Finding Lead Service Lines – Tools and Techniques – What Works?

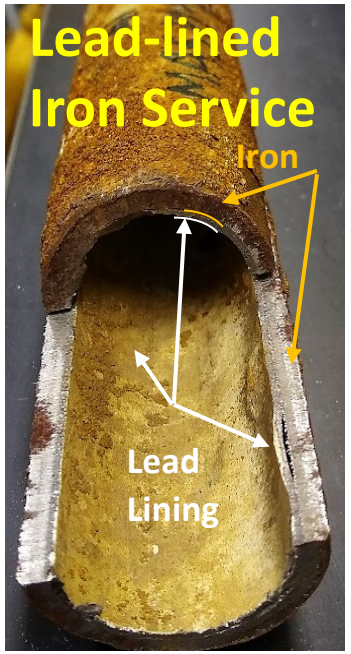
Simoni Triantafyllidou, US EPA Office Of Research and Development (ORD)
Christina Devine, ORISE postdoctoral fellow at US EPA ORD

November 14, 2022

Outline

- The challenge of legacy lead service lines
- Pros/cons of lead service line identification tools
  - Preliminary records screening
  - Community records screening
  - Basic/visual identification
  - Tap water sampling
  - Excavation
- Step-wise lead service line identification approach
- Case studies
- Summary

Legacy lead and lead-lined pipes are primary contributors to water lead contamination



Triantafyllidou et al., 2021
Variability and sampling of lead (Pb) in drinking water.

What constitutes a “lead service line”?
The definition may differ depending on context

Regulatory definition under the federal LCRR

- The Lead and Copper Rule Revisions (LCRR) were published in 2021
- Requirement for Initial Service Line Inventory (by 2024) to identify public-side and private-side:
  - Lead Service Lines (LSLs)
  - Galvanized Requiring Replacement (GRR) Service Lines
  - Lead Status Unknown Service Lines
  - Non-Lead Service Lines
- Guidance for Developing and Maintaining a Service Line Inventory was released in 2022

Galvanized requiring replacement	A galvanized service line that is or was at any time downstream of a lead service line or is currently downstream of a lead status unknown service line. If the water system is unable to demonstrate that the galvanized service line was never downstream of a lead service line, it must presume there was an upstream lead service line (40 CFR §141.84(a)(4)(ii)).
Galvanized service line	Iron or steel piping that has been dipped in zinc to prevent corrosion and rusting (40 CFR §141.2).
Gooseneck, pigtail, or connector	A short section of piping, typically not exceeding two feet, which can be bent and used for connections between rigid service piping. For purposes of this subpart, lead goosenecks, pigtails, and connectors are not considered to be part of the lead service line but may be required to be replaced pursuant to §141.84(c)[4] (40 CFR §141.2).
Lead service line	A portion of pipe that is made of lead, which connects the water main to the building inlet. A lead service line may be owned by the water system, owned by the property owner, or both. For the purposes of this subpart, a galvanized service line is considered a lead service line if it ever was or is currently downstream of any lead service line or service line of unknown material. If the only lead piping serving the home is a lead gooseneck, pigtail, or connector, and it is not a galvanized service line that is considered a lead service line, the service line is not a lead service line (40 CFR §141.2).
Lead status unknown service line	A service line where the material is not known to be lead, galvanized requiring replacement, or a non-lead service line, such as where there is no documented evidence supporting material classification. It is not necessary to physically verify the material composition (*e.g.*,, copper or plastic) of a service line for its lead status to be identified (*e.g.*, records demonstrating the service line was installed after a municipal, state, or federal lead ban[3]) (40 CFR §141.2).
Non-lead	A service line that is determined through an evidence-based record, method, or technique not to be lead or galvanized requiring replacement (40 CFR § 141.84(a)(4)(iii)).

US EPA 2022, Guidance for Developing and Maintaining a Service Line Inventory (link includes guidance template and recording) https://www.epa.gov/ground-water-and-drinking-water/revised-lead-and-copper-rule

LSL inventories - States

Lead Service Line Inventory Includes	WI (2004/2018)	OH (2016)	IL (2018)	CA (2018)	MI (2020)	NJ (2021)	Federal LCRR (2024)
Private-side (in addition to public-side)	Yes (since 2018)	Yes	Yes			Yes	Yes
Lead gooseneck		Yes		Yes		Yes	
Galvanized	Yes	Yes	Yes	Yes		Yes	
Galvanized previously connected to lead					Yes		Yes
Unknown	• Unknown • Unknown-May contain Lead	• Unknown - No Lead • Unknown - May be Lead	• Unknown - Not lead • Unknown	Unknown	• Unknown • Unknown-likely Lead	Unknown	Lead Status Unknown

