Independent Verification and Validation of DC Water's Lead Free DC Lead Service Line Removal Plan: FINAL REPORT

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Definitions for Abbreviations, Acronyms and Terms

- **ACS** – American Community Survey Data
- **AMR** – Automatic Meter Reading
- **BBB** – Block-by-block approach
- **Block** – A length of street between two intersections/dead ends used by DC Water in prioritizing lead service line replacements
- **Block Group** – A US Census designated geographic area consisting of between 600-3,000 people
- **CIP** – Capital Improvement Plan
- **CIPERR** – Capital Improvement Project and Emergency Repair Replacement
- **DDOT** - District of Columbia Department of Transportation
- **EBLL** – Elevated Blood Lead Level
- **FLSLR** – Full Lead Service Line Replacement
- **FTE** – Full Time Equivalent
- **LFDC Plan and LFDC** – Lead Free DC Lead Service Line Replacement Plan[1]
- **LPRAP** – Lead Pipe Replacement Assistance Program
- **LSL** – Lead, brass and galvanized service lines. The Council of the District of Columbia added brass and galvanized service lines to its definition of lead service lines that require replacement in January 2021.
- **LSLR** – Lead Service Line Replacement
- **Pothole** – Excavation to expose a section of water service to determine the location, size, and material type of existing water services. Also known as a test pit.[2]
- **PLSLR** – Partial Lead Service Line Replacement
- **QA/QC** – Quality Assurance/Quality Control
- **RLDWA** – Reducing Lead in Drinking Water Act
- **SDWM** – Small Diameter Water Main
- **SDWMR** – Small Diameter Water Main Replacement
- **Test pit** – Excavation to expose a section of water service to determine the location, size, and material type of existing water services. Also known as a pothole.[2]
- **VFRP** – Voluntary Full Replacement Program
- **WMR** – Water main replacement

EXECUTIVE SUMMARY

Safe Water Engineering, LLC completed a third-party assessment of the Lead Free DC Lead Service Line Replacement Plan[1] (LFDC Plan) to ensure that, as proposed, the plan will achieve both DC Water and the District's lead water service line replacement goals, including the removal and replacement of all lead water service lines by 2030, prioritization of vulnerable populations in any prioritization model, and fiscal responsibility. The Council of the District of Columbia added brass and galvanized service lines to its definition of lead service lines (LSLs) that require replacement in January 2021.

This report identifies challenges within the LFDC Plan that will make it difficult to achieve the District of Columbia's goals. Issues include not accounting for test-pitting all potential LSLs – or the replacement of verified brass and galvanized service lines. Additional concerns include unclear contract requirements, relying on individuals to initiate and fund their own lead service line replacements (LSLRs) and dividing LSLR programs by scope, time and space.

We strongly support DC Water's recommendation in the LFDC Plan to eliminate unnecessary bifurcation of programs and the distinction between funding options for partial lead service line replacements (PLSLRs) and full lead service line replacements (FLSLRs). The distinctions of funding sources, funding eligibility, and program administration decrease the efficiency of the LFDC Plan. Breaking down these distinctions and merging programs to function at the neighborhood scale will greatly improve efficiency and the timeline for removing all lead, galvanized, and brass service lines.

This report reviews practices and strategies in benchmarking cities and recommends approaches used elsewhere to improve the effectiveness of the LFDC Plan.

Summary of Recommendations

We provide the following recommendations to improve the effectiveness and efficiency of the LFDC Plan for the major decision-making points of the LFDC Plan:

Service Line Inventory

1. Clarify customer outreach, sampling strategies, and historical record-keeping;
2. Continue using current inventory dataset and excavation verification strategy; and
3. Consider statistical methods to identify areas with copper service lines that turn out to be lead, and brass service lines that turn out to be lead or brass.

Prioritization Criteria and Model Weights

1. Use Higher Resolution American Community Survey (ACS) data for children 5 and under;
2. Remove iron and chlorine sampling parameters; and
3. Use new recommended parameters and weights.

Removal Programs, Funding Sources, and Program Structure

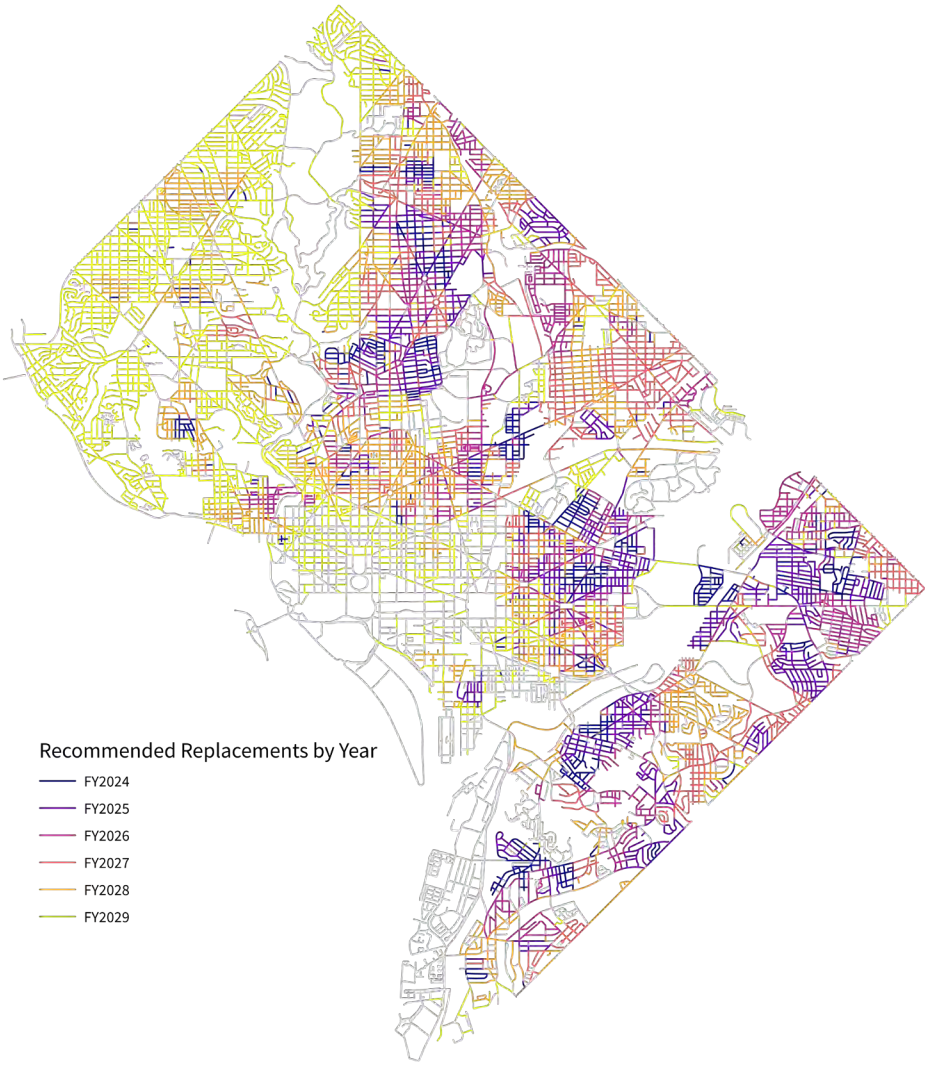
1. Pass an LSLR mandate and provide funding for all LSLRs.
2. Create a new DC Water-initiated Neighborhood Scale LSLR Program;
3. Create a new district-wide DC Water-initiated Individual High-Priority LSLR Program;
4. Group all LSLRs associated with water main replacements (WMR) together in the Capital Improvement Plan (CIP) to create the CIP Water Main Replacement LSLR Program; and
5. Continue the Voluntary Full Replacement Program (VFRP) program from the LFDC plan.

