United States Environmental Protection Agency

EPA Tools & Resources Webinar:
Identifying Lead Service Lines in the Community

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Outline

- The challenge of legacy lead service lines (LSLs)
  - Old plumbing code requirements
  - Definition, estimated numbers and unknowns
- Lead service line identification tools and pros/cons of each
  - Preliminary records screening
  - Community records screening
  - Basic/visual identification
  - Tap water sampling
  - Excavation
  - Others
- Step-wise lead service line identification approach
- Case studies/examples
- Summary
- Other corrosion research & technical support examples and resources

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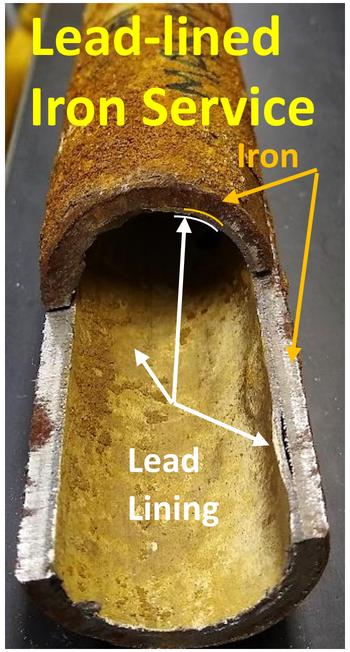
Lead service lines or lead goosenecks were required or allowed by municipal plumbing code, prior to the 1986 SDWA lead ban

WHAT THE CODE LANGUAGE MEANT	OLD MUNICIPAL CODE LANGUAGE
The entire service line was required to be made of lead.	WATER SERVICE…Sec. 23. All water pipes laid underground whether outside or inside the building and of a diameter less than two (2) inches shall be "extra strong" lead pipe.
Lead pipe was only required between the water main and the property line.	Pipe Material. Sec. 17. All service pipe, from the point of union with the main to the service stop inside of curb line shall be of lead, known and designated as "Extra Strong," weighing as follows per lineal foot…
The service line could be lead pipe, galvanized iron pipe or enameled iron pipe. However, a short lead pipe at least 18 inches long (commonly called a 'lead gooseneck') was required at the connection with the water main.	Sec. 14. PIPE, KIND USED, WATER COMMISSIONER TO PURCHASE.–Either lead, galvanized or enameled iron service pipes may be used at the option of the applicant. All lead and iron pipes must have sufficient strength to sustain a pressure of not less than two hundred (200) pounds to the square inch, and at the point of connection with the street main between the corporation cock and the coupling in the iron service pipe there must be at least eighteen (18) inches of lead pipe to retain rigidity of the iron pipe.
Lead was not required but was one of the types of pipes allowed.	Section 995. WATER CONNECTIONS FOR BUILDINGS: All pipes leaving the curb cock and used for connecting buildings with the City water system, shall be laid under ground, and at least eighteen (18) inches below the established grade, and shall be of lead or galvanized wrought iron or steel.
Lead was not required but was one of the types of pipes allowed.	Section 660 A. MATERIALS OF WATER PIPE AND FITTINGS. All water service and distribution pipes shall be of lead, galvanized wrought iron, galvanized steel, brass, copper, or cast iron with brass, copper, galvanized iron or galvanized or malleable iron fittings.

Compiled by Miguel Del Toral, 2018
Published in Hensley et al., 2021

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

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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

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LSL Estimates – National

National Surveys

- 3.3 million LSLs & 6.4 million lead gooseneck connections (Weston and EES 1990 based on 1988 American Water Works Association (AWWA) survey)
- 6.1 million partial or full LSLs (Cornwell et al. 2016 based on AWWA 2011 & 2013 surveys)

Challenges

- Level of detail
  - Smaller area analysis (i.e., # LSLs by US State or by US EPA Region) not possible (Cornwell et al., 2019)
  - Discrepancies between recent national survey and individual state survey results (Perry et al., 2018)
- Low response rates in surveys, utility records (absent/ incomplete/ inaccurate), documentation of private LSL # (Wasserstrom et al., 2014)
- May not be statistically representative & responses difficult to verify (GAO, 2018)
- How is a “lead service line” defined?

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LSL Estimates – 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

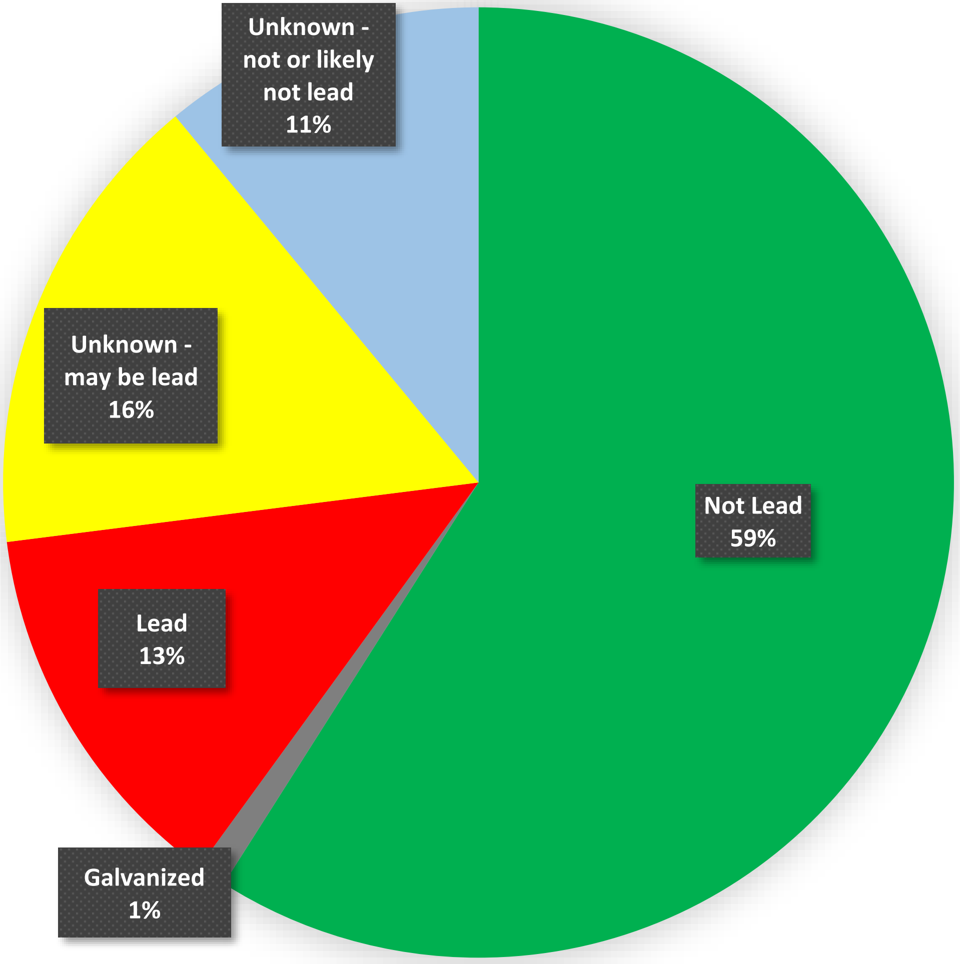
Voluntary service line surveys in IN, MA, NC, and WA not included
State requirements from ASDWA (Association of State Drinking Water Administrators) 2019. https://www.asdwa. org/wp-content/uploads/2019/08/ASDWA_Developing-LeadService-Line-Inventories.pdf
Additional State requirement for NJ (2021) from 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)

