



120Water™

STATE-DRIVEN LEAD SERVICE LINE INVENTORIES

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INTRODUCTION

Thanks to the collective efforts of social change agents, public health experts and policy makers, the sampled median blood lead level among children in the United States has decreased by 95% since 1976¹. However, the campaign continues because researchers have not yet identified a “safe” level of lead for children or adults and we now understand even low levels of exposure may harm children’s developing brains and bodies². Where present, Lead Service Lines (LSLs) are the most significant source of lead in drinking water³. Our best estimates put the national LSL count at between 6-10 million^{4,5}, but many utilities do not have accurate or complete records of service line materials, leaving us with a poor understanding of where LSLs are located and what resources would be required to finally replace them with safe alternatives.

On October 10th, 2019 EPA Administrator Andrew Wheeler announced long-awaited proposed revisions to the Lead and Copper Rule (LCRR) which was promulgated nearly 30 years ago under the Safe Drinking Water Act. One of the most important and most challenging provisions in the proposed rule is a requirement for Community Water Systems & Non-Transient Non-Community Water Systems to submit an annual Lead Service Line Inventory (LSLI).

The proposal outlines the following notable criteria for LSLIs:

- **Source Data:** infrastructure records, permits, plumbing codes and water quality results
- **Possible Formats:** List, table or map
- **An LSLI would need to include:**
 - A “Location identifier” (street, intersection or landmark)
 - Both publicly owned and privately owned LSLs or segments
 - Lines with unknown material types
- **Frequency:** Annual submission to the state primacy agency
- **Enforcement:** Allows states to establish additional inventorying methods such as, physical inspection, profile sampling or consumer identification

A clearly defined and enforceable inventory is a meaningful step toward the elimination of LSLs. Any state that has already required or encouraged utilities to proactively submit service line information has better prepared themselves and utilities for the challenges that lie ahead. In the following pages, we examine such mandatory or voluntary initiatives in 9 states. This document is intended to support state agencies as they prepare to request and oversee inventories, but it may also be relevant to utilities in the early stages of gathering service line data. Where possible, we provide links to codes and supporting documents.

¹USEPA. 2019. Biomonitoring: Lead Report. America’s Children and the Environment, 3rd Edition.

² Needleman, Herbert L. "The neurobehavioral consequences of low lead exposure in childhood." (1982): 729-32.

³ Sandvig, Anne, Pierre Kwan, Gregory Kirmeyer, Barry Maynard, David Mast, R. Rhodes Trussell, Shane Trussell, Abigail Cantor, and Annette Prescott. Contribution of service line and plumbing fixtures to lead and copper rule compliance issues. Water Environment Research Foundation, 2009.

⁴ Cornwell, David A., Richard A. Brown, and Steve H. Via. "National survey of lead service line occurrence." Journal-American Water Works Association 108, no. 4 (2016): E182-E191.

⁵ USEPA. 1991. "Drinking Water Regulations; Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper; Final Rule." Federal Register, 40 CFR parts 141 and 142. Vol. 56, No. 110. June 7, 1991.

Summary of Current State Efforts

First, we provide a brief summary of each state initiative including inventory results (table 1). Numbers in this report should not be considered final as submissions for some inventories were still being collected. If the state asked utilities to provide material information by ownership portions or segments (public vs private lines), we list those numbers separately. We do not provide a total number of lead service lines in states where information about both public and private segments was gathered because there was no meaningful way to match segments up.

In each state summary, we provide the reason for the inventory, a description of the inventory methods and definitions, and discuss the results. Next we compare metrics across all state inventories and provide two standard frameworks that could be used to collect data from utilities. Finally, we summarize some of the best practices in these approaches and provide several recommendations.

Table 1. Comparison of data collected in 9 states that required or requested water systems to complete lead service lines inventories or surveys in advance of any federal requirement.