Program Timelines and Geographies

1. Schedule the majority of LSLRs using the prioritization model at the Census Block Group Scale;
2. Plan to complete all LSLRs in 6 years (2024-2029); and
3. Complete service line verifications and LSLRs at all day care centers during the first year.

Map ES.1 shows how the recommended programs and timelines would be distributed across the district.

MAP ES.1 Recommendation for LSLR Replacements by Year



Construction Costs

1. Include the cost of test pitting all unknowns, historic copper, and historic brass service lines;
2. Plan for replacing the 50% of unknowns, 20% of historic copper, and 47% of historic brass that are estimated to be lead, brass or galvanized service lines;
3. Plan for replacing all remaining non-historic brass and galvanized service lines;
4. Update other cost percentages;
5. Explore strategies for reducing the cost of LSLRs in the Neighborhood Scale LSLR Program;
6. Include the cost of providing certified lead reducing filters to all residents with potential LSLs; and
7. Consider policy changes to reduce paving costs.

Table ES.1 quantifies and summarizes the cost savings and additions identified through our analysis and recommendations.

Table ES.1: Costs of Recommended Revisions Compared to 2022 LFDC Cost Update

Corrections to 20220331 LFDC Revised Cost Estimate	Difference
Update AA12 to correct calculation error in applying 10% contingency	-$47,530,653
Remove Test pit charges for Service Lines that are determined to be Lead per contract specifications	-$60,628,934
Analysis of Recommendations	
Move all SDWM Replacement costs to CIP	-$169,318,277
Adjust restoration to most cost-effective method cost: full street paving or individual site restoration	-$148,394,279
Account for efficiencies of scale for neighborhood scale replacement for non-water main replacement projects	-$29,398,712
Adjust Design, Engagement, Management, and Data Costs	-$90,125,122
Adjust Service Line replacement costs per DC Water bids	$32,350,860
Account for test pitting all Unknowns and Historic Brass in addition to Historic Copper	$18,284,697
Add filters for all potential LSLs and 6 months post replacement	$24,145,432
Account for Individual High-Priority LSLR Program	$8,524,177
Account for replacing LSLs found from Historic Brass and Copper test pits	$143,822,464
Account for replacing all brass and galvanized service lines	$34,895,254

Table ES.2 provides the recommended LSLR plan cost as described in this report.

Our LFDC Plan Recommendations are designed to achieve the following:

- Account for identification and removal of all potential lead, brass and galvanized service lines;
- Prioritize critical customers and equity;
- Consolidate programs and timelines to generate cost efficiencies;
- Provide certified lead reducing filters to all potential LSL locations to provide an immediate source of safe drinking water for all residents; and
- Encourage and increase public participation through lower costs, fewer participation barriers, and increased public engagement.

TABLE ES.2: Recommended LSLR Plan Cost

Program	Number of Test Pits	Number of LSLRs	Recommended Program Cost	Miles of WMR	WMR Cost
Neighborhood Scale LSLR program	77,809	31,319	$386,000,000	-	$0
CIP Water Main Replacement LSLR Program	8,875	6,771	$45,000,000	97	$338,000,000
Individual High-Priority LSLR Program	-	4,232	$49,000,000	-	$0
Total:	86,684	42,323	$480,000,000		

Grand Total Low Estimate*		$480,000,000
Grand Total High Estimate*		$628,000,000

**The low and high estimates are calculated using optimized street paving versus street paving as suggested by District of Columbia Department of Transportation regulations.*

The cost estimate for the LFDC Plan is $680 million (Appendix G), which includes $540 million for LSLR and $141 million for WMR. An additional $193 million for currently planned WMR, $15 million for future planned WMR, and $201 million for future estimated WMR is presented separately but included with the LFDC Plan cost estimate.

Our recommendations for the LFDC Plan using our analysis and recommended strategies have a total cost estimate between $480 and $628 million. **The recommended changes to the LFDC Plan provide for the replacement of all LSLs by 2030, and they account for the replacement of 14,348 more LSLs than the original LFDC Plan.** In addition to a subset of unknown and copper service lines, this includes brass and galvanized service lines that the Council of the District of Columbia added to its definition of LSLs that require replacement. The recommendations include service line verification for all unknowns and unverified historical records, addressing a total of 8,867 more potential LSLs compared to the LFDC Plan (number of LSLRs plus services planned for test pitting). Our recommendations add the provision of certified lead reducing filters to provide an immediate source of safe drinking water to all residents with potential LSLs until LSLs are removed. Further, our recommended programs continue the essential test pitting, outreach, and program and data management practices included in the LFDC plan that are critical for project success.

While we recognize the $349 million need DC Water has included for currently identified WMRs ($141 million for poor quality main WMR, $193 million for currently planned WMR, and $15 million for future planned WMR), we recommend that these WMRs be included in the CIP budget rather than the LFDC budget. These replacements are necessary for maintaining water quality and infrastructure integrity, and LSLR will be least expensive if completed at the same time. However, these are expenses DC Water must plan for even in the absence of a LFDC Plan. Therefore, we recommend funding the WMRs that DC Water identifies as necessary, but we do not include WMR costs in the recommended LFDC Plan cost estimates presented here.

To successfully implement the recommended program, the Council of the District of Columbia will need to eliminate the bifurcation of LSLR programs and the distinction between funding options for partial LSLs and full LSLs. The current LFDC distinctions of funding sources, funding eligibility, and program administration decrease the efficiency of the LFDC plan. DC Water will need new funding for removing private side LSLs and policy support to implement these recommendations. Breaking down programmatic boundaries and merging programs to function at the neighborhood scale will greatly improve efficiency and the timeline for removing all LSLs.

Study Description

The Council of the District of Columbia contracted with Safe Water Engineering to perform a third-party assessment of the Lead Free DC Lead Service Line Replacement Plan[1] (LFDC Plan) to ensure that, as proposed, the plan will meet both DC Water and the District's lead water service line replacement goals, including the removal and replacement of all lead water service lines by 2030, prioritization of vulnerable populations in any prioritization model, and fiscal responsibility.

This report examines the LFDC[1] and cost updates from March 31, 2022. These documents were the core materials evaluated for this report, along with additional materials publicly available or made available by the Council of the District of Columbia and DC Water, several of which are attached as appendices to this report.

The charge for this independent verification and validation is to provide the following:

- An assessment of whether the plan, as proposed, is reasonably structured to facilitate DC Water's successful removal and replacement of all remaining full and partial lead water services line in the District by 2030; and, where the plan is not, an analysis of elements of the plan that are insufficient to meet that goal, and any plan elements absent from the plan but necessary for the timely completion of this work.
- A review of the planning-level cost estimate within the plan, and whether individual elements of the planning-level cost estimate—including both high and low estimates—are accurate and necessary to the successful removal and replacement of all remaining full and partial lead water services line by 2030. This review shall include a comparison of how lead water service line replacements have been financed in other comparable jurisdictions, including an examination of projected and actual costs in those jurisdictions.

