THE Water Research FOUNDATION

WRF Resources Water Loss Control

Michael Dirks on behalf of Maureen Hodgins

May 2019

WRF Resources on Water Loss Control

	Reference List
Background & State Regulations	
Water Audit Goal	
Level 1 Validation of Water Audits	4639
Water Loss Control Plan	4695
Component Analysis of Real Losses	4372
Pressure Management	2928, 4321, 4695
Halifax Water	Ditto
Pipe Management research	

UK National Leakage Initiative

1990s

IWA *Performance Indicators for Water Supply Services*

2000

IWA Water Loss Group – 27 countries

2015

N. America path

2000s

Introduction to Concepts

WRF 2928
AWWA M36 3rd ed
AWWA FWAS

2010 - 2018

Analyze audits

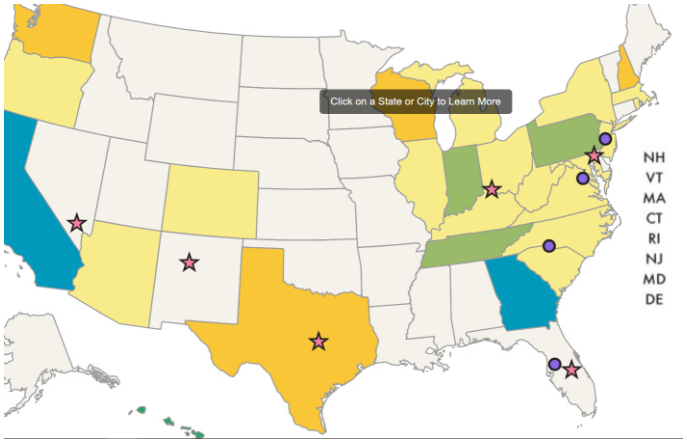
2015 - 2018

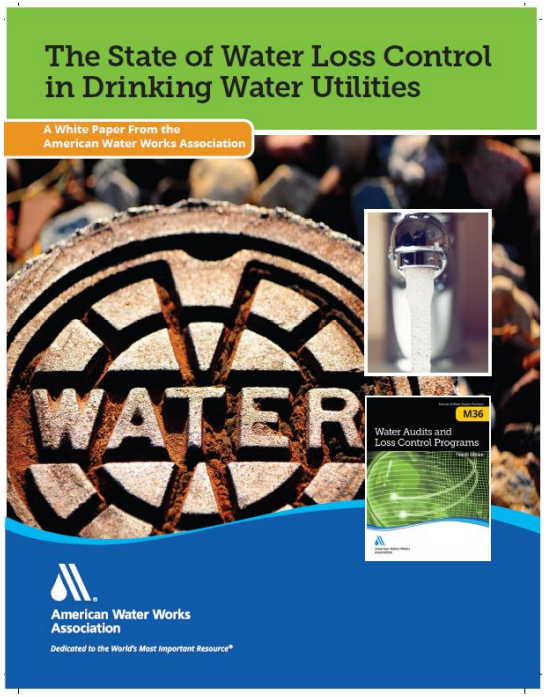
Data Grading & Validation

Utility knowledge
AWWA PI Task force
Regulations

Summary of State Regulations

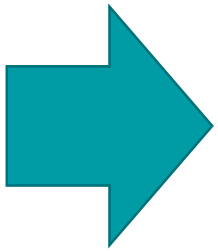
- Cutting Our Losses (nrdc.org)
- 2016, AWWA Summary of States
- GA, Metro Atlanta, TN, CA, HI, IN, PA, PR
- Requirements beyond AWWA terminology (green, dk grn, blue)
  - AWWA FWAS
  - Validated audits
  - Water loss control plans
  - Performance improvement

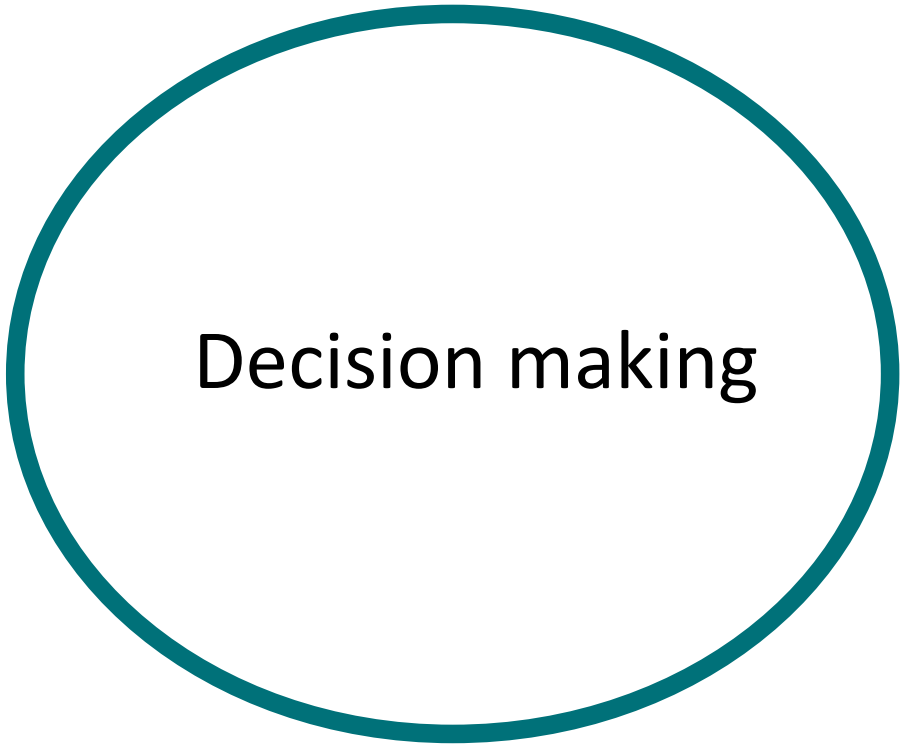




Water Audit Goal

- Systematically account for known water volumes to estimate volumes of Water Loss
- Evaluate data source reliability
- Communicate water distribution efficiency