	CA	IL	WI	OH	MI	NC	IN	MA	WA
Data Year	2019	2019	2018	2019	2019	2016-2019	2016	2016	2016
Inventory Type	Required	Required	Required	Required	Required	Voluntary	Voluntary	Voluntary	Governor's Directive
Total Utilities+	4,402	2,176	1,952	1,793	2,676	2,335	1,358	791	2,648
Respondents	2,811	1,507	518	1,919	1,029	2,195	428	547	686
Lines Inventoried	9,852,421	3,562,704	3,448,822	**	2,402,693	*	1,753,559	*	2,200,000
Public Lead Pipe	136	*	336,751	**	**	1,222	67,610	*	*
Private Lead Pipe	*	*	153,662	**	**	2,989	12,390	*	*
Total Lead Pipes	N/A	656,445	N/A	**	99,382	N/A	N/A	22,023	916
Lead Fittings	17,974	*	*	**	**	2,196	35,245	15,809	6,370
Lead Solder	*	336,652	*	**	**	648	*	*	*
Galvanized Pipes	*	51,458	24,257	**	20,558	*	*	*	27,050
Unknown SLs	860,962	723,139	*	**	1,015,796	*	268,162	*	*

*Information not required / not requested or unknown

**Data not available in a digital format

+Community Water Systems & Non-Transient Non-Community Water Systems

MANDATORY INVENTORIES



California Health and Safety Code 116885, passed in 2016, required all CWS to “compile an inventory of known lead user service lines in use in its distribution system and to identify areas that may have lead user service lines in use in its distribution system” by 2018. CWS with lead components in their distribution system were further required to develop a plan for replacement no later than 2020. California state law defines a user service line as the portion of the line between the water main and the meter but does not include the service line situated between the meter and the home. Based on this definition, the reporting requirements do not include water lines on the customer side of the meter but includes goosenecks and pigtails associated with publicly owned water lines.

In the 2019 survey, 134 CWS did not report and were listed as having an “incomplete inventory”. 361 CWS reported having “1 or more unknown user service lines/fittings”, while just 31 CWS reported “1 or more lead user service lines/fittings”. Of these 31 CWS, only 2 reported having a total of 136 lead pipes with the remaining 29 CWS reporting that their inventories included only lead fittings on non-lead pipes.



The state of Michigan amended the Michigan Safe Drinking Water Act (Act 399) to require all CWS and non-transient non-community water systems to complete a distribution systems materials inventory (DSMI) no later than January 1, 2020. The preliminary DSMI defines a service line as “the pipe from the discharge of the corporation fitting to customer site piping or to the building plumbing at the first shut-off valve inside the building, or 18 inches inside the building, whichever is shorter”, meaning that both public-side and private-side segments of service lines need to be considered when completing the inventory. All CWS and NTNCWS were asked to submit the preliminary inventory in 2020 and a final inventory is due in 2025.

The DSMI reported a total of 238 systems with known lead service lines, galvanized service lines previously connected to lead, or service lines likely to be lead. 202 systems reported having service lines in their distribution systems for which they had no information on material type. Service lines of unknown types - whether likely lead, likely not lead, or with no information - accounted for 42% of all service lines inventoried



In January 2017, [PA 99-0922](#) amended the Illinois Environmental Protection Act to require all PWS to publish an annual distribution system materials inventory beginning in 2018. The law requires annual service line materials surveys including the total number of service lines in the distribution system (including privately owned service line segments), the number of all known lead service lines, and the number of lead service lines that were added to the inventory after the previous year's submission. The survey included categories for lead service lines, copper lines with lead solder, as well as galvanized, cast iron, plastic, and other non-lead materials as well as a category for service lines of unknown material. The survey does not explicitly request information on goosenecks, pigtails, or other lead components. Although the term "Lead Service Line" is not explicitly defined within the text of PA 99-0922, other Illinois legislation defines it as, "a service line made of lead or a service line connected to a lead pigtail, lead gooseneck, or other lead fitting." For service lines of mixed materials, the [inventory instructions](#) direct utilities to select the material with the greatest lead risk.

