:
  - Active Leak Detection
  - Pressure Optimization
  - Repair Time Reduction
  - Network Renewal
- Revenue Protection:
  - Theft Mitigation
  - Meter Optimization & Renewal
  - Billing Data System Integrity
  - Revenue Recovery

Baseline Technical analysis
Economic analysis
Cost-effectiveness
Aggressive Intervention is **Over-Spending**
Example: replacement of pipes and meters before their optimal useful life

**Economic Optimum** Loss & Intervention
Economic target from benefit-cost design (M36)

Reactive Intervention is **Over-Spending**
Example: fixing only leaks that surface, replacing meters only when they stop

**Total Loss Cost**

Cost of Water & Revenue Loss

Cost of Intervention

**New $M**

**The GAP**

**New Supply**

**The target of the Water Loss Program**

AWWA M36 – Economic Optimum

M36: State of the Art
City of Asheville
Comprehensive Non-Revenue Water Program

Team: Brandon Buckner, City of Asheville
Brenna Cook, City of Asheville
Will Jernigan, P.E., Cavanaugh
Program Origins

Water Supplied
(million gallons per day)

Authorized Consumption
(million gallons per day)

Water Loss
(million gallons per day)
Audit to Action

SUPPLY

CONSUMPTION

METERING

AUDIT

PROGRAM

DETECTION

PRESSURE

RENEWAL
A Team Based Approach

• Audit Input Team
• Valve & Leak Team
• Unbilled Customer Team
• Customer Service Team
• Metering Team
• Pressure Management Team
Data Tracking & Audit Input

- Assist in Gathering Data
- Master Meter Testing
- Water Theft Tracking
- Reporting from Internal & External sources
- KPI Tracker
- Policy Relation & Review
- CIP Recommendations
Four Pillars of Managing Apparent Loss

1. Theft
2. Data Transfer / Archive Errors
3. Billing Errors
4. Customer Meter Accuracy

As each component receives more or less attention, the losses will increase or decrease.

Source: AWWA Water Loss Control Committee
Real Losses
Four Pillars of Managing Leakage

- Pressure Management
- Speed & Quality of Repairs
- Existing Real Losses
- Active Leakage Control
- Maintenance Rehab Repair
- Unavoidable Real Losses
- Economic Level

As each component receives more or less attention, the losses will increase or decrease.

Source: AWWA Water Loss Control Committee
Fire Department Audits

- Check for use of NRW
- Billing/Metering status
- Create Consistency
- Recommendations for Improvement
- Follow up
Proactive Leak Surveys

Sample Zone Flows for ‘Night Flow Analysis’ to Guide Prioritization of Leak Surveys
The Big Picture: Economic Intervention

Annual Water Balance
- Annual M36 water audit
- Apparent & Real Loss volumes
- Level 1 validation

Loss Profiling
- Validation
  - Level 2 Analytics
  - Level 3 Field Study
- Analyze sources of Apparent Loss
- Analyze 3 types of Real Loss

Cost-Benefit & Targets
- Costs of losses
  - by subcomponent
  - in aggregate
- Costs of intervention strategies
- Program design
- System-specific

Intervention
- Leakage Management:
  - Active Leak Detection
  - Pressure Optimization
  - Repair Time Reduction
  - Network Renewal
- Revenue Protection:
  - Theft Mitigation
  - Meter Optimization & Renewal
  - Billing Data System Integrity
  - Revenue Recovery

Baseline

Technical analysis

Economic analysis

Cost-effectiveness
Component Analysis of Real Losses

Real Losses

==

Background Leakage
- Pressure reduction
- Main & service replacement
- Reduce # of joints and fittings

Unreported Leakage
- Pressure reduction
- Main & service replacement
- Reduce # of joints and fittings
- Proactive leak detection

Reported Leakage
- Pressure reduction
- Main & service replacement
- Optimized repair time
Component Analysis of Real Losses

Background Leakage
- Pressure reduction
- Main & service replacement
- Reduce # of joints and fittings

Unreported Leakage
- Pressure reduction
- Main & service replacement
- Reduce # of joints and fittings
- Proactive leak detection

Reported Leakage
- Pressure reduction
- Main & service replacement
- Optimized repair time
Proactive Metering Testing & Maintenance