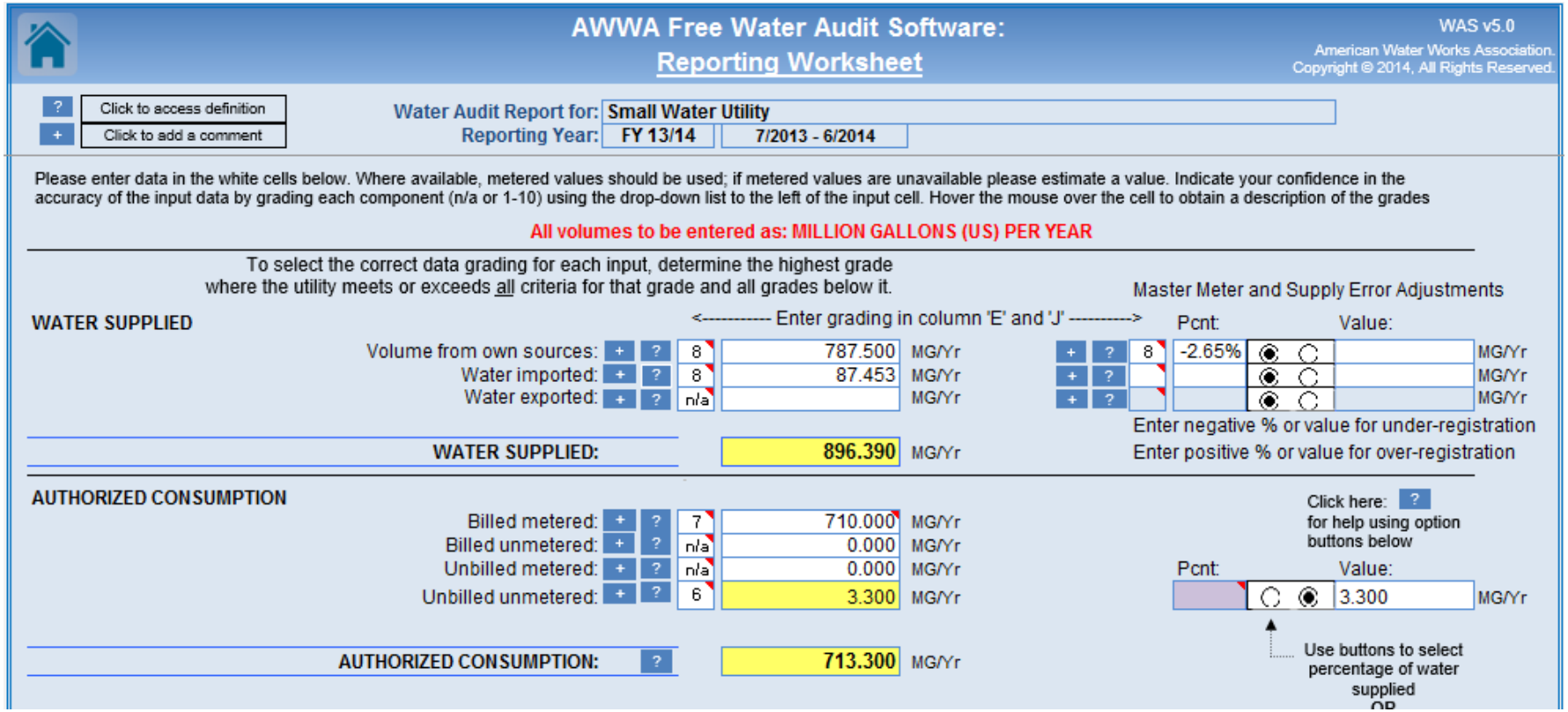
Water Audit

<table>
<tr><td rowspan="6">WATER SUPPLIED</td><td rowspan="3">AUTHORIZED CONSUMPTION</td><td rowspan="2">BILLED AUTHORIZED CONSUMPTION</td><td>BILLED METERED CONSUMPTION</td><td rowspan="2">REVENUE WATER</td></tr>
<tr><td>BILLED UNMETERED CONSUMPTION</td></tr>
<tr><td rowspan="2">UNBILLED AUTHORIZED CONSUMPTION</td><td>UNBILLED METERED CONSUMPTION</td><td rowspan="4">NONREVENUE WATER</td></tr>
<tr><td>UNBILLED UNMETERED CONSUMPTION</td></tr>
<tr><td rowspan="3">WATER LOSSES</td><td rowspan="3">APPARENT LOSSES</td><td>CUSTOMER METER INACCURACIES</td></tr>
<tr><td>UNAUTHORIZED CONSUMPTION</td></tr>
<tr><td>DATA HANDLING ERRORS</td></tr>
<tr><td colspan="3">REAL LOSSES</td></tr>
</table>

Adapted from Kunkel, George et al. ***Manual of Water Supply Practices M36: Water Audits and Loss Control Programs***, 4th ed. Denver: American Water Works Association, 2016.

What is a water audit?

AWWA Free Water Audit Software

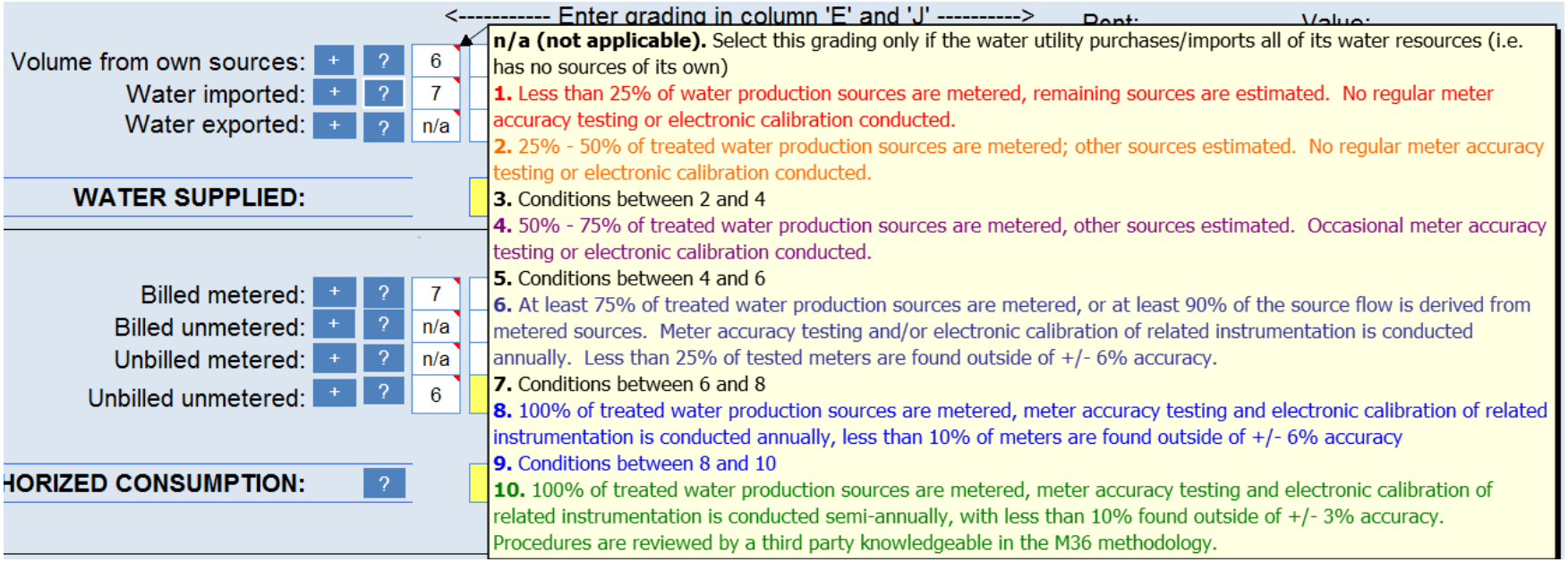


Water Loss Control Committee. ***AWWA Free Water Audit Software*** (version 5.0). Microsoft Excel. Denver: American Water Works Association, 2014.