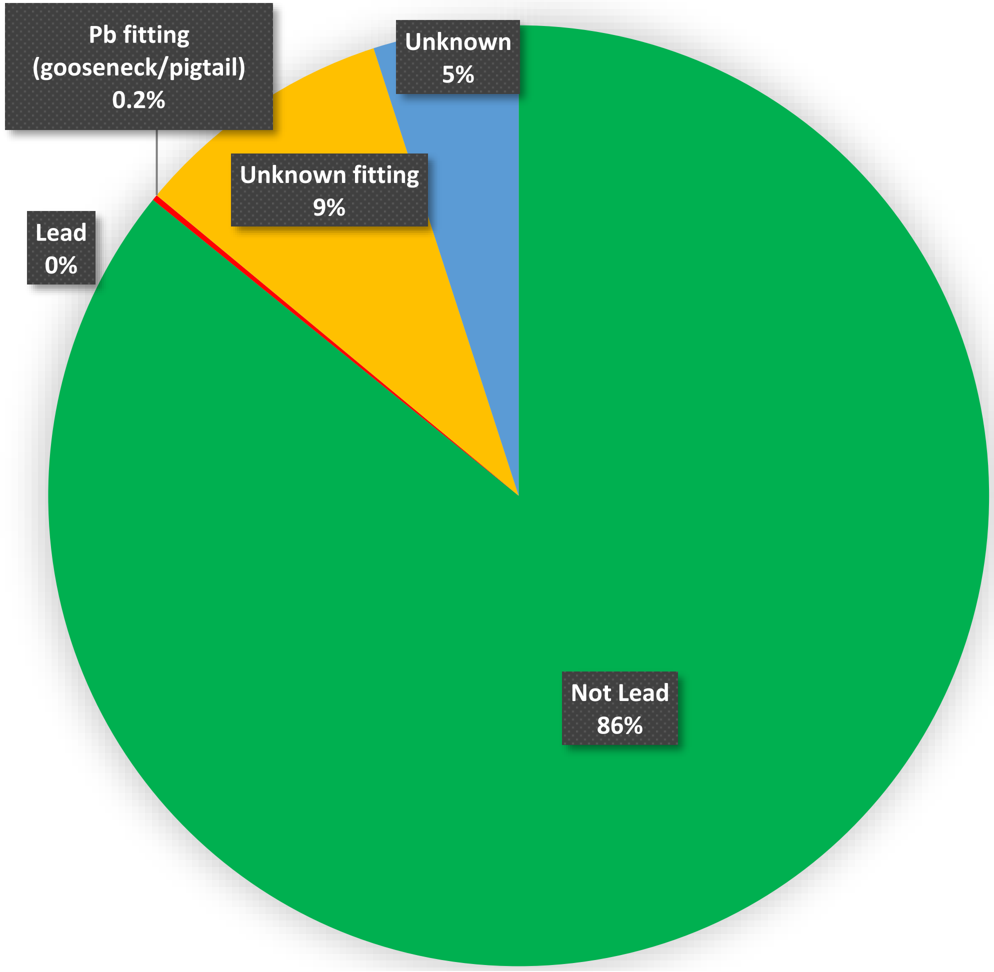
From Hensley, Bosscher, Triantafyllidou , Lytle, 2021, AWWA Water Science
"Lead Service Line Identification: A Review of Strategies and Approaches"
https://awwa.onlinelibrary.wiley.com/doi/abs/10.1002/aws2.1226

LSL Estimates – States 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
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REVIEW ARTICLE

AWWA WATER SCIENCE

Lead service line identification: A review of strategies and approaches

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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 – Service Line (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

Preliminary Records: Phase-out dates by state, after 1986 SDWA lead ban

	State	Implemented Lead Ban	Method	Date Effective	Certification Signature	Requires Solder	Use of Flux	Lead Pipe	Notes
EPA Region I	Connecticut	Yes	Public Act No. 66-192; Sec. 29-261 General Statutes; State Plumbing Code	12/31/88	Governor 03/29/89	X	X	X	Requires solder warning label
	Maine	Yes	Internal Plumbing Rules 10-144A CMR238; Chapter 9,8,10; Chapter 3, Table 3,5; and Chapter II.D.1	08/01/87	Commissioner, Dept. of Human Services 02/23/89	X	X	X	State purchased Pb solder test kits for inspectors, etc. to use in field testing.
	Massachusetts	Yes	State Plumbing Code, 2-18 CMR; Pg. 55, 201, 208, 207	01/01/86	Commissioner, Dept. of Env. Protection 03/08/89	X	X	X	
	New Hampshire	Yes	State Plumbing Code, Chapter ??? 700, Part ??? 701	08/01/87	Governor 03/28/89	X	X	X	Adopted BOCA
	Rhode Island	Yes	Regulation S.B.C.-3; Article 4 P402.3 and P402.4; and Article 5, P508.4 and P509.5	01/01/87	Governor 03/28/89	X	X	X	Adopted BOCA
	Vermont	Yes	VT Residential plumbing code, ABC Envir. Protection Rules for public buildings	12/28/88 09/10/82	Commissioner of Health, 03/27/89	X	X	X	New legislation eff. June 1989 consolidating plumbing codes and clarifying lead ban.