As of April 27, 2020, 1,507 utilities responded to the 2019 materials survey. The results for 2019 are still being collected and published [online](#). These utilities reported that they were responsible for 3,562,704 service connections and surveyed the material of all service lines. Although PA 99-0922 expressly requires utilities to include public and private service lines in their materials inventory, totals by ownership are not reported. Of the responding utilities, 283 PWS reported 656,445 lead service lines in use; while 328 PWS reported having copper lines with lead solder; 457 reported having galvanized service lines in use. 285 utilities reported that they had one or more service lines of unknown material in their distribution system.



The Wisconsin Public Service Commission (PSC) requires more than 500 public- and investor-owned utilities to provide a service line materials-survey annually, with results grouped by diameter. Utilities must also report changes in the number of service lines of each material which is a helpful way to measure progress. There is no state-wide legislation requiring utilities to participate in an inventory explicitly, however utilities fall under the regulatory authority of the PSC, giving them broad authority to direct such a survey.

518 utilities submitted data about publicly owned service lines utilizing in 2018 including 517 public utilities and one investor owned utility. The investor owned utility service line material categories included three categories - lead, all metal excluding lead, and plastic and all other non-metal excluding asbestos-cement. Public utilities provided responses to a more detailed survey identifying service lines in 13 material categories including lead and galvanized pipes. At the end of year 2018, 136 utilities reported 336,751 utility-owned lead service lines in present use. The survey did not distinguish between lead pipes, lead goosenecks, and other lead components. As of 2018 utilities in Wisconsin were also required to submit information about privately-owned LSLs in Form W29. In 2018, 113 utilities reported 153,662 privately-owned lead service lines in present use. Results from two utility submissions are included in table 2 and represent the two reports required by PSC. As private-side reporting is a relatively new requirement, inventories of private service lines is an ongoing process for Wisconsin utilities.

Table 2. Service line data submitted by two Wisconsin utilities in 2018, including publicly-owned LSLs (form W22), privately-owned LSLs (form W29), and the total number of service connections listed in the Safe Drinking Water Information System (SDWIS) for each utility.

PWS	W22 LSLs (Public)	W29 LSLs (Private)	SDWIS Total Service Lines
Milwaukee Water	153,751	76,868	218,721
Madison Water	6	6	87,037



Ohio

Ohio HB 512 was passed in 2016 to enact section 6109.121 of the Ohio Revised Code (ORC), which required all CWS to submit a distribution system lead map by 2017. The law requires CWS to identify and map portions of the distribution system that are known or likely to have lead. The law also requires CWS to identify characteristics of buildings that could contain lead solder, fixtures, or pipes. Single building community and non-transient non-community water systems are also required to map portions of their system that contain lead solder, fixtures, or pipes.

The Ohio EPA Guidelines for Lead Mapping in Distribution Systems suggests that CWS review local codes and regulations, permit records, maintenance and operations records, and customer self-reporting to determine which portions of the distribution system are likely to contain lead service lines. When mapping inventory information, a CWS must only block out areas that may contain lead service lines or other lead components. If the information is available, the Ohio EPA guidelines state that “water systems should identify individual service connections on the map” and gives a required color scheme. As of early 2020, 1,919 systems provided distribution system lead maps which are published on the Ohio EPA website.

VOLUNTARY INVENTORIES & SURVEYS



The state of Indiana currently has no legal provision requiring CWS to participate in a lead service line inventory, however, a voluntary survey was issued by the Indiana Department of Environmental Management to CWS in 2016. As indicated in table 1, IDEM requested some of the most specific data, especially among voluntary surveys. The agency also asked each utility to self-report on the confidence or accuracy of their submission.

Of the 428 respondents, 118 CWS reported a total of 205,534 service lines with any lead portion including goosenecks. However, respondents also reported that there are 67,610 cases where the public segment of the service line is lead, 12,390 cases where the private side is lead and 92,483 where the entire service line is lead. This gives a total of 207,728 service lines where any component is lead.