What is a water audit?

Data validity grades

- 1 to 10 scale corresponding to qualitative criteria
- Focus on best practices – instrument maintenance, data review



Water Loss Control Committee. ***AWWA Free Water Audit Software*** (version 5.0). Microsoft Excel. Denver: American Water Works Association, 2014.

What is water audit validation?

Water Research Foundation 4372B

– Many self-reported water audits are unrealistic

	CA	DRBC	GA	TN	TX
total audits	300	517	452	629	2,646
# of unrealistic audits	100	130	74	122	1,065
% of unrealistic audits	***33%***	***25%***	***16%***	***19%***	***40%***

– Validation required to improve water audit inputs and results

Sturm, R., K. Gasner, and L. Andrews. 2015. Water Audits in the United States: A Review of Water Losses and Data Validity. Project #4372B. Denver, Colo.: Water Research Foundation.

Guidance for Validating Water Audits

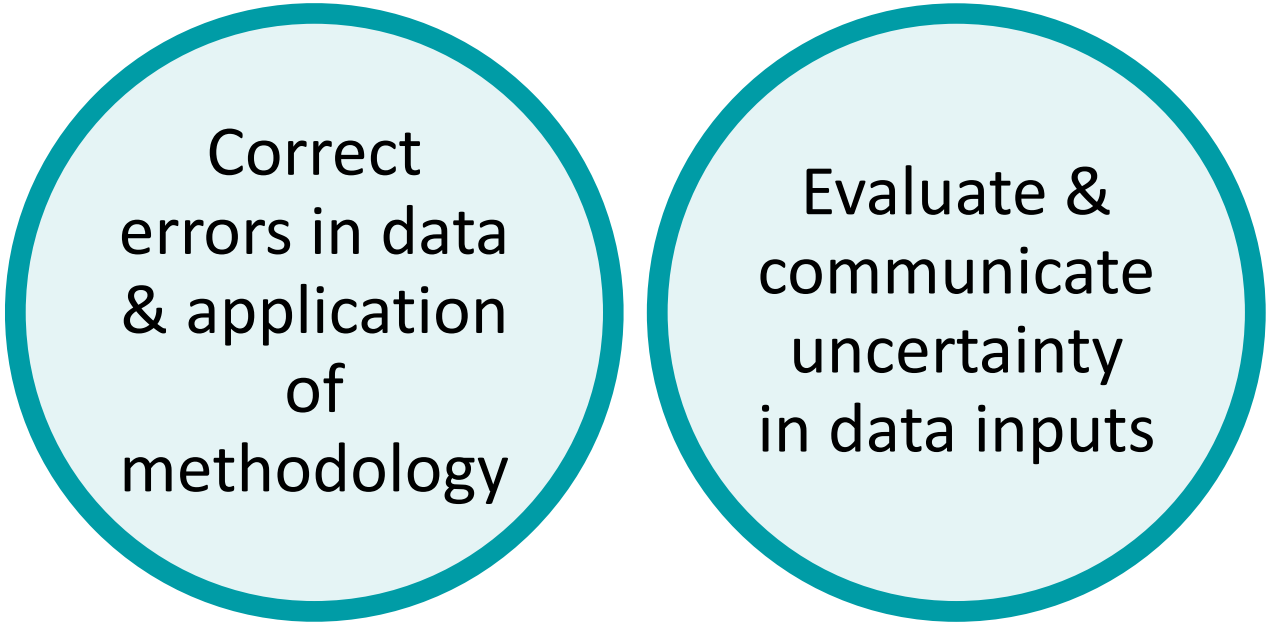
Year Published	Title	Authors *all part of AWWA WLCC
2015	WRF's 4639, Level 1 Water Audit Validation: Guidance Manual	WSO, George Kunkel, and Cavanaugh
2016	Georgia Water Systems Audits and Water Loss Control Manual, version 2	Kathy Nguyen, Brian Skeens, Will Jernigan
2018	CA-NV AWWA's Water Audit Validator Certificate Course Training Manual	WSO and Cavanaugh

All build off of the initial ideas from the AWWA WLCC

State specifics

GA and CA: validator certification exam

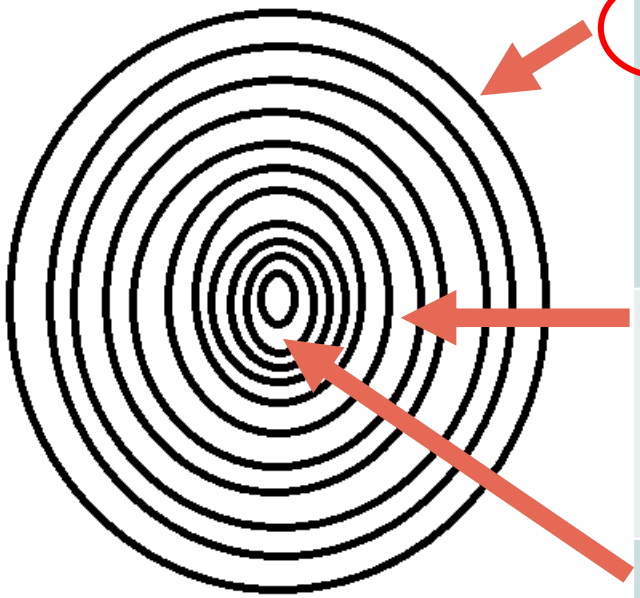
Validation Goals - Overarching



- Sources of Error: instruments, databases, people, missing information

- Data quality matters
- Inaccuracy & uncertainty of inputs & results

Levels of Validation



Imagine an onion

Validation Level	Description
1	High level review -Examine audit for errors evident in summary data & application of method -Data validity grades assigned to inputs reflect utility practices
2	Data Mining -Investigate raw data and historical reports of instrument accuracy -Use best data sources
3	Field Investigations -Field tests of instrument accuracy -Minimum night flow analysis -Pilot leak detection

Adapted from: Andrews, L., K. Gasner, R. Sturm, W. Jernigan, S. Cavanaugh, and G. Kunkel. 2016. *Level 1 Water Audit Validation*. Project #4639. Denver, Colo.: Water Research Foundation.