Effective lead ban dates on this table range from 1986 to 1991 across all states

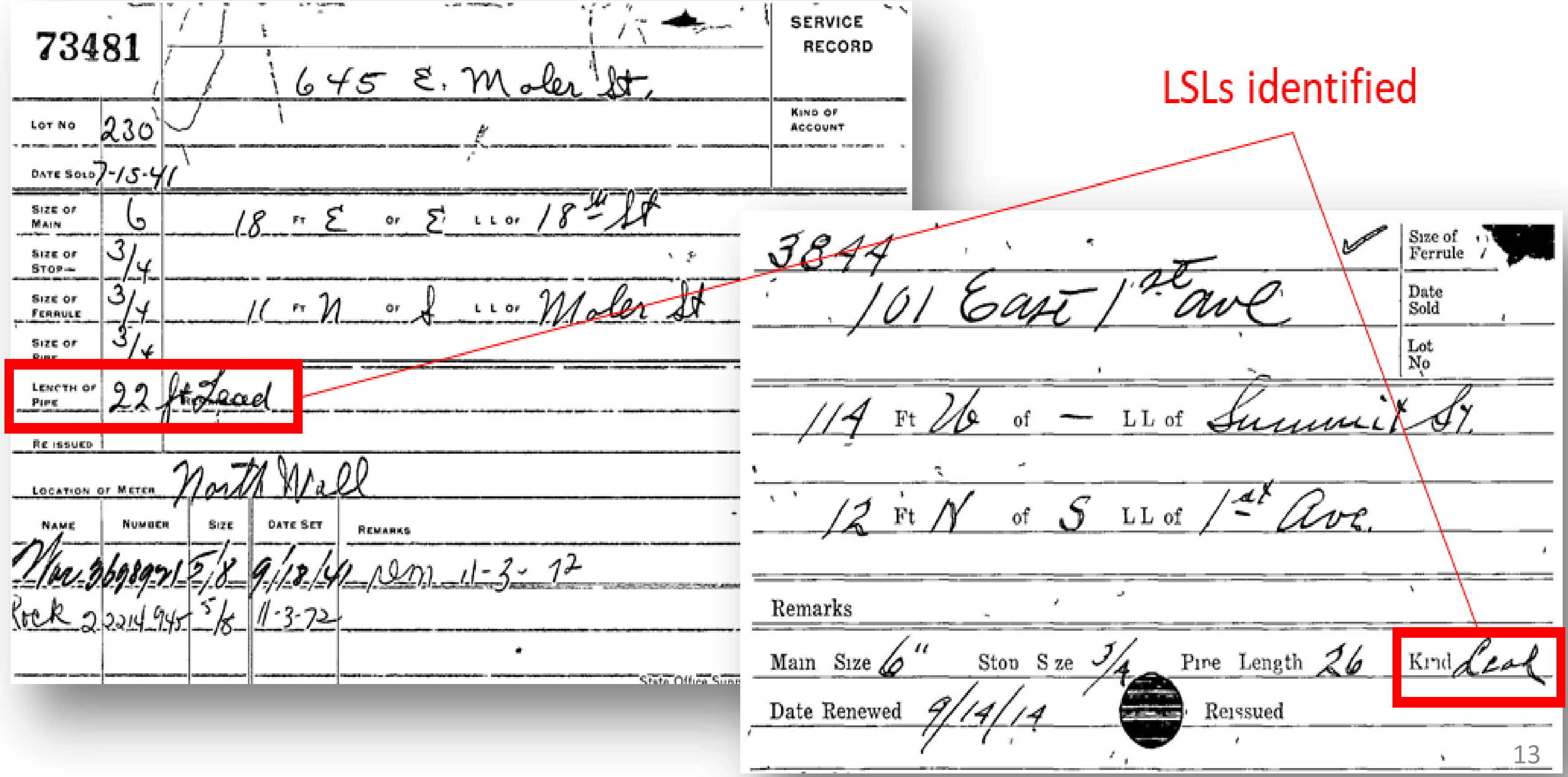
Appendix D, US EPA 2022, Guidance for Developing and Maintaining a Service Line Inventory
https://www.epa.gov/system/files/documents/2022-08/Inventory%20Guidance_August%202022_508%20compliant.pdf
Recreated from EPA 1991 LCR Guidance Manual Vol. 1 - Monitoring lead ban provisions by state, Table 3-1 Summary of lead ban provisions by state. The content has not been updated, therefore water systems should verify the lead ban effective dates with their states.

Community Records

- SL installation records
- Inspection and maintenance records, including replacement or repairs of specific SLs and larger water main replacement projects
- Plumbing permits
- Meter installation records
- Property tax records
- Distribution system maps & drawings

Caution:

- Available?
- Legible?
- Complete?
- Accurate? Up-to-Date?



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Basic/Visual

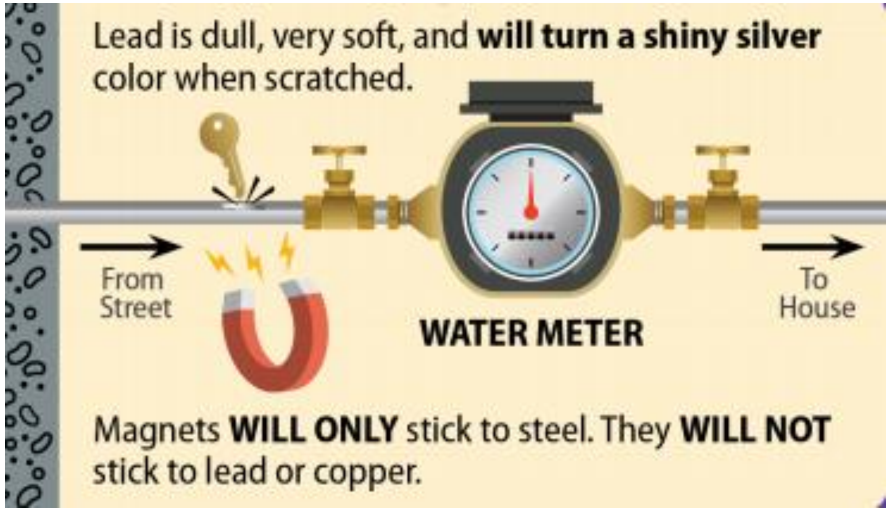
Scratch/Magnet Test

- Easy for residents if service line is accessible
- When scratched (coin, key, etc), the exposed outside pipe surface area will be shiny silver and flake off
- Magnet will not stick to Pb
- Can identify solid lead service lines but not lead-lined iron pipe

Lead Test Kit

- Surface swab kits approved for lead paint change color after contacting lead surface

https://www.epa.gov/il/advice-chicago-residents-about-lead-drinking-water



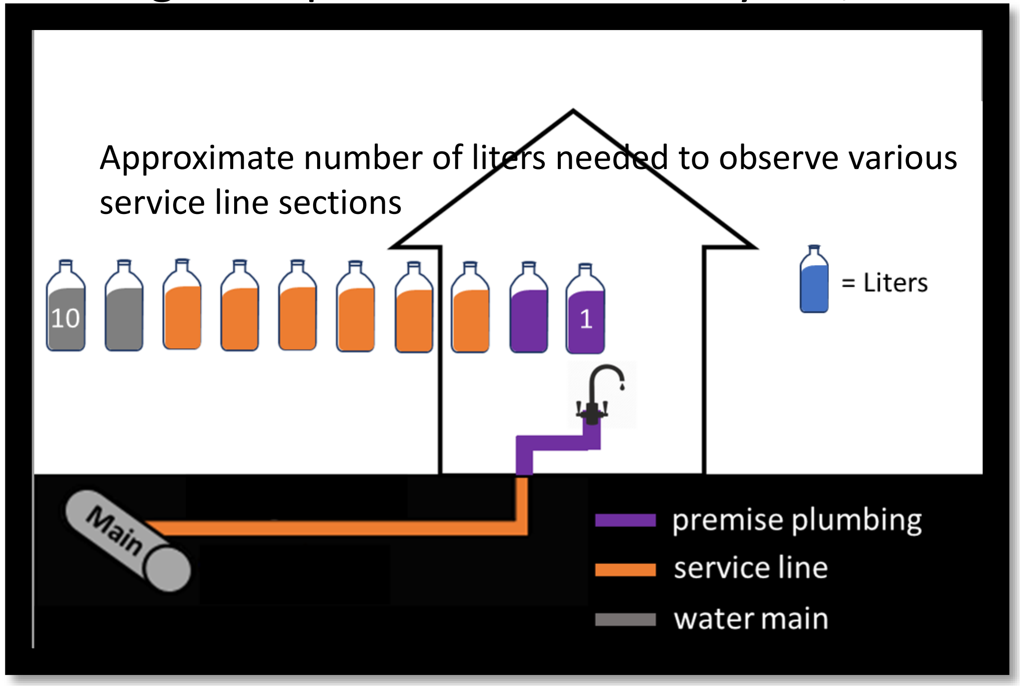
https://www.trentonnj.org/DocumentCenter/View/406/How-to-Find-Out-if-You-Have-a-Lead-Service-Line-PDF