- Radio read conversion
- Meter Testing
- Meter remediation based on payback Analysis
Historic Large Meter Testing Program

- Meter selections from payback analysis
- Establishment of testing protocol (M6)
- Field apparatus
- Getting crews setup & training
Pressure Optimization
Pressure Management

Pressure Management: Reduction of Excess Average and Maximum Pressures

<table>
<thead>
<tr>
<th>Conservation Benefits</th>
<th>Water Utility Benefits</th>
<th>Customer Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced Flow Rates</td>
<td>Reduced Frequency of Bursts and Leaks</td>
<td></td>
</tr>
<tr>
<td>Reduced Consumption</td>
<td>Reduced Flow Rates of Leaks and Bursts</td>
<td></td>
</tr>
<tr>
<td>Deferred Renewals and Extended Asset Life</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced Cost of Active Leakage Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fewer Customer Complaints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fewer Problems on Customer Plumbing &amp; Appliances</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Fantozzi & Lambert, 2010

Figure 1: Influence of pressure management on BABE components of Real Losses
Source: Fantozzi & Lambert (2007)
FAVAD – Fixed and Variable Area Discharges

- John May (UK) – 1994
- N1 – Exponent as a function of pipe type
- \[ \text{Leakage}_{\text{Post}} / \text{Leakage}_{\text{Pre}} = (\text{Pressure}_{\text{Post}} / \text{Pressure}_{\text{Pre}})^{N1} \]

Source: Lambert 2003
What causes Breaks?

Mains & Services

Unavoidable Break Frequency

Consumption/Pressure Relationship

Pressure & Break Relationship – The ‘Straw that Breaks the Camel’s Back’ Concept

\[ BF = BF_{npd} + A \times P_{max}^{N2} \]

BF$_{npd}$ is sum of burst frequency components that are independent of changes in pressure

Before Pressure Management $P_0, BF_0$

After Pressure Management $P_1, BF_1$

Burst frequency components that vary partly or wholly with pressure

Source: Thorton & Lambert 2006
Pressure Management

Pressure Zone #1
Avg. Pressure 100 psi
Total Consumption = 500 MG/year
Breaks/year = 15
Annual Real Losses = 50 MG/year
Total Water Pumped = 550 MG/year @ 100 psi

After Pressure Management
Avg. Pressure 75 psi
Total Consumption = 500 MG/year
Breaks/year = 10
Annual Real Losses = 40 MG/year
Total Water Pumped = 540 MG/year @ 75 psi
Less Water Pumped = Energy Saved
Water Pumped at lower pressure = Energy Saved

Critical Point – Minimum Delivery Pressure
Real Losses = Leaks

Operational Costs

<table>
<thead>
<tr>
<th>Reduced Production</th>
<th>$336</th>
<th>$/MG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable Production Cost</td>
<td>$336</td>
<td>$/MG</td>
</tr>
<tr>
<td>Real Loss Reduction</td>
<td>$435.34</td>
<td>$/MG/year</td>
</tr>
<tr>
<td>Annual Cost Savings</td>
<td>$146,243</td>
<td></td>
</tr>
</tbody>
</table>

| Reduced Pumping | $0.00 | $/KWh |
| Energy Cost | $0.00 | $/KWh |
| Energy Reduction | 9,051 | KWh/day |
| Daily Energy Savings | $724 | $/day |
| Annual Energy Savings | $264,293 | $/year |
Billing System Improvements
NRW Program – key points

- Challenges
  - Change of Culture
    - In department and out of department
  - Relating NRW Projects to CIP
  - Keeping Staff Focused on NRW

- Advantages
  - Decrease in Water Loss
  - Team focus – Employee Engagement
  - Improved Communications
  - Improved Business Processes
  - Good Media Answer
Water Loss in MGD (RAA)

RAA = rolling annual average
The Path Forward

Water Supplied

Authorized Consumption

Water Loss

Long-term target based on current cost profile
(Positive ROI to this level)
1. What is Pennsylvania’s driver?
2. Utility survey – Who is doing Audits?
3. Who is currently doing Leak Detection?
4. Is there interest in a Pilot?
Asheville, NC – 10 years of Water Loss Control

... and Counting

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May 10, 2018

Pennsylvania AWWA
American Water Works Association