- An assessment of the LSLR planning and prioritization model, and whether the model is reasonably structured to meet DC Water's goal of removal and replacement of all remaining full and partial lead water services line by 2030 in an efficient and equitable manner, including:
  - A review of the prioritization algorithm, individual data metrics, and data metric and element definitions to ensure compliance with goals of the model; and
  - An assessment of prioritization models utilized by comparable jurisdictions undertaking lead water service line replacement work, and costs and benefits of those models.

The following cities were selected as benchmarking cities for this study, with large variation in the quantify of information provided by each city's respective water department:

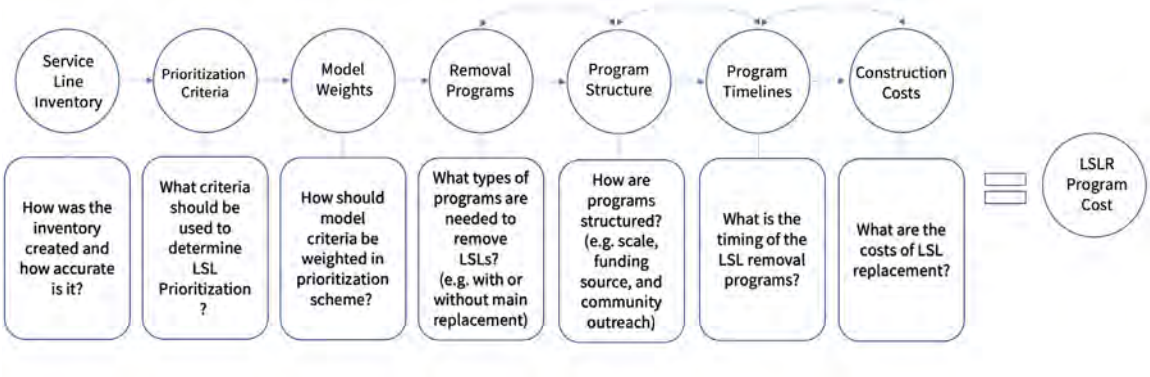
- **Baltimore, MD:** Baltimore City Department of Public Works (DPW)
  - Note: although this is a comparable city in the region, they had no active LSLR program at the time they were contacted for this study so no further information is provided here.
- **Cincinnati, OH:** Greater Cincinnati Water Works (GCWW)
- **Denver, CO:** Denver Water
- **Pittsburgh, PA:** Pittsburgh Water and Sewer Authority
- **Detroit, MI:** Detroit Water and Sewerage Department
- **Flint, MI:** City of Flint Water Department
- **Newark, NJ:** Newark Department of Water and Sewer Utilities

Information from these programs is presented to illustrate alternative strategies, practices, and implementation data from other cities that have some overlapping characteristics with Washington, DC. Rather than a comprehensive review of best practices, the benchmarking data presented in this report provides real-world examples of how alternative strategies could unfold in Washington, DC.

ANALYSIS OF LEAD FREE DC PLAN ABILITY TO REMOVE ALL FULL AND PARTIAL LEAD SERVICE LINES BY 2030

Figure 1 shows the programmatic strategy and decision-making points that determine the overall cost of a LSL removal program. As the figure shows, some of these steps are fundamentally sequential, with certain decisions dependent on previous data. Others are iterative where modifications can and should be made after considering the data.

FIGURE 1: Lead Service Line Removal Program Cost Decision Points



The analysis presented in this report will detail the following for each decision point:

- What did DC Water do in the LFDC Plan?
- How does this compare to benchmark cities?
- What do we recommend doing?

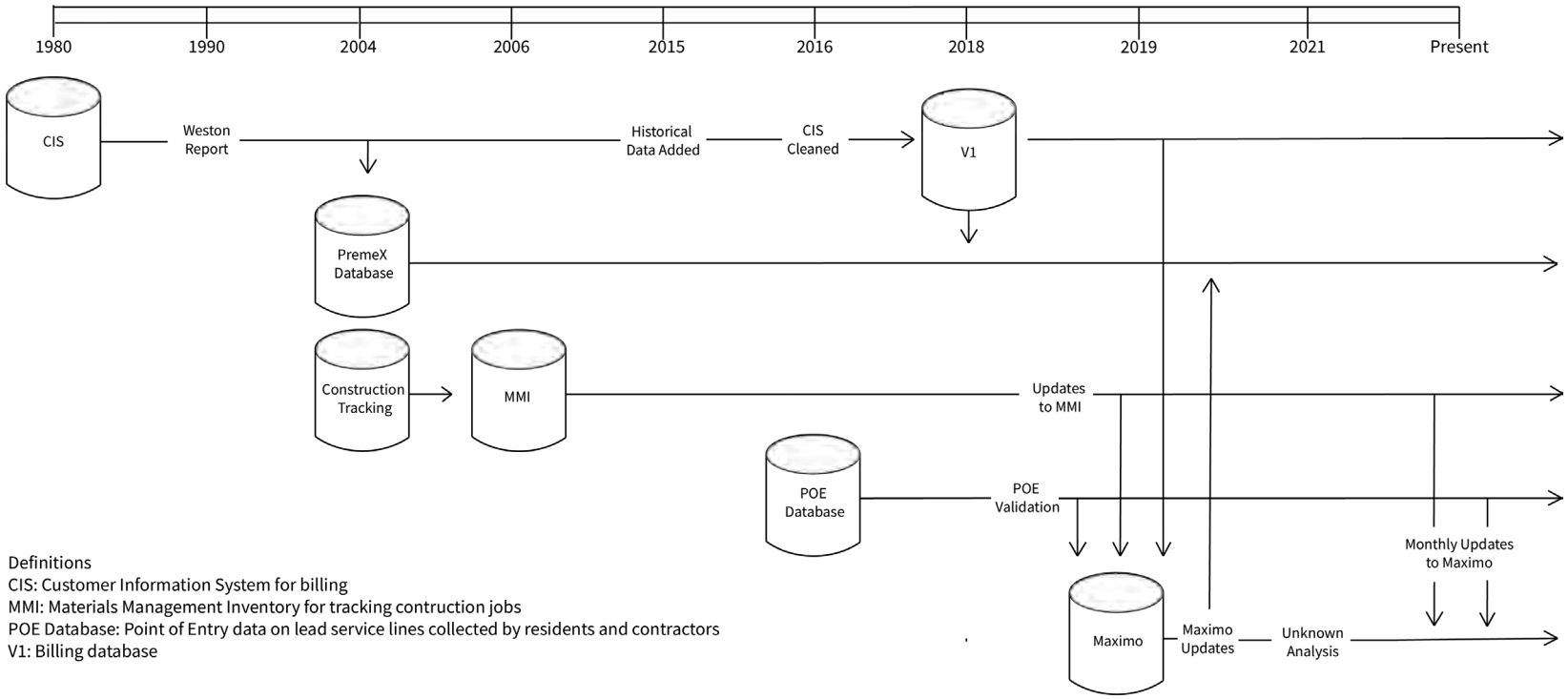
Service Line Inventory

What did DC Water do?

In 1990, Roy F. Weston produced the Lead in Water Study[3] on behalf of DC Water, anticipating the US Environmental Protection Agency's Lead and Copper Rule, which provided a comprehensive review of what was known at the time regarding Washington, DC's service line inventory, water quality, and water treatment as it pertains to lead. According to this report, the last LSL installation was in 1977. The report also states that Washington, DC has more than 126,000 total service lines of which there are 8,271 known LSLs and 19,980 probable LSLs. About 2,900 of those homes with known or probable LSLs have lead concentration of more than 20 ug/L according to the data published in 1990.[3]

Figure 2 below shows a timeline of revisions DC Water has made to the service line inventory, including software updates, process changes, and specific records review processes.