How do you perform level 1 validation?

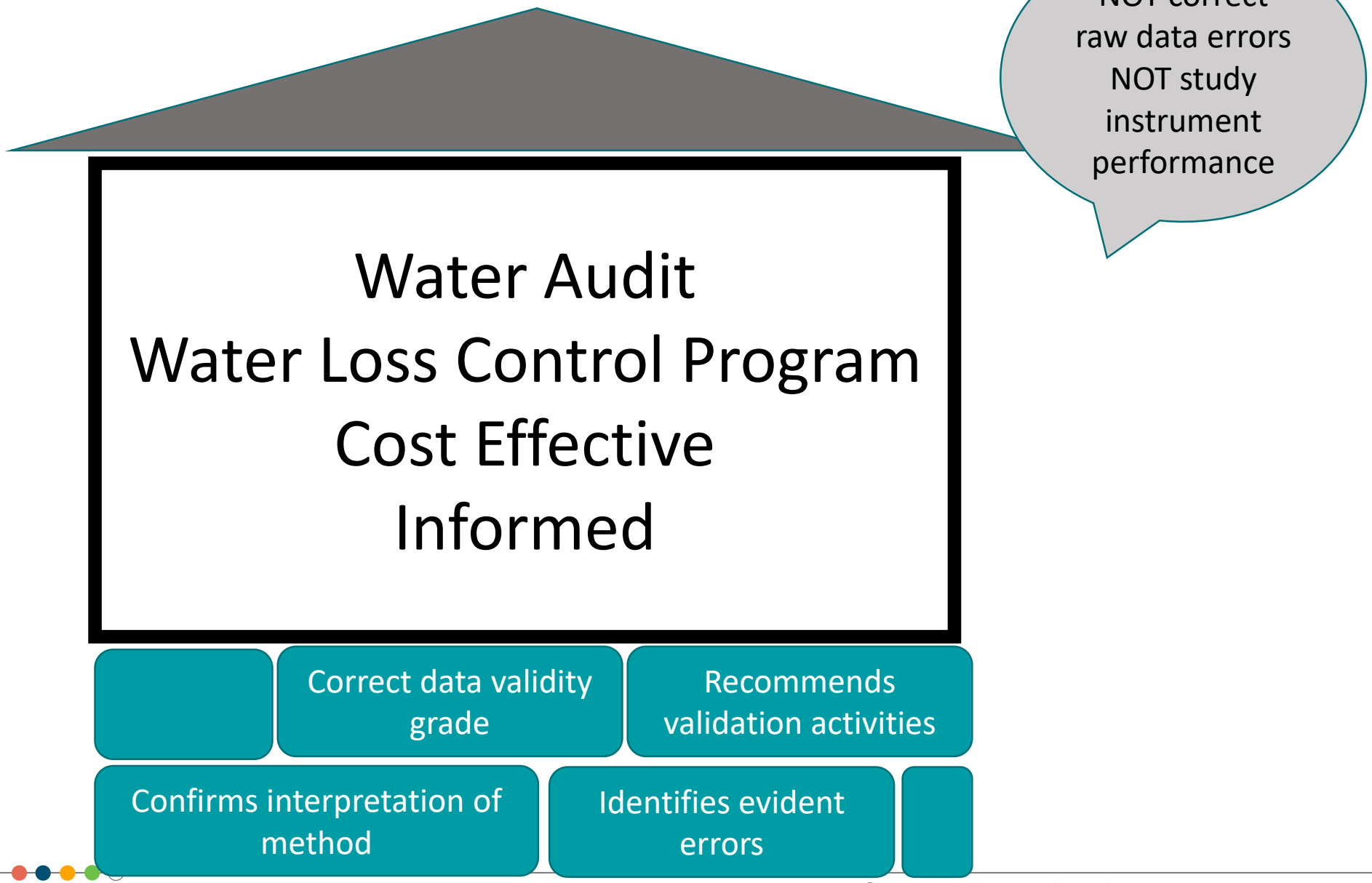
1. Collect audit and request supporting documents.
2. Examine initial performance indicators.
3. Validate audit inputs.
4. Re-examine performance indicators.
5. Document results.

Andrews, L., K. Gasner, R. Sturm, G. Kunkel, W. Jernigan, and S. Cavanaugh. 2016/2017. Level 1 Water Audit Validation. Project #4639. Denver, Colo.: Water Research Foundation.

Red Flags & Rules of Thumb

Indicators/Inputs	WRF 4639, 2016	GA Training 2019 (Carter, D., K. Nguyen, D. Kubala, B. Skeens, L. Moeti, E. Urheim, W. Jernigan, and J. Jay. 2016. Georgia Water System Audits and Water Loss Control Manual, Version 2.0. Georgia: Georgia Department of Natural Resources.)
Real Losses	< 0 (You can't have negative loss) > Total system operating costs	
Cost of Non-Revenue Water		
Incomplete Audit	-	Key fields empty
Real Losses Normalized, gal/con/day	> 0	20-200, Median 40
Variable Production Cost, $/MG	-	$200-$1,000
Infrastructure Leakage Index, ILI	> 1.0	2-10
Apparent Losses Normalized, gal/con/day	>0	1-40, Median 5
Customer Retail Cost, $/1,000 gal		$2.00-$10.00, Median $4

Level 1 Validation of Water Audit



Comparison to others' water audits

Evolving

Focus on Self
If advanced, look at benchmarking

Data Set	Analysis
AWWA Water Audit Data Initiative, 2011-2017	AWWA, WRF 4639 (2019)
Georgia, 2011 - 2017	WRF 4372b (2015)
California, 2018	?