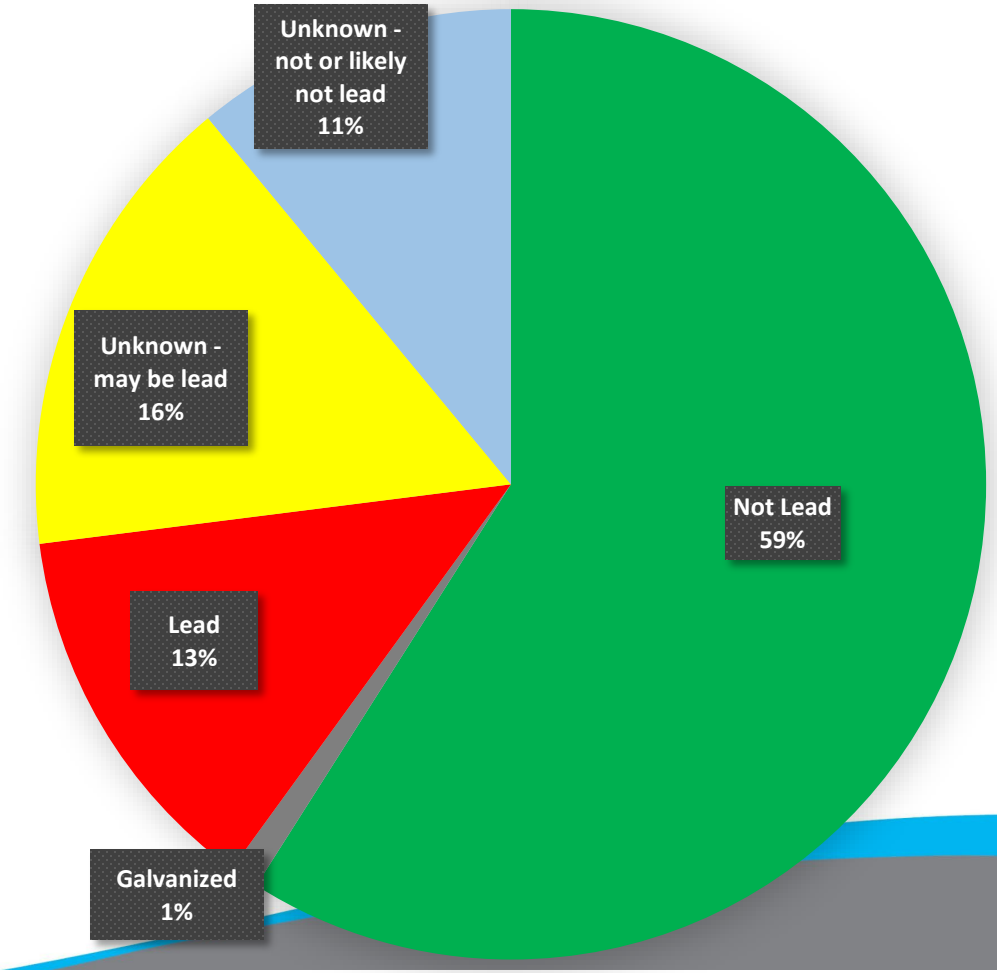
Voluntary service line surveys in IN, MA, NC, and WA not included
State requirements from ASDWA (Association of State Drinking Water Administrators) 2019. https://www.asdwa. org/wp-content/uploads/2019/08/ASDWA_Developing-LeadService-Line-Inventories.pdf
Additional State requirement for NJ (2021) from https://www.nj.gov/dep/lead/replacement.html and https://pub.njleg.state.nj.us/Bills/2020/PL21/183_.PDF
Federal LCRR requirement from https://www.epa.gov/system/files/documents/2022-08/Inventory%20Guidance_August%202022_508%20compliant.pdf

LSL estimates – States with history of LSLs

Publicly available data:

- Michigan EGLE (2020)
- Illinois EPA (2020)
- Wisconsin PSC (2020)
- Indiana, including lead goosenecks (via EDF, 2018)

- Any updated information since then not reflected



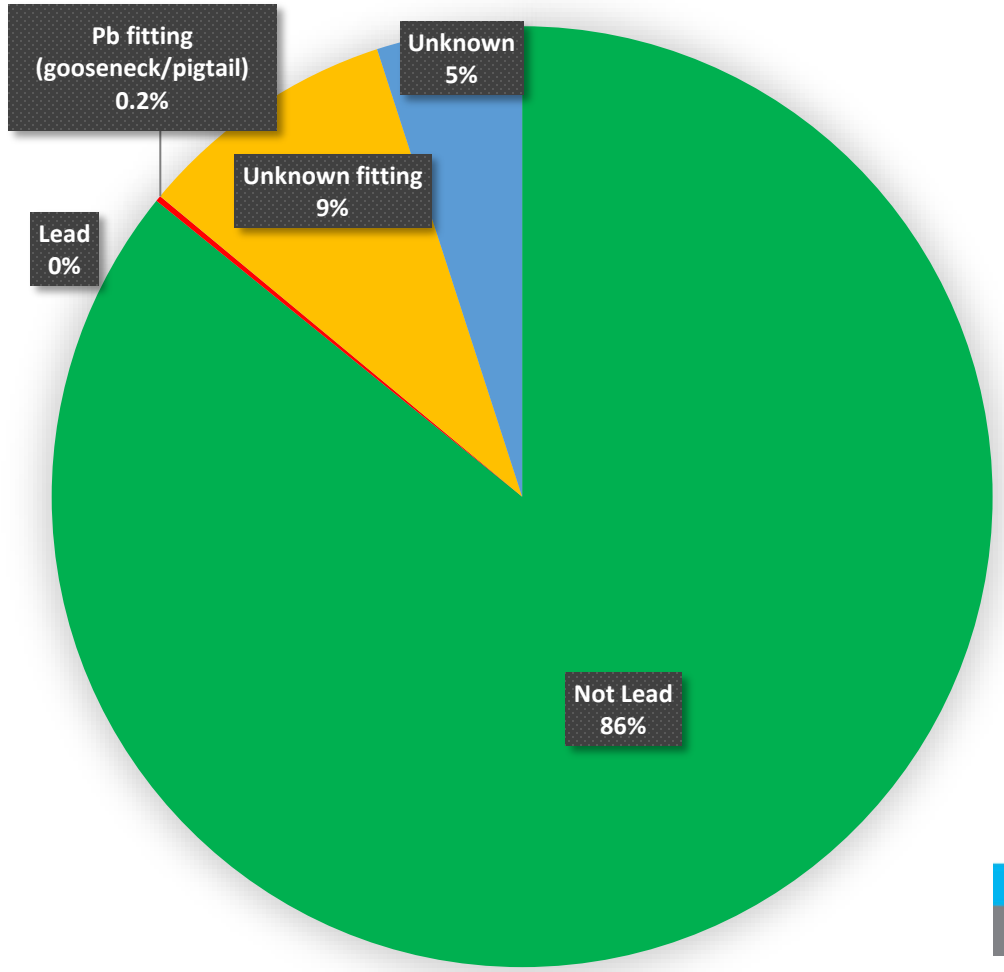
- 13% LSLs
- 16% unknown SLs that may be lead (> 1.58 million SLs)

From Hensley, Bosscher, Triantafyllidou , Lytle, 2021, AWWA Water Science
"Lead Service Line Identification: A Review of Strategies and Approaches"
https://awwa.onlinelibrary.wiley.com/doi/abs/10.1002/aws2.1226