FIGURE 2: History of DC Water Service Line Inventory Databases and Business Processes



As described in the Weston Report[3] and "Business Processes for Service Line Material Management," (see Appendix A), DC Water has completed a comprehensive review of all construction codes, permits, and records; water system records; and all inspection records. DC Water has found that using test pits, excavations to reveal the service line size and material, for verifications and construction records are the most reliable methods of verifying service line material in Washington, DC. DC Water describes rigorous data entry and QA/QC procedures that indicate that current data collection and records management should be producing high-quality and reliable inventory data. We prepared an annotated version of the DC Water "Business Processes" document based on clarifying conversations, which is provided in Appendix B.

DC Water uses a combination of the following practices to manage and update its service line inventory:

- Data collection during field work and WMR.
- Test pitting all service lines that meet certain criteria.
- Water quality sampling.
- Customer data submissions from inspecting the service line material inside the home.
- Researching administrative data such as as-built, permit, and home build documents.

Based on these data procedures, Table 1 shows the service line inventory that DC Water provided that was current as of March 2022 including the following service line counts:

Table 1: DC Water Service Line Inventory, Current as of March 2022

Material	Public Count	Private Count
Lead	10,182	21,055
Unknown	11,841	13,488
Copper (Historic)	42,212	42,212
Galvanized	75	544
Brass (Historic)	8,093	8,075
Brass	1,439	1,791
Sub-Total of Potential LSLs	*73,842*	*87,390*
Copper	43,463	28,278
Iron	87	36
Non-Lead	7,121	8,820
Sub-Total of non-LSLs	***50,670***	***37,143***
Total	**124,512**	**124,524**

Based on DC Water's review of 2022 LFDC By Block field work, they discovered that 50% of unknown service lines and 20% of historic copper service lines are found to be lead (Schmelling, Personal communication, June 23, 2022). It should be noted that the historical copper data review only accounts for a total of 130 service lines completed through Small Diameter Water Main (SDWM) contracts. It is possible that this number might change substantially with more verifications, and it may vary in different neighborhoods or regions of the district.

Further, in January 2021 the Council of the District of Columbia added brass and galvanized water service lines to its definition of LSLs that require replacement. A 2020 review of test pit data from 2,895 historic brass service lines resulted in the following service line materials: 10% lead, 2% galvanized, 35% brass, and 53% copper (Schmelling, Personal communication, June 28, 2022). If these numbers are consistent across the entire district, this means that 47% of historic brass service lines require replacement.

Table 1 provides the counts of each service line material as currently recorded in DC Water's inventory. To account for LSLs and material categories that may not be accurate as demonstrated through test pit data, we created Table 2 showing the current number of service lines in Washington, DC that must be verified and the anticipated number that must ultimately be replaced. Table 2 does not include material categories that do not need to be verified or replaced based on DC Water's data.

Table 2: Service Lines in Washington, DC That Must Be Accounted for and the Anticipated Number Requiring Replacement

Material	Number of public and/or private services accounted for	Estimated Replacements Required (Lead, brass, and galvanized)
Lead	21,792	21,792
Unknown	11,399	5,700
Copper (Historic)	41,675	8,335
Galvanized	660	660
Brass	2,021	2,021
Brass (Historic)	8,118	3,815
Totals:	**85,665**	**42,323**

Table 1 and Table 2 have slightly different values for the number of service lines due to the use of different data sources. Table 1 is derived from the service line inventory while Table 2 is derived from the LFDC shapefiles whose lead and public unknown estimates are summarized by block. Furthermore, the unknown estimate in Table 2 accounts for public unknowns while Table 1 also includes private side only unknown estimates.

How does this compare to benchmark cities?

Like Washington, DC, many water utilities have incomplete service line inventories that require substantial updates and verification.[4] Many water utilities are in an active process of updating and maintaining their service line inventories and use a variety of practices as described in the following list. Each water utility may be using more service line data collection methods than listed here, but the ones listed have been emphasized by each of the programs. Potholing is another term used to describe a test pit, or excavation of a service line for physical verification. The terms provided by each community have been included in the following:

- **Denver:** Statistical modeling, customer data submissions and potholing.
- **Detroit:** Statistical modeling, data collection and verification during field work and WMR, customer data submissions.
- **Flint:** Statistical modeling and potholing.
- **Newark:** Excavation of every service line.
- **Pittsburgh:** Excavation of all lead and unknown service lines within the project area, records review, water meter and health department inspection.[5]

What do we recommend doing?

1. Stop using lead in water sampling for LSL verification.

The LFDC plan describes the use of lead in water sampling for service line verification. The efficacy of lead sampling for service line identification is highly dependent on the sampling protocol used, and no documents on the sampling procedure were provided. Presence of lead in water samples can indicate the presence of an LSL or lead components, but low or non-detect lead results cannot prove the absence of an LSL.[2] This practice can create confusing messaging or interpretation at the household level regarding whether an LSL exists at the house. The costs of this sampling program were not included in the cost spreadsheets. Due to the lack of clarity around efficacy, lack of cost inclusion, and the recommended neighborhood based LSLR program that will include test pitting of every potential LSL, we recommend ending this program. Because service lines identified through water quality sampling will be identified through test pits in the recommended plan, this change results in no loss of accuracy or efficiency. Lead in water sampling should continue to be made available for purposes other than LSL identification.

2. Clarify public information about service line identification.

DC Water has prepared many outreach materials regarding its LSLR programs in the district. They provide detailed guidance to residents on how to check service line material inside the house, but they do not clearly state that buried service lines can and do turn out to be made of different materials. If lead is not found inside the house but is found during an excavation, the service must be replaced. Lack of clear communication can result in residents consuming water with elevated risk of lead for years until their service line can be verified. We recommend all outreach materials clearly state, especially for homes or properties developed before 1977, that positive documentation and verification of the buried service line material is necessary to ensure there is a non-lead service line. Clear customer outreach and education is essential for building trust and support for the overall plan.

3. Maintain historical service line data, even when records are updated.

DC Water has gone through several inventory review and update processes over the past 30-plus years. It currently overwrites information when service line records are updated. Maintaining historical records for each service may provide critical information for future maintenance work or understanding water quality challenges at an individual location. It is useful to maintain historical data as a weight of evidence where questions might arise regarding service line material. We recommend maintaining historical records even as records are updated.

4. Continue using current inventory dataset and excavation verification strategy.

Because DC Water continues to find that its most accurate records come from new construction projects and excavations, we recommend continuing DC Water's approach of verifying every service line as they work. While data modeling techniques for identifying probabilities of LSLs exist and have been useful in some cities, these techniques only identify probabilities of LSLs that can be used to prioritize work; they do not generate a verified service line inventory. The verification process must still be used even when modeling techniques are used. Given current data quality and verification plans at DC Water, we recommend relying on the current inventory and continuing the current verification strategy with programmatic modifications as described below.

5. Consider statistical methods to identify areas with copper that turn out to be lead and brass service lines that are found to be lead or brass.