Water Audit Results (Refs next slide)

	Performance Indicators (Average or Median)	GA 2013	GA 2013	WADI 2015	CA 2018	WADI Plus 2009-2017
Volumetric	Water Losses per Service Connection per Day (gal)				40.5	
	Apparent Losses per Service Connection per Day (gal)	5.96	5	14.8	8.6	7.8
	Real Losses per Service Connection per Day (gal)	51.57	40	83.2	31	41
	Real Losses per Service Connection per Day per PSI	0.75			0.4	0.57
	Infrastructure Leakage Index (ILI)	2.5	3	4	1.9	2.2
Financial	Annual Cost of Apparent Losses				$153,789	$355,000
	Annual Cost of Real Losses				$219,769	$261,000
	Non-Revenue Water as a % of Total Operating Cost	6.7%	6.4%		3.9%	5.4%
	Data Validity Score	59.4		79	60	71
	Sample size	188	226		279	223
	Reference	1	2	3	4	5

References (for previous slide)

1. Sturm, R., K. Gasner, and L. Andrews. 2015. Water Audits in the United States: A Review of Water Losses and Data Validity.
   Project #4372B. Denver, Colo.: Water Research Foundation.
2. Carter, D., K. Nguyen, D. Kubala, B. Skeens, L. Moeti, E. Urheim, W. Jernigan, and J. Jay. 2016. Georgia Water System Audits and Water Loss Control Manual, Version 2.0. Georgia: Georgia Department of Natural Resources.
3. Sayers, D., W. Jernigan, G. Kunkel, and A. Chastain-Howley. 2016. The Water Audit Data Initiative: Fiver Years and Accounting. Journal AWWA, November 2016 (108:11).
4. Water Systems Optimization, Inc. and Cavanaugh & Associates. 2018. Water Loss Technical Assistance Program Final Report. CA: The California Nevada Section of the American Water Works Association.
5. Trachtman, G., J. Cooper, S. Sriboonlue, A. Wyatt, S. Davis, and G. Kunkel. Forthcoming. Guidance on Implementing an Effective Water Loss Control Plan. #4965. Denver, Colo.: Water Research Foundation.

- Note: Reference 3 and 5 is from utilities all around N. America.

WADI Plus Median FWAS Indicators

223 audits
68 utilities
2009-2017
US & Canada

	System Configuration / Context		Median Value
	Connections	Conns	32,250
	Connection Density	Conns/Mile	60
	Average Operating Pressure	psi	71
	Billed Authorized Consumption (BAC)	Gals/Conn/Day	306
**	Customer Retail Unit Cost (CRUC)	$ / 1000 gallons	$4.83
**	Variable Production Cost (VPC)	$ / 1000 gallons	$0.43
	Data Validity Score		71
	Volumetric Indicators		
	Apparent Loss Volume	Gals/Conn/Day	7.8
	Real Loss Volume	Gals/Conn/Day	41
	NRW / System Input Volume	%	18.5%
	Real Loss / Average Operating Pressure	Gals/Conn/Day/psi	0.57
	Infrastructure Leakage Index (ILI)		2.2
	Financial Indicators		
**	Apparent Loss Value	1000 $ / Year	$355
**	Real Loss Value	1000 $ / Year	$261
**	NRW Value / Water Operating Cost	%	5.4%

** May require further validation

Source: Trachtman, G. et al. Forthcoming. *Guidance on Implementing an Effective Water Loss Control Plan*. #4965. Denver, Colo.: Water Research Foundation.

Can add slide from WADI based on Region

Initial Water Loss Control Program

- 1-2 yrs water audits
- Data understanding!!!
- No target setting for PI
- Improve data validity
- Capture easily recoverable losses

Source: Trachtman, G. et al. Forthcoming. *Guidance on Implementing an Effectiven Water Loss Control Plan*. #4965. Denver, Colo.: Water Research Foundation.

AWWA Free Water Audit Software:
Determining Water Loss Standing

Water Audit Report for:	**<< Please enter system details and contact information on the Instructions tab >>**	
Reporting Year:		
Data Validity Score:	**N/A***	*** Confirm Units and Data Grading are Complete**

Functional Focus Area	Level I (0-25)	Level II (26-50)	Level III (51-70)	Level IV (71-90)	Level V (91-100)
Audit Data Collection	Launch auditing and loss control team; address production metering deficiencies	Analyze business process for customer metering and billing functions and water supply operations. Identify data gaps.	Establish/revise policies and procedures for data collection	Refine data collection practices and establish as routine business process	Annual water audit is a reliable gauge of year-to-year water efficiency standing
Short-term loss control	Research information on leak detection programs. Begin flowcharting analysis of customer billing system	Conduct loss assessment investigations on a sample portion of the system: customer meter testing, leak survey, unauthorized consumption, etc.	Establish ongoing mechanisms for customer meter accuracy testing, active leakage control and infrastructure monitoring	Refine, enhance or expand ongoing programs based upon economic justification	Stay abreast of improvements in metering, meter reading, billing, leakage management and infrastructure rehabilitation
Long-term loss control		Begin to assess long-term needs requiring large expenditure: customer meter replacement, water main replacement program, new customer billing system or Automatic Meter Reading (AMR) system.	Begin to assemble economic business case for long-term needs based upon improved data becoming available through the water audit process.	Conduct detailed planning, budgeting and launch of comprehensive improvements for metering, billing or infrastructure management	Continue incremental improvements in short-term and long-term loss control interventions
Target-setting			Establish long-term apparent and real loss reduction goals (+10 year horizon)	Establish mid-range (5 year horizon) apparent and real loss reduction goals	Evaluate and refine loss control goals on a yearly basis
Benchmarking			Preliminary Comparisons - can begin to rely upon the Infrastructure Leakage Index (ILI) for performance comparisons for real losses (see below table)	Performance Benchmarking - ILI is meaningful in comparing real loss standing	Identify Best Practices/ Best in class - the ILI is very reliable as a real loss performance indicator for best in class service

For validity scores of 50 or below, the shaded blocks should not be focus areas until better data validity is achieved.

Source: Adapted from AWWA Free Water Audit Software. Copyright © 2014 AWWA

M36, 4th ed

Potential Activities of a Water Loss Control Program – Short, Medium and Long Term			
Water Auditing Activities		**Apparent Loss Control Activities**	**Real Loss Control Activities**
S: Top-down water audit	**S**: Verify accuracy of production flowmeters (*this is a very important procedure!*)		**S**: Review maintenance records, gather and summarize statistics on water system failures (leaks and breaks). Establish this process and improve performance, as described in M36 Ch 7.
M: Start bottom-up water audit by launching field investigations into specific loss occurrences.		**S:** Flowchart the customer billing process; compile general statistics on the demographics of the customer/meter population.	**S:** Review policies for customer service connection piping ownership and maintenance, and opportunity to reduce customer service connection piping leakage durations.
	Ongoing: Bottom-up water audit: gather field measurement data and	**S**: Perform meter accuracy testing on a small sample of customer meters. Place priority on larger commercial and industrial account meters.**	**S**: Conduct an initial leak detection survey; perhaps via a leak detection contractor; consider use of leak noise monitors.
		S: Audit billing records and visit premises of a representative sample of customer accounts to determine the potential for missed billings or unauthorized consumption.	**S**: Compile data on the variation of water pressure throughout the water distribution system. Identify areas of excessive pressure and evaluate potential for proactive pressure management.
Ongoing: Bottom-up water		**M**: Install, upgrade, or replace	**S**: Establish a pilot District

SOURCE: ADAPTED FROM AWWA 2016.