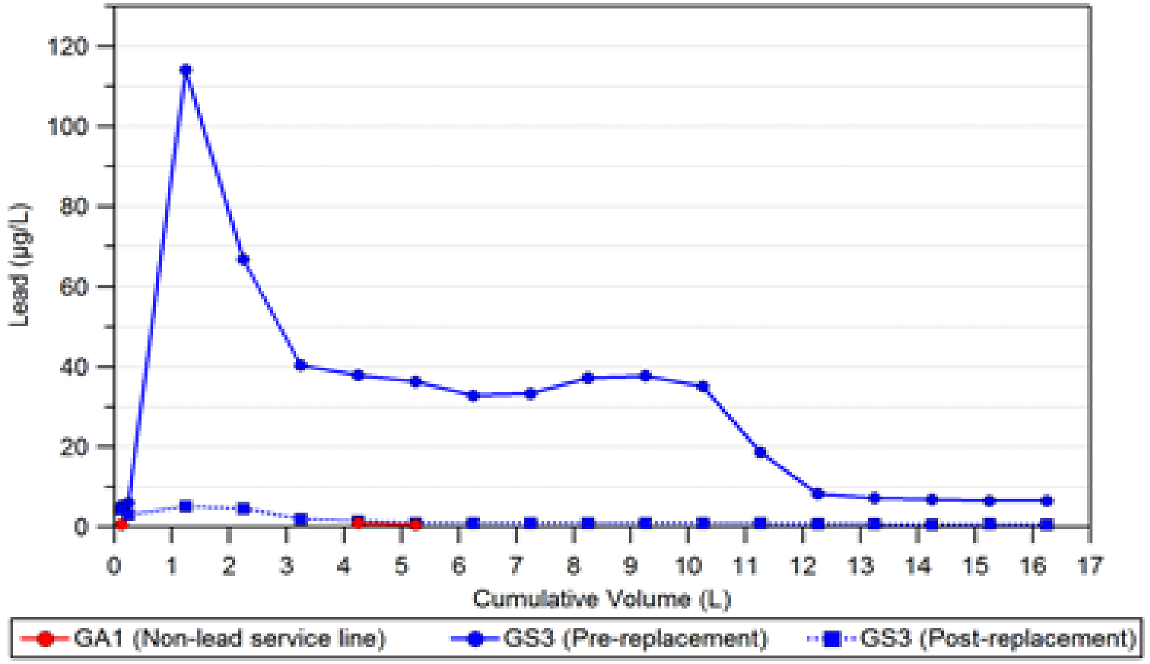
EPA, 2021. Protect Your Tap: A Quick Check for Lead. Guide to help people identify LSLs in their homes: https://www.epa.gov/ground-water-and-drinking-water/protect-your-tap-quick-check-lead-0

National Public Radio., 2016. Do you have lead pipes in your home? https://apps.npr.org/find-lead-pipes-in-your-home/en/#intro

Tap sampling – Sequential (profile)

- Community-specific LSL ID water concentration thresholds needed
- High Pb “peaks” indicate likely LSL; Multi-metal analysis (e.g., Cu, Zn, Fe, Sn, Cd) helpful





Denver Water 2019 – 6 h stagnation profiles

- LSL indicated by maximum Pb ≥ 5 µg/L (lower Pb in water samples from homes with copper & Pb solder)
- 1/16 false negative. Confirmed LSL had Pb <1 µg/L in all samples (suspected lack of stagnation)

DC Water 2019 - 6 h stagnation profiles 10x1L

- LSL indicated by total Pb mass ≥ 5 µg and shape of profiles
- 2/30 false negatives

Tap sampling – Flushed or Targeted

Flushed: Sampling after a standardized time of flushing to distinguish LSL sites from non-lead

Canadian water systems without CCT: Cartier et al 2012 – 5min flush samples in Montreal

- ≥2 µg/L Pb high probability of LSL; confirmed if 2nd liter after 15min stagnation exceeded 3 µg/L and/or any >3µg/L for 3rd-6th liter 15MS profile
- ≤1 µg/L Pb very low probability of LSL

Denver Water 2019. If built <1952

- Average 5 µg/L Pb in 3-bottle set (1st draw, 30 sec flush, another 30 sec flush) considered LSL

Targeted: Flush out the volume of water contained within premise plumbing, to collect liter of water contained within SL

Cartier et al 2012 – 2nd liter after 15min stagnation in Montreal, Canada

- 2nd liter chosen based on typical premise plumbing volumes in community
- ≥ 3 µg/L Pb was indicative of an LSL
- False negatives attributed to temperature effects, short LSLs, or larger premise plumbing volumes

Caution:

- Community-specific LSL ID water lead thresholds needed
- Community-specific SL volumes needed
- If Pb(IV) is controlling, or CCT truly optimized, LSL sites harder to differentiate through water sampling