Statistical modeling approaches, like those used by several benchmarking cities, can be very useful for calculating the probability of finding a LSL. These data can be used to prioritize where to initiate LSLRs to ensure that actual LSLs are replaced quickly. Statistical modeling to predict service line material becomes more important the lower the hit rate for finding LSLs in a water system and the longer the time period provided for LSLR. With a LSL hit rate of 20% for 42,212 service lines it may be appropriate for DC Water to consider using statistical methods to predict LSLs, especially if the timeline for replacing all LSLs in Washington, DC must be expanded past 2030.

The shorter the time period allotted for LSLR, the less value a statistical model provides since it will divert resources from the LSLR and verifications themselves which are needed regardless.

Prioritization Criteria and Model Weights

What did DC Water do?

DC Water developed a LSLR prioritization model in conjunction with Mott Macdonald within the InfoAsset Planner software, described in the memo InfoAsset Planner LFDC Model Development[6] provided as Appendix D to this report. The model is used to identify high-priority replacements and uses two categories of parameters: consequence of lead (CoL) and likelihood of lead (LoL). The 1-to-10 scores for each category are multiplied together to reach a final Risk Score. This method prioritizes blocks with a moderate score in each category over blocks with a very low LoL or CoL. Parameters within the CoL category include health and equity, number of children, and childcare facility metrics, while parameters within the LoL category include physical condition and performance of the water distribution system.

Half of the weight of CoL is composed of the Area Deprivation Index (ADI) created by University of Wisconsin.[7] The index is a weighted score of over 17 different social indicators including income, poverty, and education. DC Water uses the index as calculated at the census block group scale for years 2014-2018, however newer data is available.

The other half of CoL weight is derived from the census tract level children under 18 (20%) and licensed childcare facilities (30%). DC Water recognized that children 5 and under are most impacted by lead exposure; however the model did not find sufficient variation in the number of children 5 and under across census tracts.

Finally, the CoL childcare facility parameter prioritizes blocks within 200 feet of a childcare facility, while blocks at all other distances from childcare facilities are not considered.

The LoL category is split into four parameters with the following weights: Water Main Failures (10%), Iron Concentration (27%), Chlorine Concentration (9%), and Service Line Material (54%). Water main failures are recorded from 1960 onwards with some significant gaps in the data. Iron and chlorine data were taken from hydrant tests and automatic flushing units. Iron and chlorine sample data are from 2020. Service line material score was taken as an average of the total number of service lines on a block with 10 representing lead lines, 1 representing non-lead, and 3 representing unknown.

DC Water runs the model annually based on updated inventory information.

TABLE 3: LFDC Prioritization Model

Indicator	Description	Weight	Original Geographic Resolution
Consequence of Lead (CoL)			
Area Deprivation Index (ADI)	The ADI Score for each census block group.	50%	Census Block Group
Children 18 and Under	The number of children under 18 years of age by census tract.	20%	Census Tract
Licensed Childcare Facility	Blocks within 200 feet of a Licensed Childcare Facility	30%	Coordinates
Likelihood of Lead (LoL)			
Water Main Failures	The number of water main failures on a block from 1960 onwards.	10%	Coordinates
Iron Concentration	The level of iron in blocks within 300 feet of a hydrant testing point or automatic flushing unit.	27%	Coordinates
Chlorine Concentration	The level of chlorine in blocks within 300 feet of a hydrant testing point or automatic flushing unit.	9%	Coordinates
Service Line Material	Presence of lead or unknown material in service line materials	54%	Households

How does this compare to benchmark cities?

Denver

Denver, Colorado is one of two benchmarked cities that uses a prioritization model. Denver Water's prioritization plan differs from the LFDC Plan as Denver calculates risk for individual households instead of blocks. This method allows flexibility when determining the geographic scale at which Denver Water can work, and it can be a scale as small as the individual household.

Denver Water's prioritization model uses the following Consequence of Lead parameters, whose sum is subsequently multiplied by the Likelihood of Lead as determined by a predictive model for each household.

TABLE 4: Denver Water Prioritization Model Consequence of Lead Parameters*

Criticality Factor (Cf)	Description	Criticality Weight (%) (Cw)
Public Health Consideration	Odds Ratio (OR) Contours from the Spatial Confounder Adjusted Spatial Risk Model for elevated childhood blood lead level (Berg, et al, 2017)	0.2
Filter Adoption Rate	Areas where filter adoption is low.	0
Critical Customers	Day care centers, child care providers, schools, dialysis centers, formula fed infants	0.3
Age (Census Data)	Children under 5 years of age	0.4
Expecting Families	Population estimates of existing families within XX-XX years of age	
Socio-Economic Factors	Probability of being below the Federal Poverty Level	0.1
Median Income Level	Weighted Income Distribution	

**As published by Denver Water (Appendix K.i)*

There are several notable differences between the prioritization models from Denver Water and the LFDC Plan:

- Denver includes modeled blood lead levels in children as a public health metric;
- Denver uses Children under 5 years of age instead of 18;
- Denver Water uses Filter Adoption Rate as a metric, although data were not yet available to assign
  a weight to this metric;
- Denver uses a complex statistical model to determine likelihood of lead;
- LFDC Plan has a much higher weight for socio-economic factors than Denver, and the Area Deprivation Index includes more indicators than poverty and income; and
- LFDC Plan includes water quality and water main quality.

Pittsburgh

Pittsburgh developed their Neighborhood LSLR program using a prioritization model in conjunction with an advisory committee. The model evaluates each of the Pittsburgh neighborhoods against the following criteria:

TABLE 5: Pittsburgh Prioritization Model Factors and Model Weights

Factor	Source of Data	Weighing in Model
Number of children under 6 years old and number of women of childbearing age	US Census	40%
Blood Lead Levels in Children	ACHD	40%
Neighborhood Income Level	US Census	10%
Number of Lead and Unknown Service Lines	PWSA Inventory	10%

According to Pittsburgh:

> *"Each time we use the model to develop a program we use the latest data from each of these sources. We then rank the neighborhoods from 1-5 (5 being highest priority) and select the highest ranked neighborhoods when we develop a program. For our 2022 Neighborhood LSLR program we had more level 5 neighborhoods than funding, so we next ranked them based on a neighborhood affordability study prepared for PWSA.*
>
> *We also use this model as one of the criteria evaluated when determining our water main replacement locations, although that program also needs to consider such factors as history of main breaks, fire flow concerns, undersized mains, etc."*

The other benchmarking cities did not report the use of a prioritization model for their LSLR program.

In comparison to these benchmarking cities, the DC Water model is more complex than the Denver or Pittsburgh models and includes parameters that do not relate to the risk of LSLs (e.g., iron and chlorine data).

What do we recommend doing?

The LFDC prioritization model and its weights do not have a direct impact on the overall cost of the LFDC Plan. The prioritization model determines which LSLs get replaced first, thus the model determines prioritization of health and equity. To improve the efficacy of the prioritization model in maximizing health and equity we suggest the following changes to the LFDC prioritization model.