Water Loss Control Program

- 3-5 yrs water audits
- Analyze trends for relevant PI
- Set targets
- Evaluate candidate strategies

Source: Trachtman, G. et al. Forthcoming. *Guidance on Implementing an Effective Water Loss Control Plan*. #4965. Denver, Colo.: Water Research Foundation.

4695 Situational Assessment - Levels

TABLE 2.2 CRITERIA FOR SELECTION OF ASSESSMENT PROTOCOL			
Criterion	Beginner	Intermediate	Advanced
Years of Validated Audit Completed	None or One	Three to Five	Greater than Five
Data Validity Score	Less than 51	Between 52 and 71	Greater than 71
NRW Management Experience	Activities not underway or just beginning	Activities underway for less than five years	Activities underway for over five years
NRW Management Plan in Place?	No	Probably only an "informal" plan	Yes – with objectives, ongoing activities, and monitoring

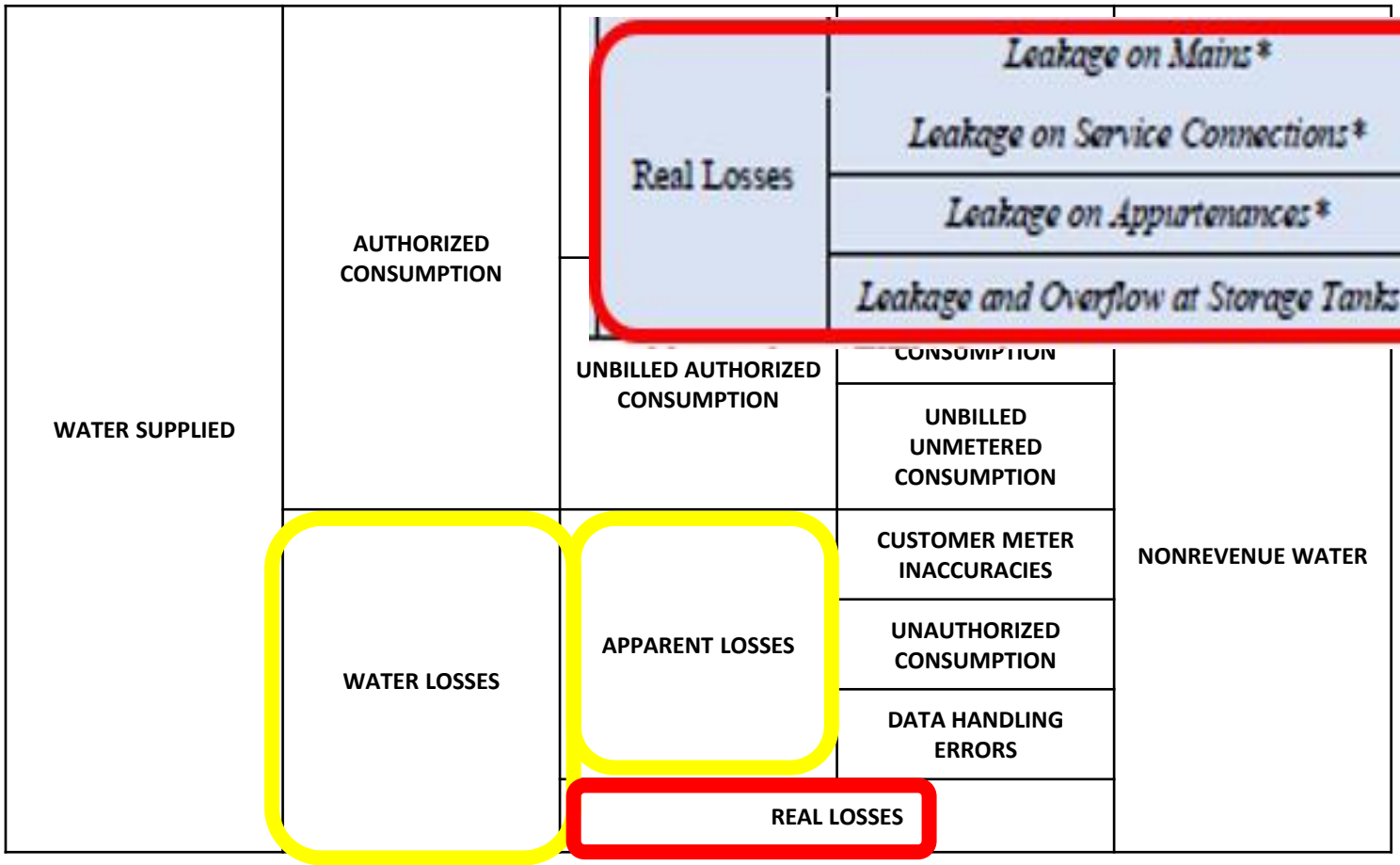
Source: Trachtman, G. et al. Forthcoming. *Guidance on Implementing an Effective Water Loss Control Plan*. #4965. Denver, Colo.: Water Research Foundation.

4695 Situational Assessment

Step	Purpose
1. Review Water Audit and Validation	Determine Volumes and Values of NRW Components and Audit Validity
2. Conduct Trend Analysis	Detect changes in NRW volumes and values; identify problems or errors
3. Conduct Uncertainty Analysis	Determine statistical confidence of volumes and values of NRW Components
4. Benchmark Current Performance	Performance on NRW Components to help set Program Objectives
5. Assess Apparent Loss in Detail	Identify sources and causes of apparent loss components to help select reduction strategies
6. Assess Real Loss in Detail	Identify sources and causes of real loss components to help select reduction strategies
7. Conduct Practices Assessment	Identify current practices underway and gaps in the Program portfolio
8. Assess Drivers and Constraints	Identify particular drivers or constraints with regard to the NRW Program