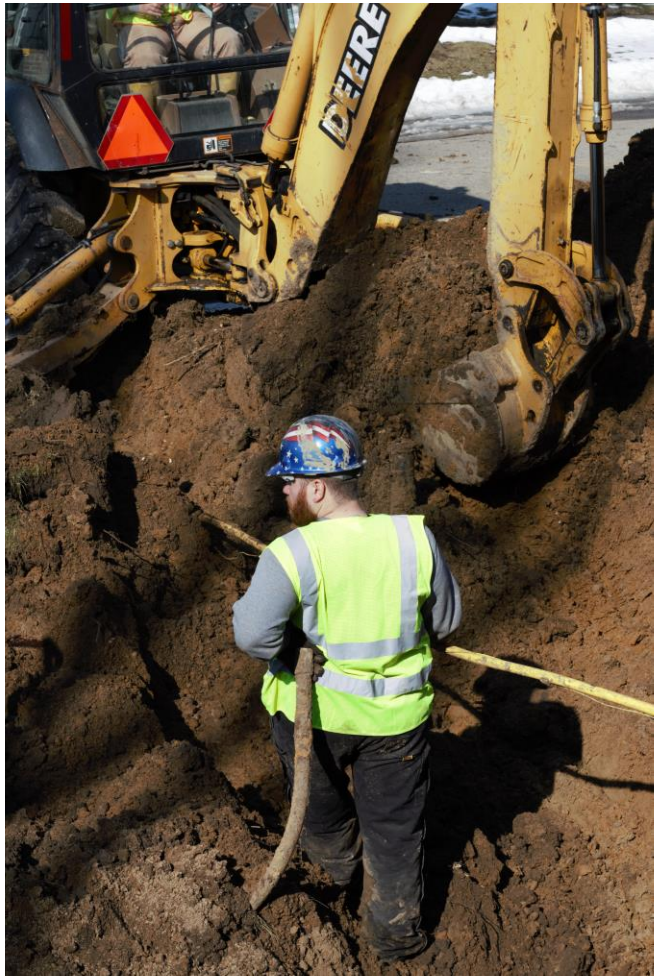
Mechanical Excavation

Backhoe or another mechanical excavator to dig a test pit down to the SL to expose it

- Reliable
- Costly
- Disturbance due to removal of topsoil, sidewalk, or other obstacles
- Higher accuracy rate than other excavation methods because a longer length of SL is exposed for observation, up to 10 ft in some instances

Caution:

- Cost
- Time and
- Disturbance (specially to dig SLs that are not lead)



Vacuum Excavation

Hydro-vacuum truck consists of a high-pressure water jet and industrial vacuum. Jet loosens soil, vacuum removes it into a holding tank until the SL is exposed

- Smaller hole, less expensive, less disturbance

Caution:

- Heterogeneous SL may have lead segments that could be missed by single hole

Relative pros/cons of LSL identification methods

L-Low; M-Medium; H-High

LSL ID Method	Utility Cost: Financial	Utility Cost: Onsite time	Utility Cost: Pre-/Post-time	Disturbance: Service line	Disturbance: Traffic flow	Impact to Homeowner: Water service disruption	Impact to Homeowner: Property damage	Impact to Homeowner: Homeowner involvement (includes pre-/post-time)	Utility Skills Required: Technical interpretation	Utility Skills Required: Labor	Overall: Time	Overall: Accuracy
Community Records Review	L or M (if digitized)	NA	M to H (L if digitized)	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 Sampling-Flushed	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-Vacuum	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"
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Suggested stepwise SL identification approach

1. **Preliminary Records Review**
   For example:
   - Local plumbing code history, e.g. determine when Pb was last used
2. **Community Records**
   - SL installation/maintenance records
   - Plumbing permits
   - Property tax records
   - Meter installation records
3. **On-site Basic/Visual Examination**
   - Resident survey, e.g. photos
   - Utility staff, e.g. meter inspection
   - Partners, e.g. plumbers and non-water utilities
4. **Specific Water Analyses**
   - Flushed samples
   - Targeted service line
   - Sequential/profile samples
5. **Excavation**
   - Mechanical
   - Vacuum-excavation

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

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Predictive methods

Geospatial

- Spatial patterns and proximity to **known LSLs**
- Predictions can be made for unsampled sites

Machine Learning

- Uses a predictive self-learning algorithm with a geospatial model

Caution

- Relies on data inputs (e.g., LSL ID approaches on previous slides)
- Data quality and confidence?

Abernathy et al 2018. Active Remediation: The Search for Lead Pipes in Flint, Michigan (see also BlueConduit.com)
https://arxiv.org/abs/1806.10692

ASDWA 2020. Predictive Tools for Lead Service Line Inventories webinar
https://www.asdwa.org/past-events-webinarrecordings/?mgi_158=19130/predictive-tools-for-lead-service-line-inventories

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Alternative methods

Some lab/field evaluation

- Electrical resistance
- Acoustic wave
- Eddy current

Conceptual

- Metal detectors
- Magnetometers/Gradiometers – locate iron, not lead/copper
- Ground penetrating radar

Arnette, V. (2020). Lead service line identification, inventories, and replacement. *Water Research Foundation*. Webcast at https://www.waterrf.org/sites/default/files/file/2020-06/WRF%20LSL%20Inventory%20Webcast_FINAL.pdf

Ballinger, R., Coates, D., Jallouli, A., Lu, H., & Roy, V. (2020). *Evaluation of lead pipe detection by electrical resistance measurement.* Water Research Foundation, Project No. 4698.Webcast at https://www.waterrf.org/sites/default/files/file/2020-06/WRF%20LSL%20Inventory%20Webcast_FINAL.pdf

Bukhari, Z., Ge, S., Chiavari, S., & Keenan, P. (2020). *Lead service line identification techniques.* Water Research Foundation, Project No. 4693. Report for members https://www.waterrf.org/resource/lead-service-line-identification-techniques

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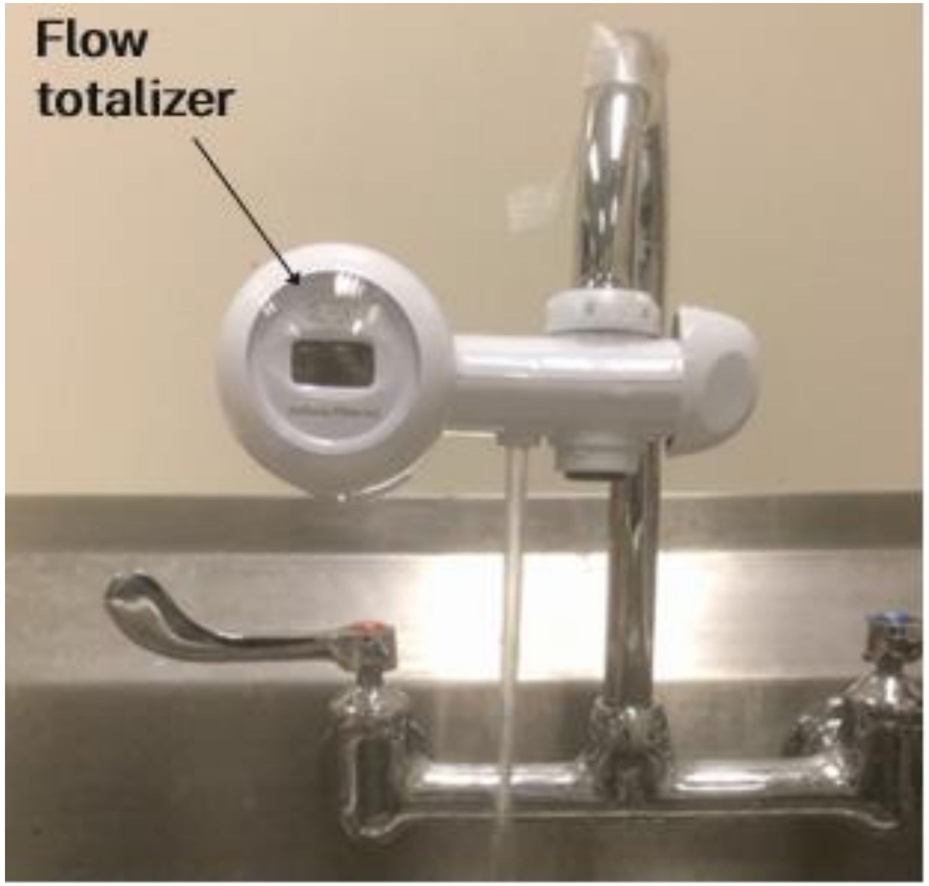
Alternative methods – Cumulative sampler