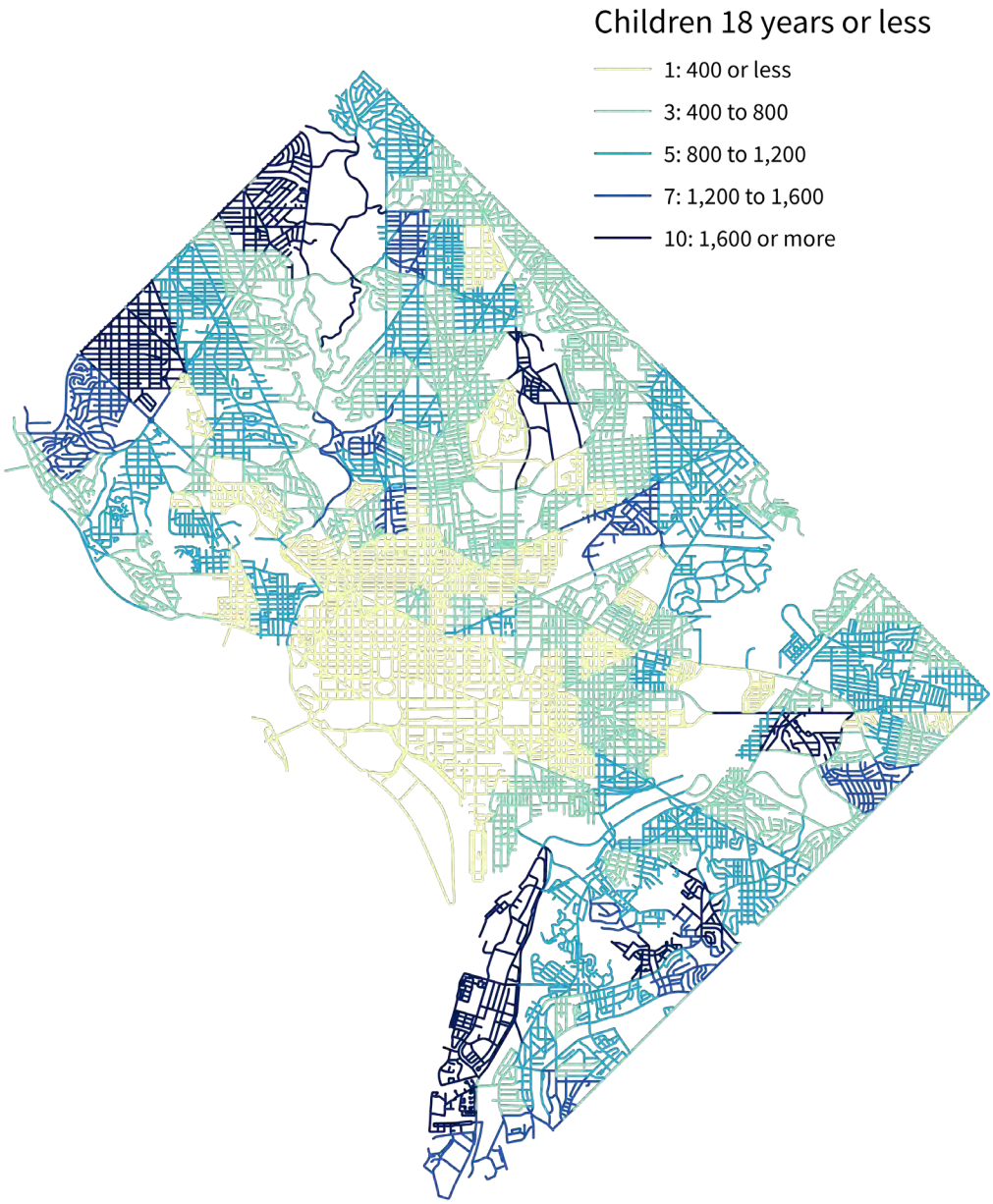
1. Use Higher Resolution American Community Survey (ACS) data for children 5 and under.

The current LFDC prioritization model calculates the geographic location of families by using the number of children 18 and under by US census tract (Map 1). Census tracts contain on average 1,200 and 8,000 individuals.[8] The census block group is a smaller geographic area generally defined to have between 600 and 3,000 people. In the District of Columbia there are 179 census tracts compared to 450 block groups. The additional geographic precision of using block groups for the Children 18 and Under parameter can be seen in Map 1. In a removal program that replaces service lines by city block, it is important that all variables are as precise as possible. Using block-group data ensures that blocks with children are prioritized and blocks without children do not receive the priority weight. We additionally note that the ADI score is calculated at the block group level, therefore the scale used for children 18 years of age and under should match.

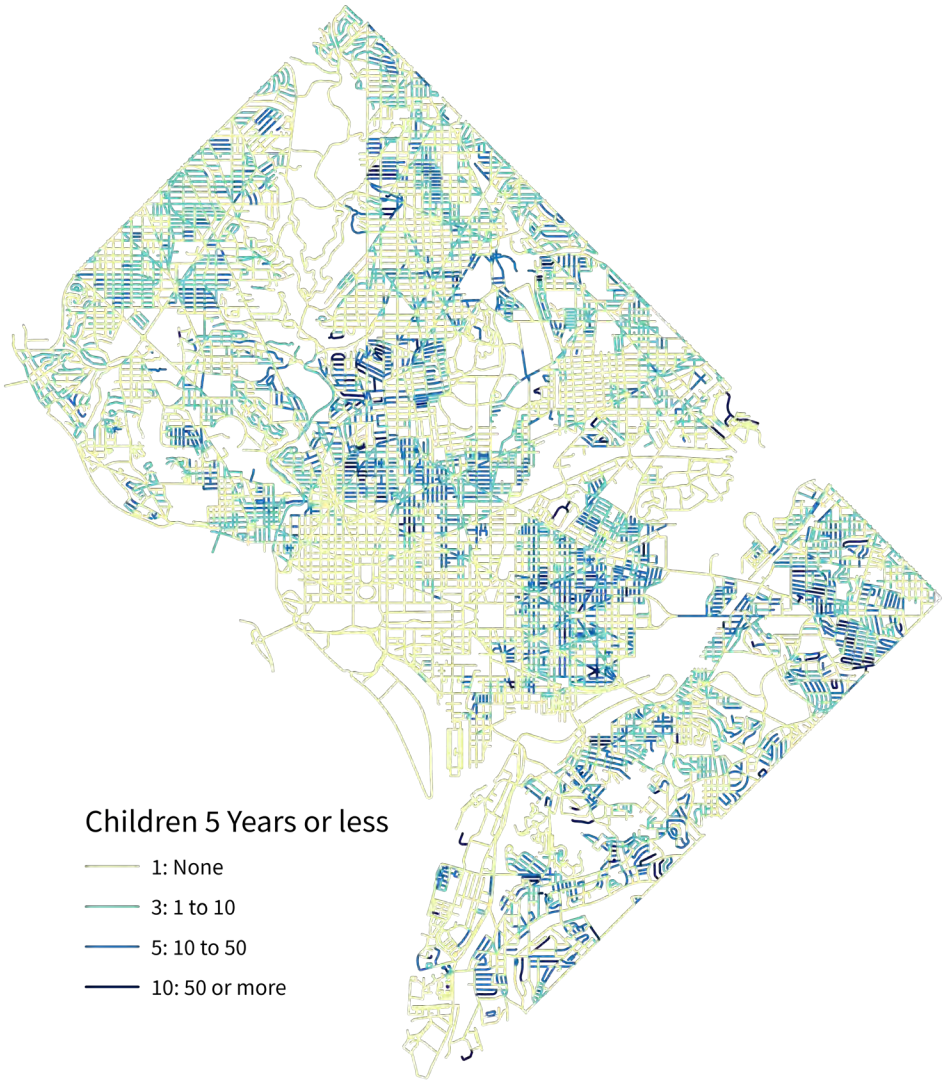
> The Census Bureau collects socioeconomic data from the American Community Survey. At small geographic scales, representative data must be collected from multiple years.
>
> The scales referenced in this report are the **Census Tract** and **Census Block Group**. Census Tracts consist of 1,200 to 8,000 individuals on average, while Census Block Groups consist of 600 to 3,000. There are 179 Census Tracts and 450 Census Block Groups in the District of Columbia.