LSL estimates – State without history of LSLs

Publicly available data:

- California Waterboards (2018)
- Any updated information since then not reflected



- Practically 0% LSLs (0.002%)
- 0.2% lead fittings
- 9% unknown fittings that may be lead
- 5% unknown SLs

From Hensley, Bosscher, Triantafyllidou , Lytle, 2021, AWWA Water Science "Lead Service Line Identification: A Review of Strategies and Approaches" https://awwa.onlinelibrary.wiley.com/doi/abs/10.1002/aws2.1226

Received: 5 February 2021 | Revised: 8 April 2021 | Accepted: 23 April 2021
DOI: 10.1002/aws2.1226

REVIEW ARTICLE

AWWA WATER SCIENCE

Lead service line identification: A review of strategies and approaches

Kelsey Hensley[1] | Valerie Bosscher[2] | Simoni Triantafyllidou[3] | Darren A. Lytle[3]

[1]EPA Region 3, Applied Science and Quality Assurance Branch, U.S. Environmental Protection Agency, Philadelphia, Pennsylvania, USA
[2]EPA Region 5, Ground Water & Drinking Water Branch, U.S. Environmental Protection Agency, Chicago, Illinois, USA
[3]U.S. Environmental Protection Agency, Office of Research and Development, Center for Environmental Solutions & Emergency Response, Water Infrastructure Division, Cincinnati, Ohio, USA

Correspondence
Darren A. Lytle, U.S. Environmental Protection Agency, Office of Research and Development, Drinking Water Management Branch, Center for Environmental Solutions & Emergency Response, Water Infrastructure Division; 26 W. Martin Luther King Dr., Cincinnati, OH 45268, USA.
Email: lytle.darren@epa.gov

Funding information
U.S. Environmental Protection Agency

Abstract

Lead service lines (LSLs) represent the greatest source of lead in drinking water. Identifying the locations of LSLs can be challenging, and recent service line (SL) material surveys in Michigan, Illinois, Wisconsin, and Indiana found that on average the materials making up 16% of SLs in these states are unknown and may be lead. Given the large number of possible LSLs in the United States, new and pending regulatory requirements, LSL replacement costs, associated lead exposure risks, and the public's desire to reduce lead exposure, there is a need to rapidly and cost-effectively identify where LSLs are located, on public and private property. This review summarizes current industry LSL identification methods, including records screening, basic visual examination of indoor plumbing, water sampling, excavation, and predictive data analyses. A qualitative comparison of method cost, accuracy, disturbance, and other impacts is provided as a starting point for utilities that are developing a feasible approach for their specific needs/constraints. Lastly, an example stepwise approach to identify unknown SL materials is proposed.

KEYWORDS
drinking water, identification, lead, pipe material, service line

https://awwa.onlinelibrary.wiley.com/doi/abs/10.1002/aws2.1226

- Overview of LSL identification tools
- Relative pros/cons
- Stepwise LSL identification approach

LSL identification tools

- Preliminary Records Screening - phase out dates after 1986 SDWA lead ban, local/state plumbing codes, construction specifications
- Community Records - SL installation records, Inspection and maintenance records, plumbing permits, meter installation records, others
- Basic/Visual – visual scratch/magnet test or lead test kit
- Tap Sampling - flushed, sequential, targeted
- Excavation - traditional, vacuum
- Predictive Methods - geospatial, machine learning
- Alternative Methods - electrical resistance, acoustic wave, eddy current, others

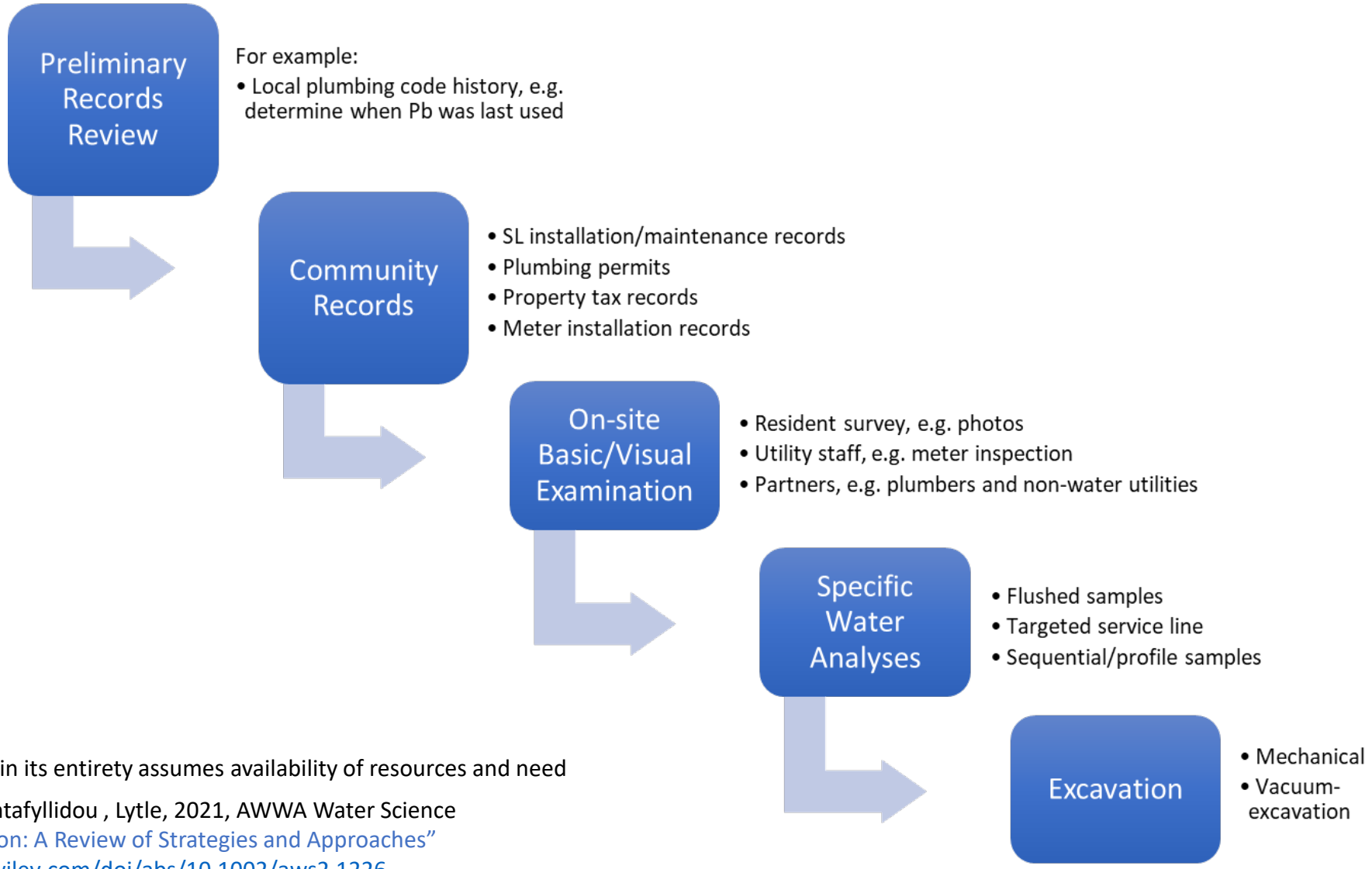
Relative pros/cons of LSL identification tools