EPA ORD research in-progress

Lead Evaluation and Assessment Device (LEAD): Install point-of-use (POU) filter at kitchen tap, use per manufacturer, return cartridge for analysis

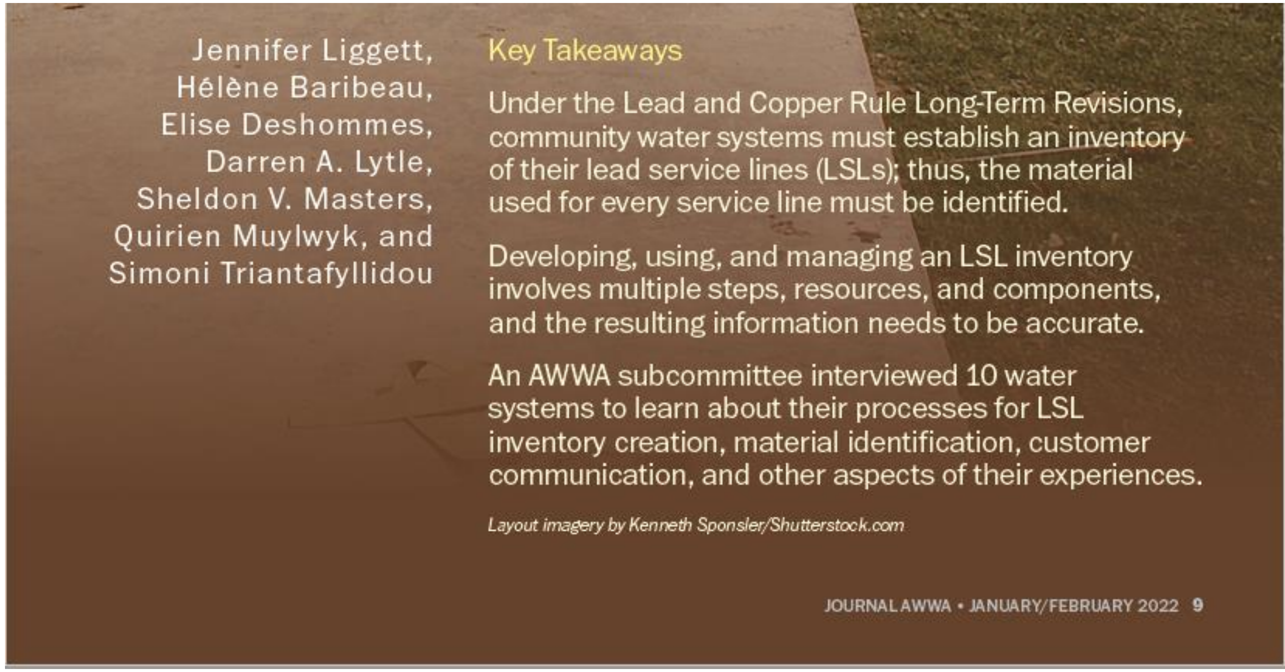
- Extract total lead mass (µg) accumulated on the POU filter
- Hypothesis: Average lead mass in home with LSL>> home that never had a LSL



SERVICE LINE MATERIAL IDENTIFICATION:

Experiences From North American Water Systems

“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



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Key Takeaways

Under the Lead and Copper Rule Long-Term Revisions, community water systems must establish an inventory of their lead service lines (LSLs); thus, the material used for every service line must be identified.

Developing, using, and managing an LSL inventory involves multiple steps, resources, and components, and the resulting information needs to be accurate.

An AWWA subcommittee interviewed 10 water systems to learn about their processes for LSL inventory creation, material identification, customer communication, and other aspects of their experiences.

Layout imagery by Kenneth Sponsler/Shutterstock.com

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Inventory experiences from 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

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:

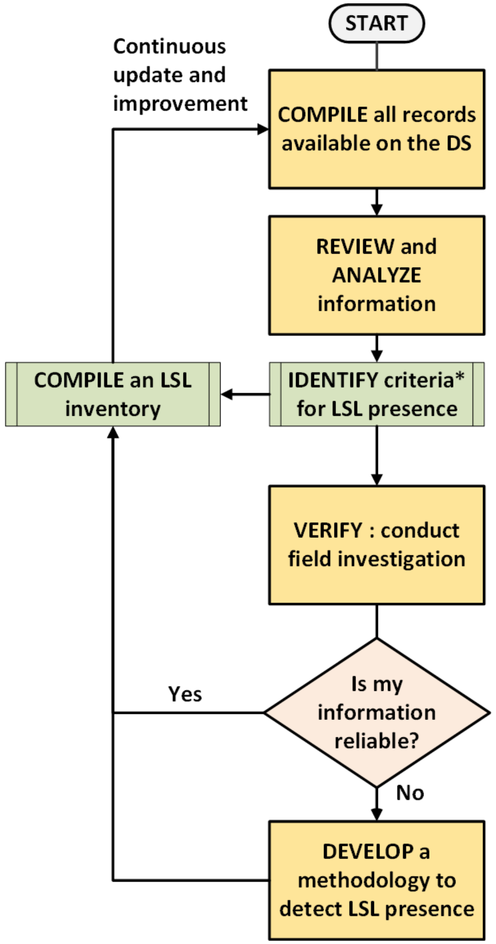
- 1-2 engineers (full-time) and 20-24 interns (summer screening sampling), to
- 7 full-time staff (engineers, technicians, administrative agents), plus 6 telephone operators and 75 summer interns
- Team for LSL inventory only. Two additional teams manage LSL inspection and replacement.