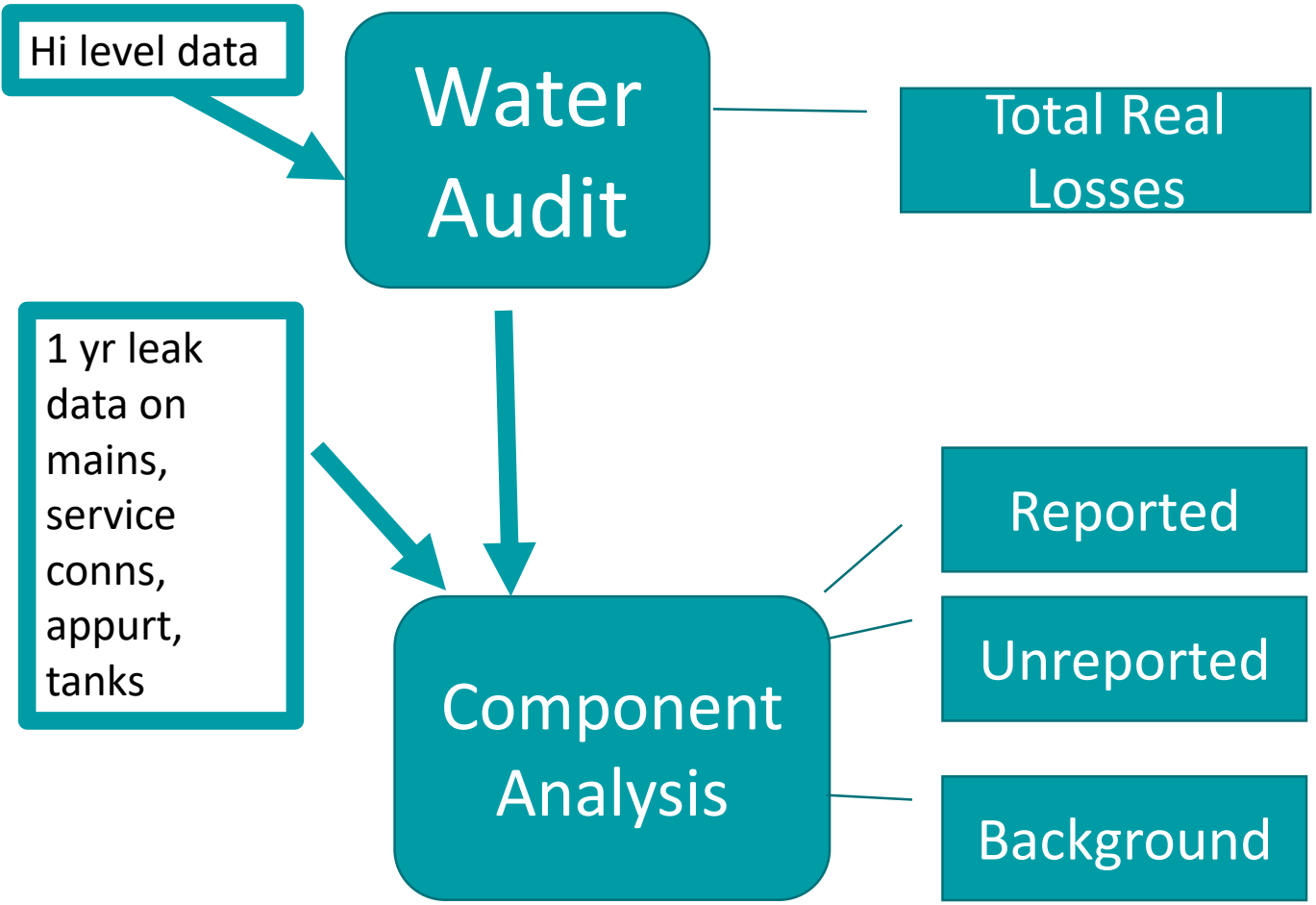
Source: Trachtman, G. et al. Forthcoming. *Guidance on Implementing an Effective Water Loss Control Plan*. #4965. Denver, Colo.: Water Research Foundation.

Component Analysis of Real Losses



Adapted from Kunkel, George et al. ***Manual of Water Supply Practices M36: Water Audits and Loss Control Programs***, 4th ed. Denver: American Water Works Association, 2016.

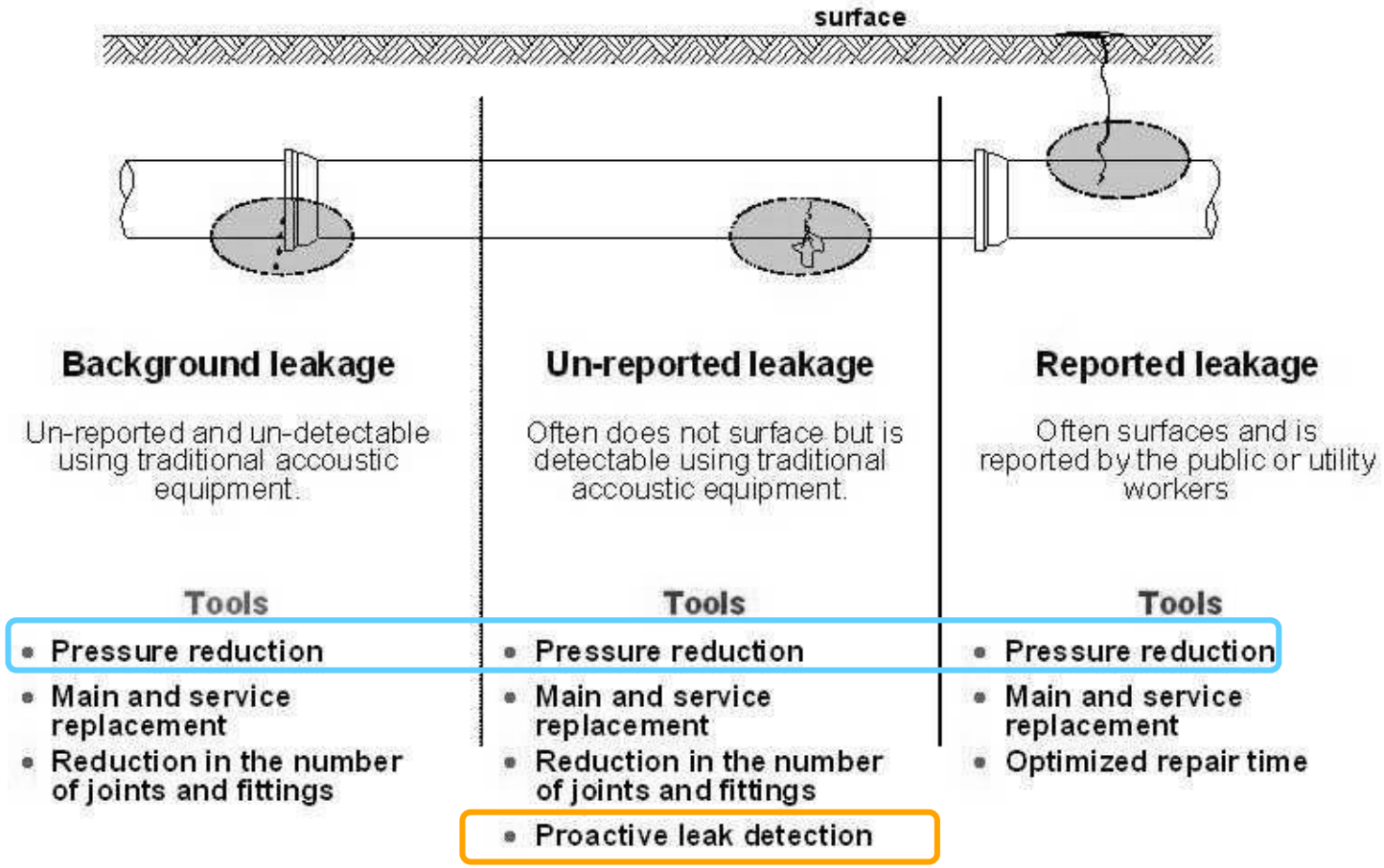
Component Analysis of Real Losses (WRF 4372a, WSO, 2014)