L = Low
M = Medium
H = High

LSL ID Method	Utility Cost			Disturbance		Impact to Homeowner			Utility Skills Required		Overall	
	Financial	Onsite time	Pre-/Post-time	Service line	Traffic flow	Water service disruption	Property damage	Homeowner involvement (includes pre-/post-time)	Technical interpretation	Labor	Time	Accuracy
Community	L or M (if	NA	M to H (L if	None	None	None	None	None	L to M	None	M	L to H
Basic/Visual Observations (on private-side)	L	L	L to M	None	None	None	None	L	L	L	L	M to H
Water Quality	L	L	M to H	None	None	None	None	L	M	L	M	L to M
Water Quality Sampling-Sequential	M	L	M to H	None	None	M	None	M to H	M	L to M	M	L to H
Water Quality Sampling-Targeted	L	L	M to H	None	None	M	None	M to H	M	L to M	M	M
Excavation-Mechanical	H	H	M to H	H	M to H	H	H	L	L to M	H	H	H
Excavation-	M to H	L to M	M to H	M	L to M	M to H	M to H	L	M	M to H	M	M to H

From Hensley, Bosscher, Triantafyllidou , Lytle, 2021, AWWA Water Science
"Lead Service Line Identification: A Review of Strategies and Approaches"
https://awwa.onlinelibrary.wiley.com/doi/abs/10.1002/aws2.1226

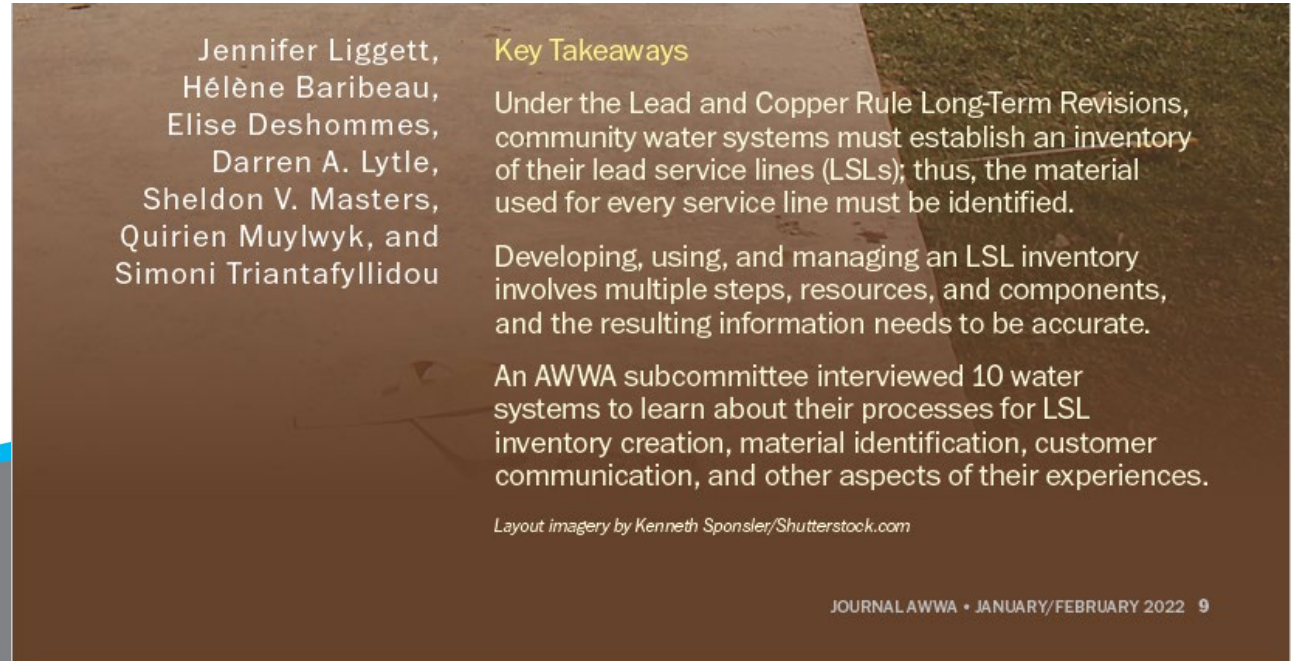
Suggested stepwise SL identification approach



Note: Adopting the approach in its entirety assumes availability of resources and need

From Hensley, Bosscher, Triantafyllidou , Lytle, 2021, AWWA Water Science "Lead Service Line Identification: A Review of Strategies and Approaches" https://awwa.onlinelibrary.wiley.com/doi/abs/10.1002/aws2.1226