- 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

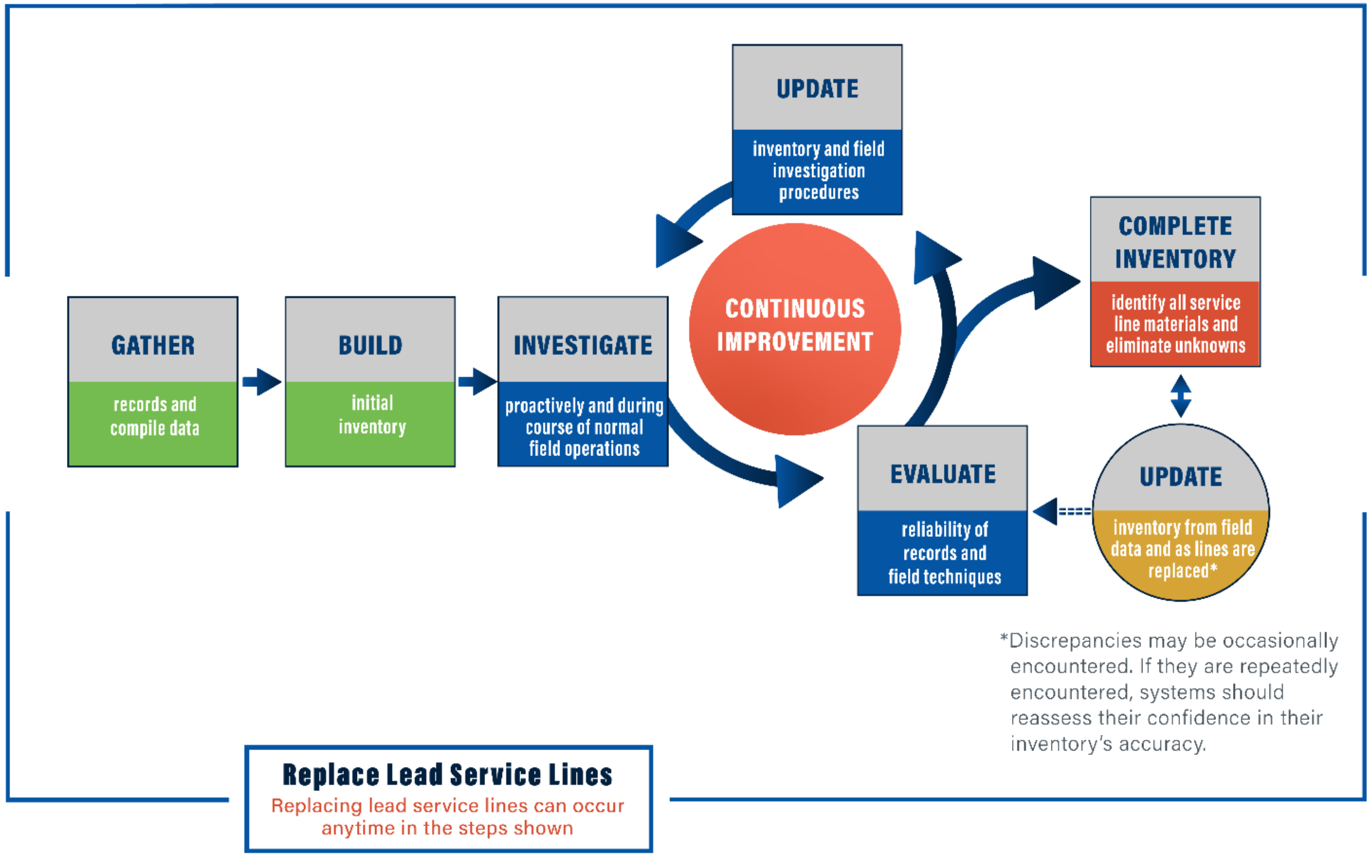
Approaches for determination of service line materials

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

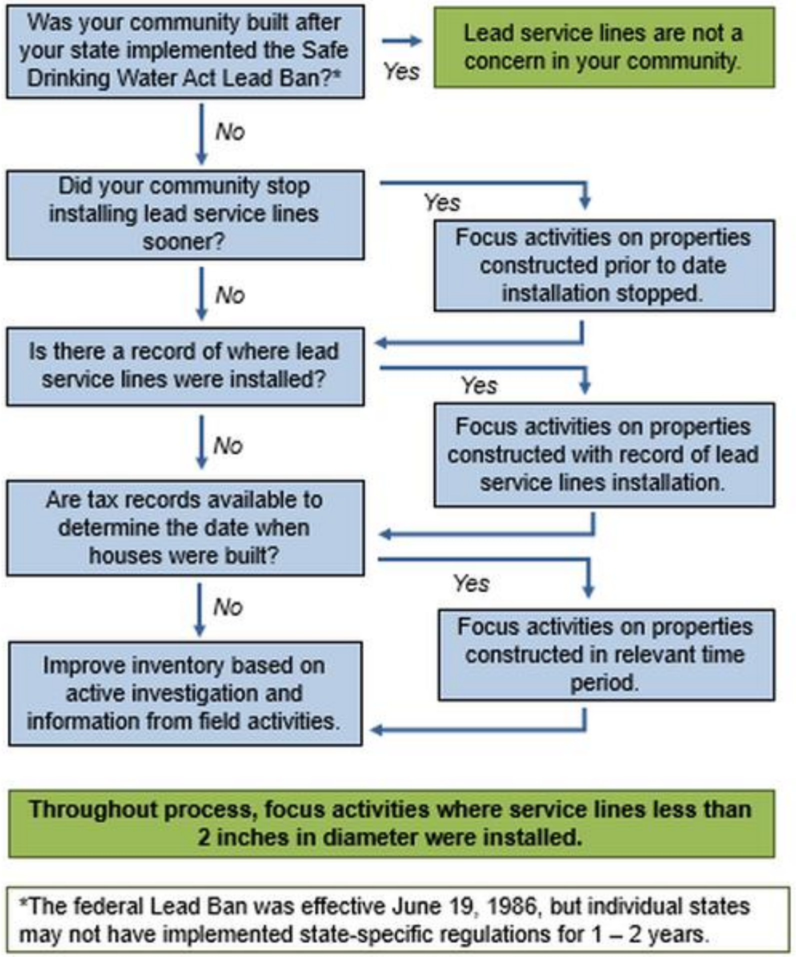


US EPA 2022, Guidance for Developing and Maintaining a Service Line Inventory
https://www.epa.gov/ground-water-and-drinking-water/revised-lead-and-copper-rule