In our exploration of this parameter, we also tested using a younger age threshold, such as 10 years or 5 years, due to the fact that lead exposure has the greatest impact on young children under the age of 6.[9] The number of children age 5 and under per census block group compared to the number of children age 18 and under per census tract can be seen in Map 1.

Map 1A: **Number of Children Age 18 and Under Per Census Tract**



Map 1B: **Number of Children Age 5 and Under Per Census Block Group**

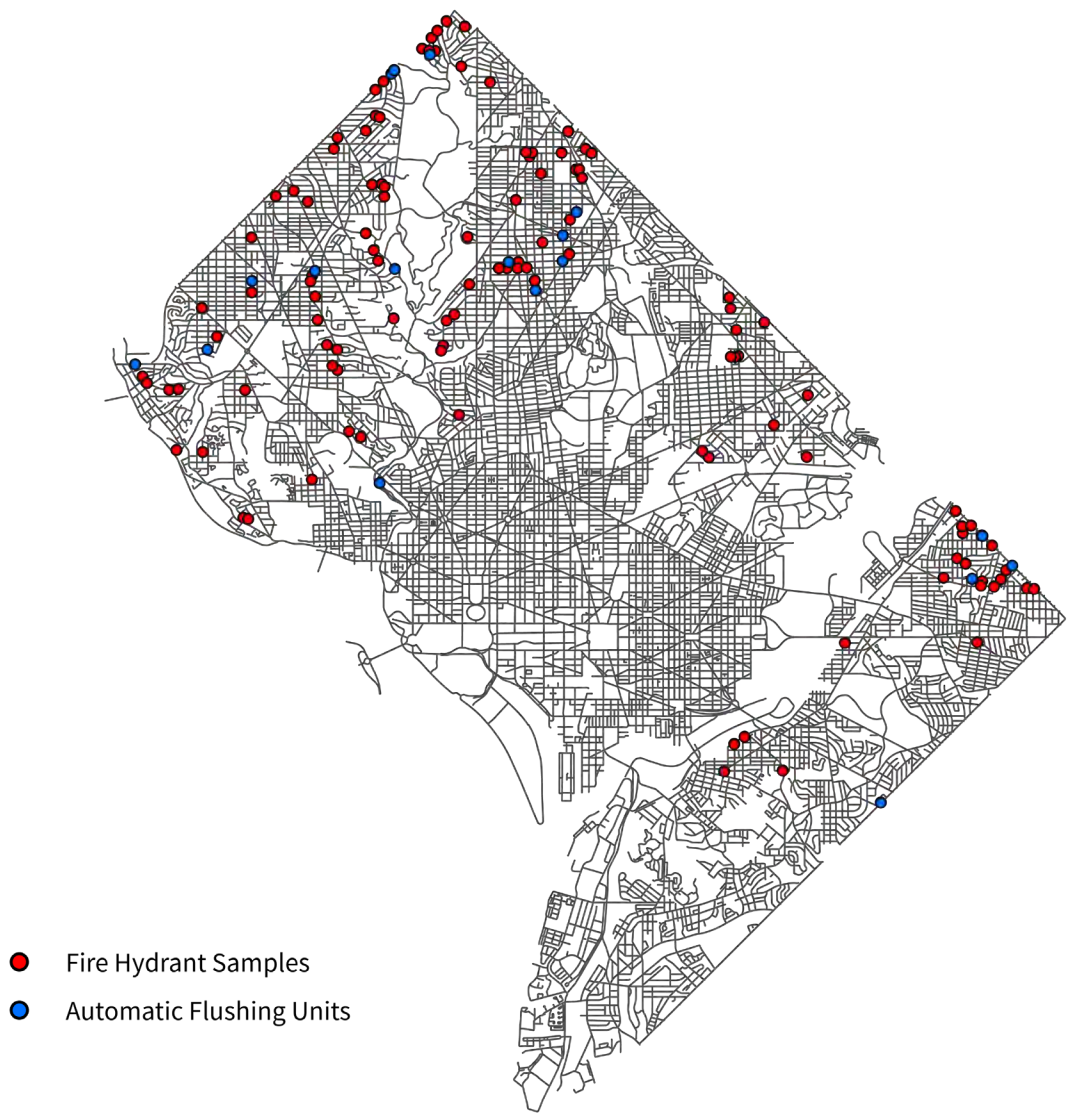


Made by Safe Water Engineering
Children Under 5 is derived from the American Community Survey 2020 Block Group Data.
Children under 18 is provided by DC Water Department.

2. Remove iron and chlorine sampling parameters.

The LFDC Plan includes water hydrant iron and chlorine sampling data from 2020 as parameters to determine which city blocks should receive higher priority in receiving LSLRs. The InfoAsset memo[6] states that iron was used to identify areas where customers may experience red water and increased lead exposure and low chlorine sites were used to identify areas where customers may experience low chlorine and possible lead exposure. The LFDC plan prioritizes city blocks within 300 feet of sample sites with high iron and low chlorine levels or within 300 feet of automatic flushing units. However, the hydrant tests and flushing units are not evenly distributed across the district. Currently 11,945 city blocks are not within 300 feet of a chlorine hydrant sample site or automatic flushing unit, and 12,958 city blocks are not within 300 feet of an iron hydrant sample point or automatic flushing unit. As seen in Map 2, both flushing and hydrant testing are concentrated in the east and northwest sides of Washington, DC. These parameters do not give enough information to make prioritization decisions from and bias prioritization to areas which either have already received water quality treatment (i.e. automatic flushing units) or have undergone extra testing.

MAP 2: Water Quality Sampling Points



3. Use new recommended parameters and weights.

We recommend using the model parameters, weights and geographic resolution summarized in Table 6.

TABLE 6: Recommended Model Parameters, Weights, and Geographic Resolution

Parameter	Description	Weight	Geographic Resolution
Consequence of Lead (CoL)			
Area Deprivation Index (ADI)	The ADI Score	50%	Census Block Group
Children 5 and Under	The number of children 5 years and under	50%	Census Block Group
Likelihood of Lead (LoL)			
Service Line Material	Probability of lead, brass, or galvanized service line	100%	Service Line

Each parameter would get a score from 1 to 10. For consequence of lead, the ADI already provides scores for each Census Block Group between 1 and 10. Children under 5 are scored by Census Block Group with a score of 1 representing no children under 5. A score of 3 represents 1-10 children, a score of 5 representing 11-50 children, and a score of 10 representing 50+ children under 5.