"Service Line Material Identification Strategies: Experiences From North American Water Systems"
Liggett, J., Baribeau, H., Deshommes, E., Lytle, D., Masters, S., Muylwyk, Q., Triantafyllidou, S. *JAWWA* 114 (1):8-19, 2022.
https://awwa.onlinelibrary.wiley.com/doi/abs/10.1002/awwa.1841



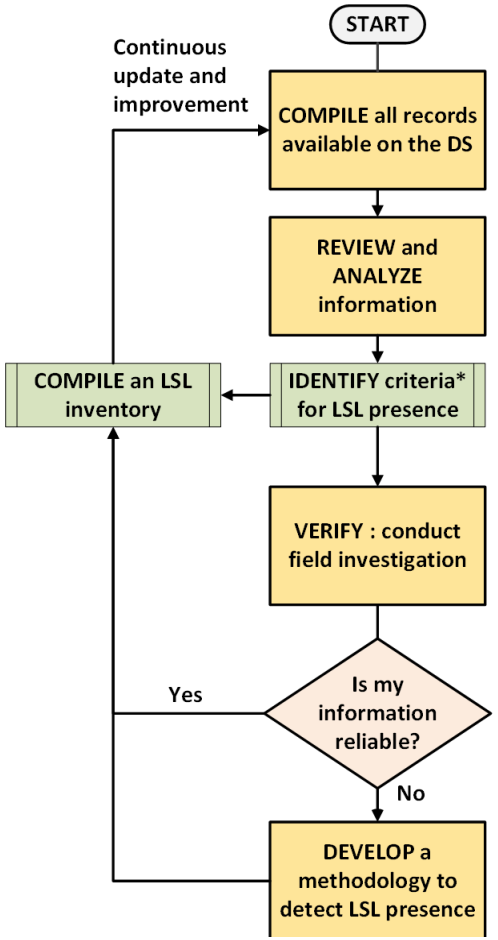
Service line inventories in North American water systems

Water System Name	Water System Location	Number of Service Connections or Customers	Estimated LSL Number at time of reporting (2021)	Corrosion Control Treatment	Tool(s) Used	Categorization of LSL	
						Water System Ownership	Includes Galvanized Iron Pipe?
Greater Cincinnati Water Works (GCWW)	Cincinnati, Ohio	1.1 million wholesale and retail customers	29,000 private 16,300 full 175 public	High consistent ORP (free chlorine at approximately 1.3 mg/L) and pH promoting lead (IV) scales	Historical records review Customer driven data Visual inspection	Water main to curb stop	No
District of Columbia (DC) Water	Washington, District of Columbia	700,000 residents and commercial and government customers	21,910 private 10,750 public	Orthophosphate and pH control (lime and sodium hydroxide)	Historical records review Customer driven data	Water main to curb stop	Yes
Green Bay Water Utility	Green Bay, Wisconsin	105,000 customers 33,000 wholesale 36,000 service connections	As of October 2020, all LSL have been removed.	pH adjustment	Historical records review Customer driven data CCTV Vacuum excavation Visual inspection CCTV/camera	Water main to curb stop	No
Denver Water	Denver, Colorado	1.5 million customers	64,000 to 84,000 LSL at launch of Lead Reduction Program in 2020	pH adjustment with sodium hydroxide (pH > 8.5)	Historical records review Investigative potholing Water quality sampling Predictive modeling	Customer owned	Yes
City of Montreal	Montreal, Quebec	258,038 service connections	48,000 LSLs (not replaced yet) 7,500 private LSLs remaining from past public side lead service line replacement (LSLR) (2006-2020)	None	Historical records review Water quality sampling Investigative potholing	Water main to property line	Yes
City of Guelph	Guelph, Ontario	100,000 population	5,000 at start of Lead Reduction Strategy in 2010 Less than 100 LSLs remain on the private side Unknown number of galvanized services	None	Historical records review Water quality sampling	Water main to property line	Yes
Pittsburgh Water and Sewer Authority (PWSA)	Pittsburg, Pennsylvania	300,000 customers 71,000 residential connections 12,000 non-residential connections	10,995 public side 28,171 private side 14,440 public unknowns 4,997 private unknowns	Orthophosphate and (seasonal) pH adjustment	Historical records review Curb box inspections Machine learning Mechanical excavation	Water main to curb stop	Yes
Tucson Water	Tucson, Arizona	Main System 736,000 customers 260,000 service connections	1,500 originally installed on the public side; 1,100 have been removed over the years; the remaining were inspected and 177 were found and removed. Only 1 LSL was found on the customer side (replaced by the customer)	pH adjustment	Historical records review Curb box inspections CCTV Excavation	Water main to curb stop	Yes
Cleveland Water	Cleveland, Ohio	1.4 million customers 440,000 service connections	120,000 public 7,200 private	Orthophosphate-based inhibitor	Historical records review Customer-driven data Water quality sampling Hydro-excavation CCTV/cameras Mechanical excavation	Water main to curb stop	No
Newark Water and Sewer	Newark, New Jersey	300,000 customers 39,000 service connections	8,000 SLs to be inspected 17,000 LSLs already replaced	Orthophosphate-based inhibitor	Historical records review and digitization Visual inspection inside house Curb box inspection Mechanical excavation	Customer owned	Yes