Optimize Strategies

- **Locate/repair leaks**
- **Leak detection campaigns**
- **Pressure management**

Investing in the Right Interventions



From Filho 2004

Pressure Management Goals (4109)

- Distribution System Optimization
  - Disinfectant residual
  - **Pressure management**
  - Main breaks
- Optimized Pressure Management Goals
  - >0 psi during emergencies
  - > 20 psi under max day and fire flow conditions
  - Between 35 – 100 psi under normal conditions
- Optimized Pressure Monitoring
  - Min 2 pressure recorders in each pressure zone, placed at min and max pressure locations

Source: Friedman et al. 2010. *Criteria for Optimized Distribution Systems*. #4109. Denver, Colo.: Water Research Foundation.

Pressure Mgmt – Industry Practices (4321)

- Pressure management is fundamental to protecting public health, maintaining infrastructure, & effective utility management.
- Although pressure monitoring is required by regulations, implementation varies across the country
  - Permanently installed monitors do not exist in all pressure zones
  - Routine pressure monitoring is mostly at convenient locations
  - Most pressure monitors either never calibrated or annual calibration
  - Monitoring frequency does not capture short term events
- Negative pressure events may occur
  - Main breaks, power outages may occur routinely
  - Power outages may cause regional depressurization events

Source: LeChevallier, M. et al. 2014. *Pressure Management: Industry Practices and Monitoring Procedures*. #4321. Denver, Colo.: Water Research Foundation.

Halifax Water – Pressure Mgmt

	1999	2013
Pressure	55 pressure zones	75 DMA, 110 pressure control & metering stations
ILI	9.0	2.5
Real Losses, g/sc/d	143	44
System inputs		Less 10.6 M gal/day
Water Production Costs		Savings $600,000/yr

2007, Fanner et al. Leakage Management Technologies, 2928.
2014, Canadian Society of Civil Engineers Conference
2016, The Evolution of Pressure Management

Dartmouth Central DMA

- 2 incoming feeds and 3 outgoing feeds
- Flow Modulated PC test
  - reduced background leakage
  - Did not impact consumption
- Implemented
  - 80% of main breaks occur at night when pressure creeps up
  - Reduce breaks from 32 to 17/yr
  - Minimum night flows reduced about 10%
  - Problems controlling the 2 supply flows, yet solved

PAYBACK PERIODS - PRESSURE MANAGEMENT

City	Estimated Reduction in Mains Breaks	Estimated Net Annual Financial Savings	Estimated Initial Cost	Simple Payback Period, years
Asheville, NC	Good	$30,800	$45,000	**1.5**
	50%	$228,856	$500,000	**2.2**
El Dorado, CA	Data not reported	$4,000	$13,000	**3.3**
Farmington Hill, MI	Data not reported	$3,300,000	$16,000,000	**4.8**
Halifax, NS	50%	$60,000	$200,000	**3.3**
Near Cookeville, TN	Data not reported	$30,300	$19,000	**0.6**
Philadelphia, PA	Data not reported	$102,500 real loss savings & $32,000 revenue loss	$392,000	**5.6**
Pittsburgh, PA	Estimated at 60%	$1,400,000	$5,000,000 approximately	**3.6**
Toronto, ON	6-8 breaks/year fell to zero in 1st year	$38,903	$163,800	**4.0 - 4.5**
York Region, Ontario	Data not reported	$224,000	$697,600	**3.1**
Trabuco Canyon, CA	Data not reported	$120,000	$216,000	**1.8**
			Average	**3.1**
			Median	**3.3**

Source: Trachtman, G. et al. Forthcoming. *Guidance on Implementing an Effective Water Loss Control Plan*. #4965. Denver, Colo.: Water Research Foundation.

4917, Utilizing Smart Water Networks to Manage Pressure and Flow to Reduce Water Loss and Extend Useful Life of Pipes

- Utilize smart water network solutions to help water utilities better manage pressures and flows to extend the life of the piping network and reduce water loss.
- Four case studies
- Deliverable: a a guidance manual of best practices for implementing smart water network technology

WRF Pipe Management

Visual Guidance for Common Pipe Failures - 4490 (2017)

Research Area - Water Utility Infrastructure: Applying Risk Management Principles and Innovative Technologies to Effectively Manage Deteriorating Infrastructure

Plastic Pipe State of the Science of Plastic Pipe – 4680 (2016)

Durability and Reliability of Large Diameter HDPE Pipe for Water Main Applications – 4485 (2015)

Investigation of Buried Large-Diameter Steel Pipes with Controlled Low-Strength Material (#4587) - design criteria

Long-Term Performance Prediction of Steel Pipe (#4318)

Leveraging Data from Non-Destructive Examinations to Help Select Ferrous Water Mains for Renewal – 4471, 2018

The Assess-and-Fix Approach: Using Non-Destructive Evaluations to Help Select Pipe Renewal Methods – 4473, 2015

Retrofit and Management of Metallic Pipe with Cathodic Protection – 4618, 2018

WRF is sponsored by a once/yr annual subscription. Please contact mdirks@waterrf.org, 303.3476104 for questions about supporting and sponsoring WRF, utility:utility research collaboration.

For more on this subject, please contact Maureen!

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