Although the survey requested information on whether any portion of the service line is lead, not lead or unknown, 17 CWS did not account for all of their service connection material status. 29 CWS actually accounted for more than their total number of service connections. This is likely because the system knew with some certainty that the service line was “not lead” but could not identify the exact material of the service line, therefore “double counting” some service lines. However, 17 of the 29 simply did not provide an estimate of the total number of service connections but did provide estimates of pipes with lead, non-lead, and unknown material components. Three CWS were listed as responding to the survey but did not have any data listed for any category on the survey.



The Massachusetts’s Department of Environmental Protection developed an informational mailing and online survey for all CWS and NTNCWS in response to a 2016 letter from EPA, which emphasized the need to review LCR implementation activities to ensure that state programs are addressing risks to lead in drinking water. The stated goal of the survey was to identify technical assistance needs and to collect best management practices related to LSL program implementation and consumer communication and transparency.

547 utilities responded to the survey, indicating 22,023 lead service lines, with ownership not reported by the state. Utilities also reported 15,809 lead fittings with 12,717 of them being publicly owned attached to homes, 6 reported in municipal buildings, and 108 in schools or childcare facilities. This is the only survey we are aware of that specifically asks utilities to identify LSLs in schools and childcare facilities.



North Carolina

Title 15A of the North Carolina Administrative Code, subchapter 18C defines a lead service line as, “Lead service line means a service line made of lead which connects the water main to the building inlet and any lead pigtail, gooseneck or other fitting which is connected to such lead line”. Although there is not a legal requirement to conduct a service line materials survey, the state requested voluntary responses to a survey beginning in 2016.

1,295 utilities responded to the survey between 2016-2019; the results are published [online](#). 22 Utilities reported 4,094 total lead service lines in their water systems. The same utilities reported 1,222 utility-owned lead service lines and 2,989 customer-owned lead service lines for a sum of 4,211 total lead service lines. Some utilities have reported the entire service line as a single line (e.g. 100 utility side service lines, 100 customer side service lines for a total of 100 lead service lines). Other utilities report service line segments (e.g. 1000 utility side service lines, 500 customer side service lines, for a total of 1500 lead service lines). Six utilities answered “Yes” to whether they had lead service lines in their distribution systems but estimated no lead service lines on either the public or private side.



Washington

In 2016, the governor of Washington issued [Directive 16-06](#), directing state agencies to identify and replace water infrastructure components containing lead. The data collected from state-wide surveys is not published online, instead the Department of Health has [published several reports](#) related to the survey and its results. The agency also maintains a [“lead exposure risk” tool](#), enabling residents to determine if they live in a county with a high risk of general exposure to lead.

There were 686 respondents serving more than 85% of the state’s service connections. While 48 utilities indicated that they did not know whether they had lead service lines in their distribution system. 39 utilities reported the presence of 27,050 galvanized service lines while 65 utilities reported they did not know whether they had galvanized service lines in their distribution system. Fifteen utilities reported that 6,370 galvanized service lines are connected to the water main by lead gooseneck or other lead component. The survey questions did not explicitly distinguish between publicly and privately owned service lines. The Washington State Department of Health used these survey responses to extrapolate that there are approximately 1000-2000 lead service lines currently in use across the state.

CONSIDERATIONS & RECOMMENDATIONS FOR POLICY MAKERS

We compare the results of all state inventories in **table 3** based on standard reporting criteria listed by at least two states and provide four recommendations for policy makers to consider as they prepare to help water systems comply with the LCRR.

Table 3. An overview of inventory components from 9 state-wide mandatory or voluntary inventories or surveys from 2016-2019.