https://awwa.onlinelibrary.wiley.com/doi/abs/10.1002/awwa.1841

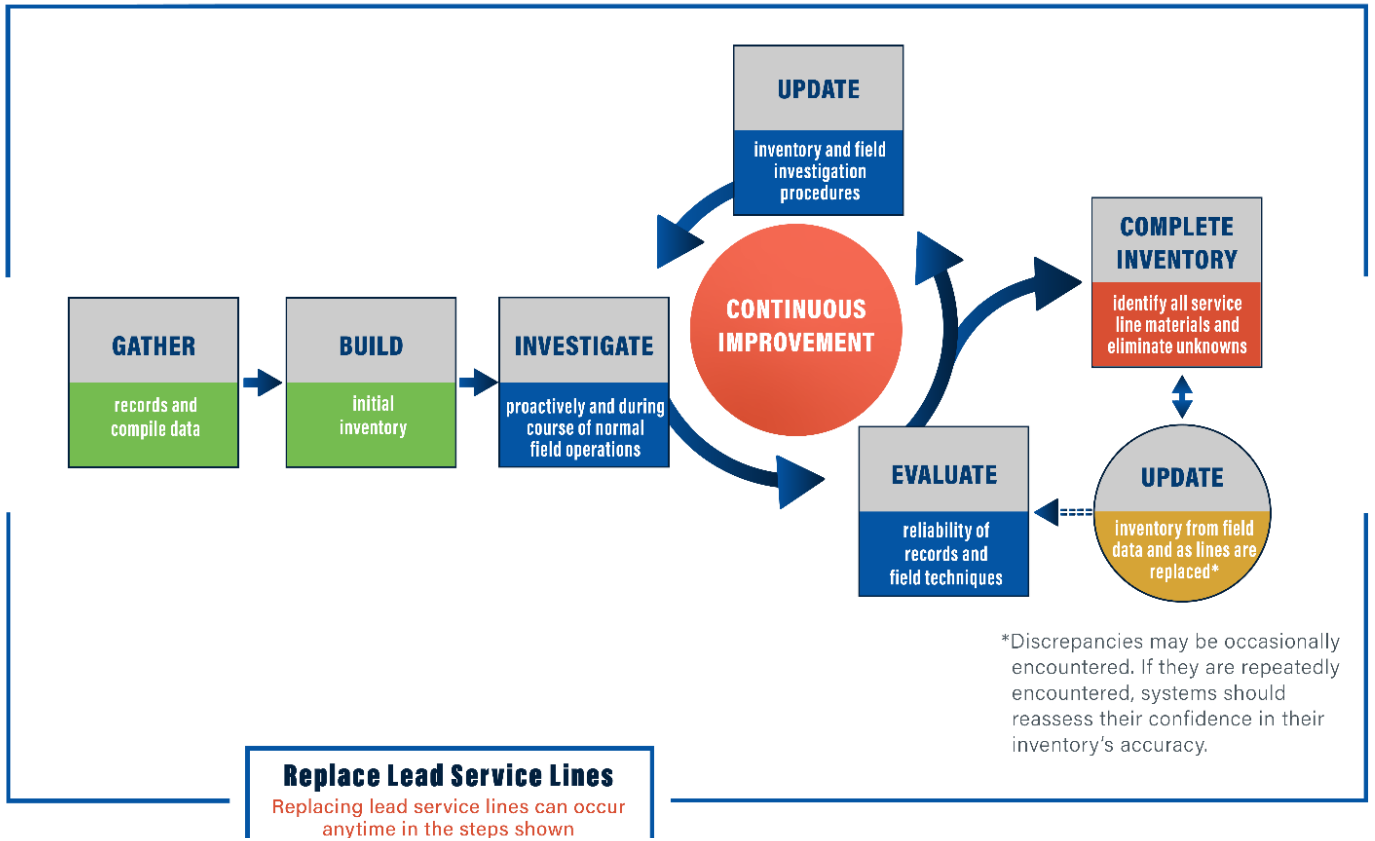
Approaches for determination of service line materials

Outline to determine service line materials



Liggett et al., 2022. Service Line Material Identification Strategies: Experiences From North American Water Systems
Notes: Criteria to determine LSL presence are site-specific and should be developed by the utility based on the analysis of their records and data; Capital letters signify actions; Yellow and green colors signify processes and sub-processes respectively.
https://awwa.onlinelibrary.wiley.com/doi/abs/10.1002/awwa.1841

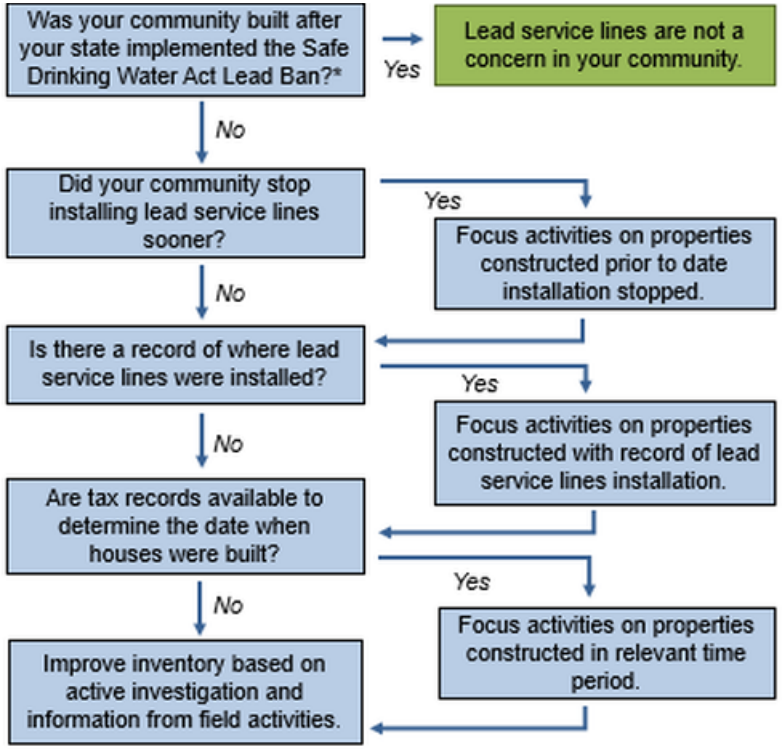
Service line inventory lifecycle



US EPA 2022, Guidance for Developing and Maintaining a Service Line Inventory
https://www.epa.gov/ground-water-and-drinking-water/revised-lead-and-copper-rule