Approaches for determination of service line materials

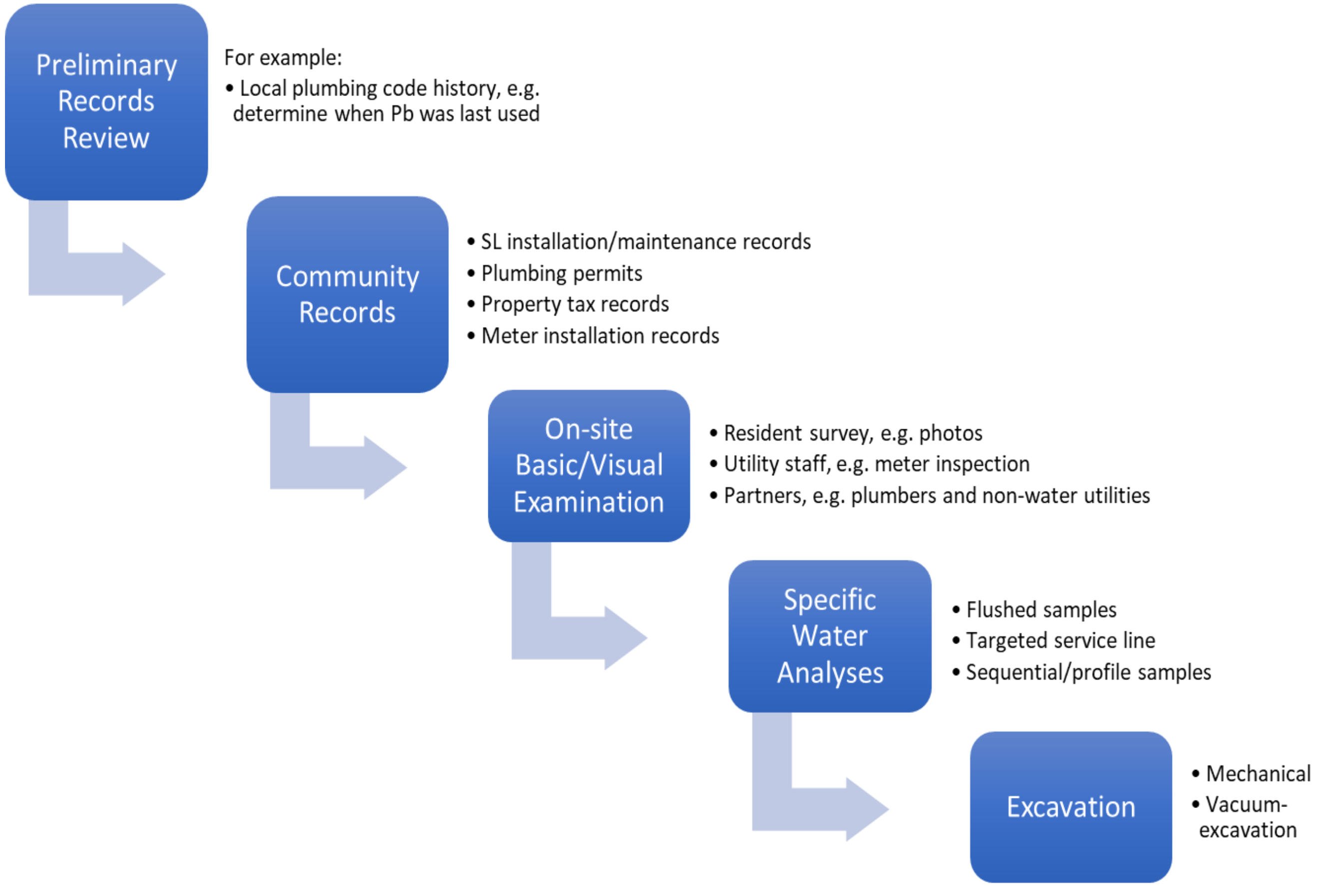
United States Environmental Protection Agency

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



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

Step-wise 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.

EPA United States Environmental Protection Agency

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

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

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United States Environmental Protection Agency

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 identification tools available
- 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 will be better defined in practice

Summary

- Different suggested approaches available for LSL identification:
  - 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 step 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?

Corrosion research & technical support examples and resources

EPA Science Matters Newsletters (https://www.epa.gov/sciencematters)

- EPA Researchers Share Approaches to Identify Lead Service Lines, *March 15, 2022*
- Scaling Back: EPA Researchers Help Communities Protect Drinking Water Systems from Lead, *April 8, 2019*
- Revealing the Complicated Nature of Tap Water Lead Contamination: A Madison, Wisconsin, Case Study, *July 30, 2018*
- Identifying the Best Lead Sampling Techniques to Protect Public Health, *October 22, 2018*

Fact Sheets

- How to Identify Lead Free Certification Marks for Drinking Water System and Plumbing Products
- Consumer Tool for Identifying POU Drinking Water Filters Certified to Reduce Lead

Workshops

- 19th Annual EPA Drinking Water Workshop. https://www.epa.gov/water-research/19th-annual-epa-drinking-water-workshop-small-system-challenges-and-solutions, August 29- September 1, 2022

- Corrosion Training session (recorded from 18th Workshop): https://www.youtube.com/watch?v=mYSwmzqKXp0)

Technical Support Summaries (ORD Water Infrastructure Division), including lead

Technical Support Summary, Water Infrastructure Division, Fiscal Year 2021
Technical Support Summary, Water Infrastructure Division, Fiscal Year 2020
Technical Support Summary, Water Infrastructure Division, Fiscal Year 2019

Webinars

- ORD/OW Small Systems Monthly Webinar Series: Lead Management in Homes/Buildings, DeSantis, Tully, and Latham, March 26, 2019

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Peer-review Journal Articles

Our journal articles now become freely accessible after about a year of publication in a journal!

- Harmon, S. Tully, J., DeSantis, M., Schock, M., Triantafyllidou,S., Lytle, D. A holistic approach to lead pipe scale analysis: Importance, methodology, and limitations. AWWA Water Science, 2022, https://awwa.onlinelibrary.wiley.com/doi/full/10.1002/aws2.1278
- Schock, M., Lytle, D., James, R., Lal, V., Tang, M. Rapid and simple lead service line detection screening protocol using water sampling. AWWA Water Science, 2021, https://awwa.onlinelibrary.wiley.com/doi/abs/10.1002/aws2.1255
- Hensley, K., Bosscher, V., Triantafyllidou, S., Lytle, D. Lead Service Line Identification: A Review of Strategies and Approaches. AWWA Water Science, 2021, https://awwa.onlinelibrary.wiley.com/doi/10.1002/aws2.1226
- Doré, E., Formal, C., Muhlen, C., Williams, D., Harmon, S., Pham, M., Triantafyllidou, S., Lytle D. Effectiveness of point-of-use and pitcher filters at removing lead phosphate nanoparticles from drinking water. Water Research, 2021. https://doi.org/10.1016/j.watres.2021.117285
- Lytle, D., Formal, C., Cahalan, K., Muhlen, C., Triantafyllidou, S. The Impact of Sampling Approach and Daily Water Usage on Lead Levels Measured at the Tap. Water Research, 2021. https://doi.org/10.1016/j.watres.2021.117071
- Triantafyllidou, S., Burkhardt, J., Tully, J., Cahalan, K., DeSantis, M., Lytle, D., Schock, M. Variability and Sampling of Lead (Pb) in Drinking Water: Assessing Potential Human Exposure Depends on the Sampling Protocol. Environment International, 2021. https://doi.org/10.1016/j.envint.2020.106259 **[JOURNAL OPEN ACCESS]**
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- Tully, J.; DeSantis, M. K.; Schock, M. R. Water Quality–Pipe Deposit Relationships in Midwestern Lead Pipes. AWWA Water Science 2019, 1 (2), e1127. https://doi.org/10.1002/aws2.1127 **[JOURNAL OPEN ACCESS in March 2019],** https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7336533/ **[EPA PUBLIC ACCESS in July 2020]**