State	Private/ Public Line Distinction	Lead Solder	Lead Fittings	Galvanized	Unknowns	Asked for Non-lead materials	Submission Format
Regulatory/Mandatory Inventories							
Wisconsin				X		X	Digital count
Illinois		X		X	X	X	Digital count
California			X		X		GIS-based
Michigan				X	X		Digital count
Ohio	X	X	X	X		X	Paper Map
Voluntary Inventories/Surveys							
North Carolina	X	X	X	X	X	X	Digital count, Yes/No
Indiana	X		X		X		Digital count
Massachusetts			X				Digital count
Washington			X	X			Digital count

Ask for a digital inventory of data by location

At present, many of the state inventories and surveys appear to most commonly be count-based, meaning water systems review records and service line data internally, but only report a final count of lead services. In a location-based inventory, material types for each service line are provided by address or location marker. The proposed LCRR language currently requires utilities to submit LSLs by location, but not address specifically. There are still a number of open questions regarding how EPA expects inventory data to be reported and of course nothing is final yet. As we await the final regulatory language, we provide examples of both count-based (table 4) and location-based (table 5) inventory reporting metrics. Definitions for data inputs reflect the practices of many states in this paper as well as the recommendations of the Association of State Drinking Water Agencies⁶ (figure 1).

Assuming it would be permissible under the final LCRR, a count-based inventory would be simple to review and would provide utilities with flexibility, but may be difficult to enforce. For example, a count of LSLs could not be cross-referenced with Tier list homes or to verify annual LSL notifications. This approach may also limit the cross functionality of the inventory and could reduce the usefulness of the data for assessing financial need. It is important to acknowledge that smaller systems may especially struggle to gather and report service line data at the detailed level we recommend. This style of inventory could also require more oversight by state employees, further stressing already underfunded agencies⁷.

Despite these challenges, we suggest location-based inventories create the clearest roadmap for an effort that may take many years. For agencies, location-based inventories would provide a more meaningful opportunity for enforcement, produce more accurate data for decision-making, and support other cross functional initiatives. Utilities would benefit from this approach because location-based inventory methods are clear, support long-term project management, and reduce the potential of a reduplication of efforts later.

Table 4. Seven standardized data fields and inputs agencies could request during annual inventories based on the efforts of other states. This is a simplified count-based submission and would not require utilities to submit service line location information

	Lead Pipes		Copper with Lead Solder		Galvanized Pipes		Unknown Material		Unknown Likely Lead		Lead Fittings	Data Sources
	Public	Private	Public	Private	Public	Private	Public	Private	Public	Private	Total	Codes (see key)
Inputs	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total		

⁶ Association of State Drinking Water Administrators. 2019. Developing Lead Service Lines Inventories. https://www.asdwa.org/wp-content/uploads/2019/08/ASDWA_Developing-Lead-Service-Line-Inventories.pdf. March 2020.

⁷ Association of State Drinking Water Administrators. 2018. Beyond Tight Budgets: 2018 Resource Demands Analysis for State Drinking Water Programs. <https://www.asdwa.org/wp-content/uploads/2018/12/Beyond-Tight-Budgets-2018.pdf>. February 2020.

Table 5. Five standardized data fields and inputs agencies could request during annual inventories based on the efforts of other states.

	Service Line Location Information	Public Line Material	Private Line Material	Lead Fittings	Data Source
Input Selections	Address, Lat/Long or Location ID	7-16 options (see key)	7-16 options (see key)	Yes or No	4 options (See key)
Reason to Collect	Valuable for enforcement, promotes transparency, supports public health initiatives, produces cross-functional data set	Valuable for enforcement, provides clear implementation guidance, useful for determining financial need	Valuable for enforcement, provides clear implementation guidance, useful for determining financial need	Valuable for enforcement, clear definitions, useful for determining financial need	Valuable for enforcement

Figure 1. Data Input Key & Definitions

Public & Private Material Line Types (7-16)

- L=Lead Pipe
- CLS= Copper with Lead Solder
- G=Galvanized
- GPC=Galvanized previously connected to lead
- C=Copper (no lead solder)
- ULL=Unknown, Likely Lead or CLS
- UK=Unknown