Approaches for determination of service line materials

Key questions to ask when starting the process of preparing an LSL inventory

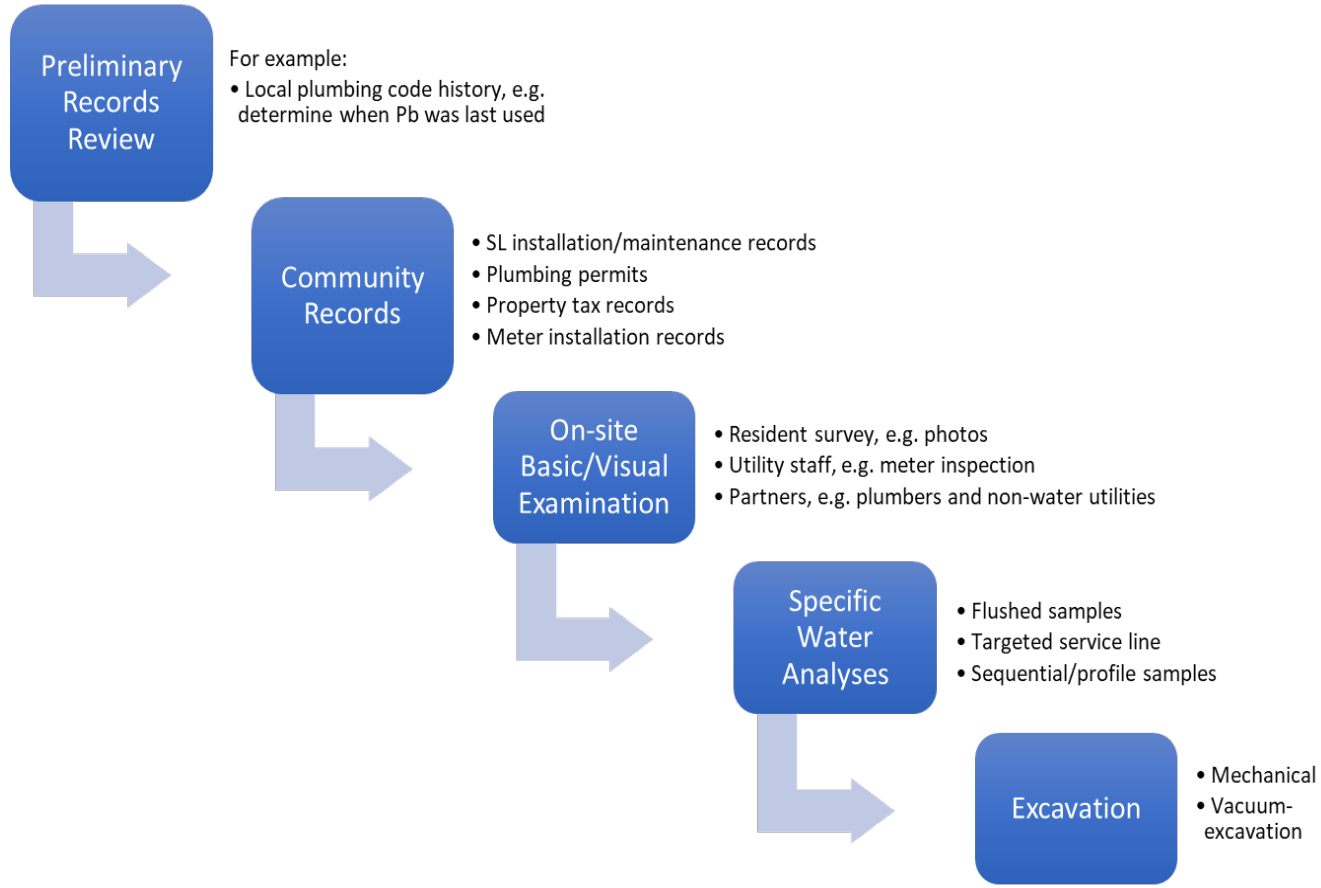


Throughout process, focus activities where service lines less than 2 inches in diameter were installed.

*The federal Lead Ban was effective June 19, 1986, but individual states may not have implemented state-specific regulations for 1 – 2 years.

Lead Service Line Replacement Collaborative. Preparing an Inventory: Where Do We Start?
https://www.lslr-collaborative.org/preparing-an-inventory-where-do-we-start.html

Stepwise service line identification approach



Note:
Adopting the approach in its entirety assumes availability of resources and need
https://awwa.onlinelibrary.wiley.com/doi/abs/10.1002/aws2.1226

Does the stepwise approach fit? Town in VT

Preliminary & Community Records

- LSLs common in Bennington from 1880s-1920s
- SRF funding of $11 million
- Records indicated 40% of SLs were lead or unknown

On-site Basic/ Visual Examination

- Basement inspections (paused during COVID):
  - Observe SL material entering foundation
  - Swab test when visual observation was inconclusive
- 700 basement inspections proved records unreliable

Specific Water Analyses

- Fully flushed sampling
- Sequential profile sampling

Excavation

- Partial excavation at curb stop
- Observe pipe materials

Summarized from: Smart, 2022. Development and Implementation of a Stepwise Approach to Service Line Identification. Presented at the 19th EPA Small Systems Workshop.

Does the stepwise approach fit? Town in VT (more detail)

Preliminary & Community Records

- Bennington, VT population of 15,300
- Municipal water system constructed in 1890
- LSLs common from 1880s-1920s
- SRF funding of $11 million
- Records indicated 40% of SLs were lead or unknown (records proved unreliable)

On-site Basic/ Visual Examination

- Basement inspections (paused during COVID):
  - Observe SL material entering foundation
  - Swab test when visual material observation was inconclusive
- 700 basement inspections proved records unreliable:
  - No lead at 71% of homes listed as LSLs
  - Lead at 14 % of homes listed as non-lead

Specific Water Analyses

- Fully flushed sampling: 1 L sample after 5-minutes flush
- Sequential profile sampling (SPS) after 6+ h stagnation:
  - Approximate interior plumbing lengths/diameters, bottle count/ volume to represent 6 linear ft per sample

Excavation

- Excavate at curb stop, >2 linear ft of SL on each side
- Observe pipe materials
- Disturbs pipe (WQ impacts); requires sidewalk/lawn repair; high cost

Summarized from: Smart, 2022. Development and Implementation of a Stepwise Approach to Service Line Identification. Presented at the 19th EPA Small Systems Workshop.

Does the stepwise approach fit? City in CA

Preliminary Records Review

- Sanitary plumbing code in Pasadena, CA adopted in 1892
  - Lead pipes not explicitly banned but not listed as a pipe option
  - Required lead connections between iron pipes (i.e., lead goosenecks)

Community Records

- LSLs believed unlikely
- Lead goosenecks common until 1930s – known goosenecks/pigtails since removed
- Community records deemed unreliable (not often available, legible, or sufficiently detailed)
- Homes grouped into risk categories based on age for verification

On-site Examination (Verification)

- ~1% high/highest risk homes sampled
- Swab test portion of service line exposed in the meter box (private side)
- No LSLs found

Surface swab kit turns pink for lead gooseneck but not for stainless steel

Retrofitted from: Kimbrough, 2022. A study of lead service lines in California. https://iwaponline.com/wpt/article/doi/10.2166/wpt.2022.099/90307/A-study-of-lead-service-lines-in-California

Does the stepwise approach fit? City in CA (more detail)

Preliminary Records Review

- Federal Safe Drinking Water Act (SDWA) Amendments in **1986**
  - Prohibited plumbing materials that were not "lead-free" (<8% lead), including lead service lines and lead goosenecks
  - Effective Date in California: July 7, **1986**
- State regulations for lead in CA began in the **1880's**
- Sanitary plumbing code in Pasadena, CA adopted for wastewater in **1892**
  - Lead pipes not explicitly banned but not listed as a pipe option
  - Required lead caulking with oakum and lead connections between iron pipes (i.e., lead goosenecks)
  - Assumed to apply to drinking water side but not explicitly applied until **1930**

Community Records

- City of Pasadena: Founded in 1975; Incorporated in 1882, population of 9,100 in 1900
  - LSLs believed unlikely to be installed in Pasadena
  - Lead goosenecks common until 1930s – but known goosenecks/pigtails since removed
- Community records deemed unreliable (not often available, not entirely legible, not sufficient detail)
- Instead group homes into risk categories based on age for subsequent verification
- 38,000 homes with service in Pasadena
  - 28,000 built after **1930** (low risk)
  - 10,000 built before **1930** (high risk)
  - 74 built before **1892** (highest risk)

On-site Examination (Verification)

- Swab test portion of service line exposed in the meter box (private side).
- 109 out of 133 intended pre-1930 sites sampled **(~1% high/highest risk homes)**
  - 2 services per each year of instillation (1881-1930)
    - Not in the same zip code, not on the same street
    - 24 locations were inaccessible at the meter
- 11 post-1930 sites sampled
  - one site for every 3-5 years of installation past 1930
- No LSLs found

Surface swab kit turns pink for lead gooseneck but not for stainless steel

Retrofitted from: Kimbrough, 2022. A study of lead service lines in California. https://iwaponline.com/wpt/article/doi/10.2166/wpt.2022.099/90307/A-study-of-lead-service-lines-in-California

Summary

- Uncertainty in the estimates of LSLs present, different and broadened definitions
- Increased need for LSL inventories
- Larger drinking water utilities and/or utilities with state requirements have developed inventories
- Variety of LSL ID tools available, combinations of tools needed
- Tool selection criteria may include:
  - Accuracy
  - Overall time
  - Cost
  - Skill (labor, technical interpretation)
  - Disruption to homeowner (water service interruption, property damage, participation)
  - Disturbance (service line, traffic flow)
- As more utilities share their experiences, the pros/cons in different situations will be better defined

Summary

- Different suggested approaches/flowcharts available for LSL ID/inventory development
  - Primarily developed for communities with history of LSLs in mind
  - Offer general framework to follow
- Step-wise identification is one suggested approach that we will keep refining
  - VT case study demonstrated no step 100% accurate (short of full excavation), but that cost-savings could be realized in prior steps depending on regulatory approval
  - CA case study retrofit demonstrated that the general logic holds even in communities without long history of LSLs, with modifications
- Some parts of the country have long history of LSLs, whereas others do not
- Customization of approach and combination of tools can meet specific needs
- How can this framework fit your needs?

Contact

Simoni Triantafyllidou
Environmental Engineer
Center for Environmental Solutions
and Emergency Response
Triantafyllidou.simoni@epa.gov
(513) 557-9950

Acknowledgements

- Lytle D. (EPA ORD) Hensley K. (EPA Region 2) and Bosscher V. (EPA R5) for article "Lead Service Line Identification: A Review of Strategies and Approaches"
- Liggett, J., Baribeau, H., Deshommes, E., Lytle, D., Masters, S., Muylwyk, Q (AWWA Lead-in-Water Subcommittee) for article "Service Line Material Identification Strategies: Experiences From North American Water Systems"
- All other authors for resources cited herein

Staff and time to develop inventory

- Ranged from:
  - 2-3 full time employees 6 days a week for 2 months, to
  - several employees working continuously from the start of lead reduction programs
- Interns hired to perform water sampling and other tasks in some cases
- Customers engaged for water sampling or visual identifications in some cases. Water system staff available to assist customers, gather information from customers, validate the information

Montreal, Canada accelerated inventory effort (target completion in 2023).

Dedicated staff increased from:

- 1-2 engineers (full-time) and 20-24 interns (summer screening sampling), to
- 7 full-time staff (engineers, technicians, administrative agents), plus 6 telephone operators and 75 summer interns
- Team for LSL inventory only. Two additional teams manage LSL inspection and replacement.

- All water systems indicated a significant staff allotment for at least some initial period of time
- Level of effort will vary from one system to another depending on size, the proportion of LSLs in the system, the availability and reliability of the water system records and other needs/constraints

From "Service Line Material Identification Strategies: Experiences From North American Water Systems"
Liggett, J., Baribeau, H., Deshommes, E., Lytle, D., Masters, S., Muylwyk, Q., Triantafyllidou, S. *JAWWA* 114 (1):8-19, 2022.
https://awwa.onlinelibrary.wiley.com/doi/abs/10.1002/awwa.1841