-----Non-Lead Related-----

- CI=Cast Iron
- HDPE=High density polyethylene
- PVC=Polyethylene
- PB=Polybutylene
- AC=Asbestos Cement
- S=Steel
- CN=Concrete
- O=Other

Lead Fittings

Includes leaded goosenecks, pigtails or corporation stops

Data Source Options (4)

V=Visual inspection
R=Records indicating material type
M=Modeling
A=Service line install date or home age

Clearly define lead service lines

Inventory information often lives in multiple systems and sources (GIS, work order software, etc.) and pulling this information together can involve a large group of utility staff and a considerable amount of time and energy. States can of course assist utilities in making this sometimes resource-intensive process efficient and effective by providing clear guidance on how to conduct the inventory and specifically what data to include. EPA provides this LSL definition in the LCRR Proposal:

“Lead service line means a service line 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 or building is a lead gooseneck, pigtail, or connector, and it is not a galvanized service line that is considered an LSL the service line is not a lead service line.”⁸

EPA’s current definition of an LSL is pipe-centric and leaves out lead solder and some lead fittings. This is somewhat perplexing as homes served by services with lead solder are considered Tier 2 monitoring sites, which means systems would need to make some attempt to identify those homes if there are no lead pipes in the service area. Research indicates that lead solder can be a significant source of lead in drinking water and it may be most efficient to ask utilities to locate these as part of the annual inventory .

To protect public health and reduce the likelihood that utilities would have to repeat inventory work in the future, “Lead Service Lines” could be defined more comprehensively to include:

- Lead pipes
- Galvanized pipes connected to lead pipes
- Lead Solder
- Lead Fittings: Goosenecks, pigtails and corporations

In practice, it may be advantageous to collect data about each of these sources, so that systems can prioritize replacing lead pipes over soldered lines for example. Further segmenting service line data by capturing fittings may also support more accurate cost estimates.

Choose a sustainable & enforceable submission method

Digital submissions of either method will provide the most meaningful opportunity to review the accuracy of the information submitted. Static lists and PDF maps are difficult to compile, review, and share with the public, but simple CSV files, databases, and GIS files were utilized by many of the states included in this report and would support a more efficient process for all.

⁸ USEPA. 2019. “Drinking Water Regulations; Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper; Proposed Rule.” Federal Register, 40 CFR parts 141 and 142. Vol. 56, No. 110. Page 222. November 13, 2019.

⁹ Subramanian, Kunnath S., and John W. Connor. "Lead contamination of drinking water: Metals leaching from soldered pipes may pose health hazard." *Journal of Environmental Health* (1991): 29-32.

Embrace the unknowns but understand the basis of each inventory

Because the LCRR does not include a date for a “final” LSLI, utilities are encouraged to be honest about what they do not know yet by listing pipe materials as “unknown” in the early years and then decreasing the number of unknown pipes overtime. This flexibility is important because it can be costly to verify service material types in the field with standard methods like water testing, hydro-vacing and trenching. At the same time, it is equally important to understand how inventories were conducted. Metrics like self-reported confidence numbers may be difficult to interpret. Instead, we suggest states permit utilities to rely on four data sources and to report which sources were used: Visual inspection, infrastructure records, service line install dates or home age, and modeling (figure 1). These four categories are based on current inventory practices and existing research on the effectiveness of modeling^{10,11}.

¹⁰ Goovaerts, Pierre. "How geostatistics can help you find lead and galvanized water service lines: The case of Flint, MI." *Science of the total environment* 599 (2017): 1552-1563.

¹¹ Abernethy, Jacob, Alex Chojnacki, Arya Farahi, Eric Schwartz, and Jared Webb. "ActiveRemediation: The Search for Lead Pipes in Flint, Michigan." In *Proceedings of the 24th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining*, pp. 5-14. 2018.