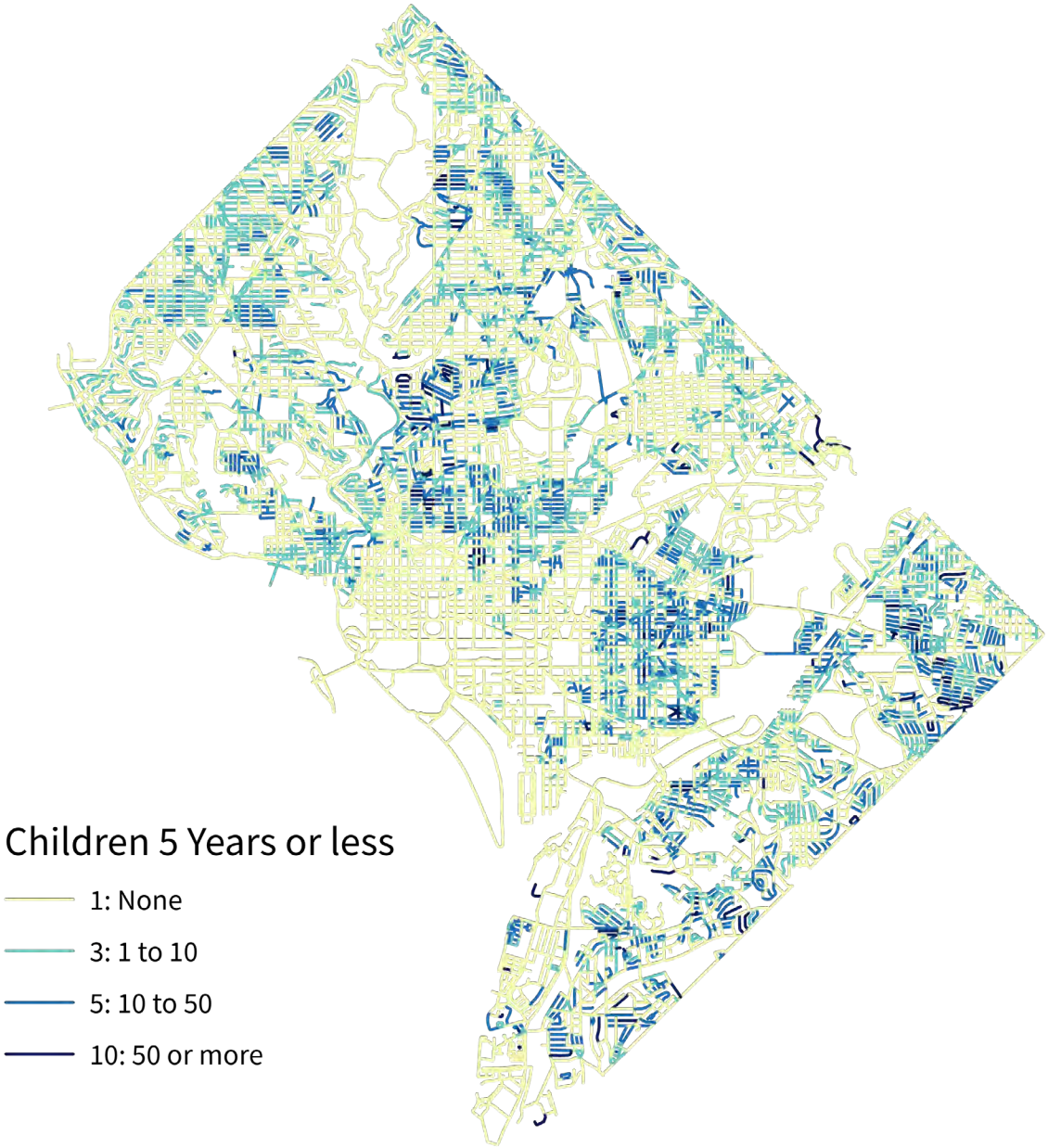
The Likelihood of Lead score would be calculated using only the likelihood that each service line needs to be replaced. Each service line would be assigned a score according to the following:

- Lead and galvanized lines: 10.
- Unknowns: 5
- Historic brass lines: 4.7
- Historic copper: 2, and
- Non-lead: 0.

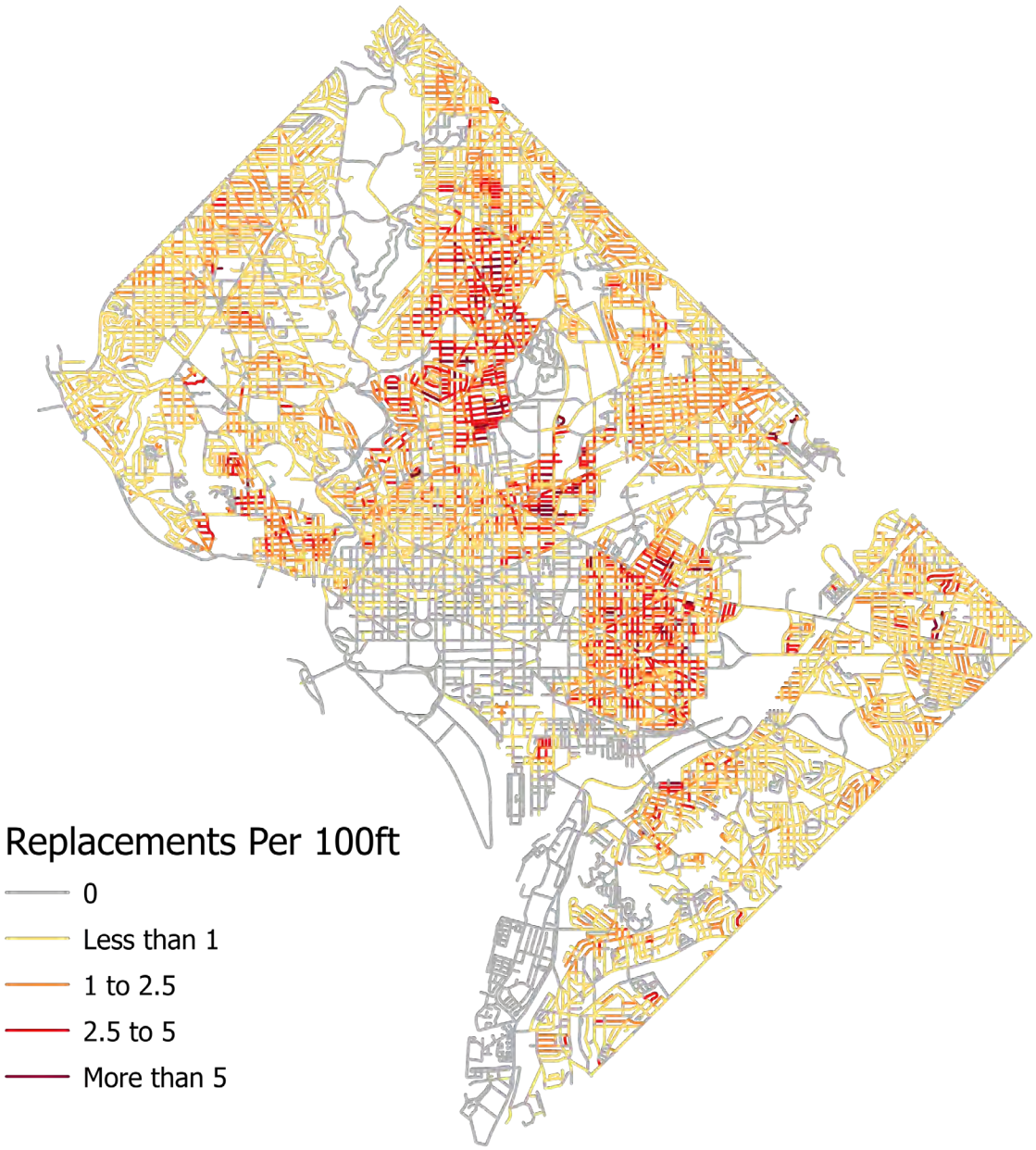
Service line material would then be averaged by Census Block Group.

The model parameters and total risk scores can be seen in Map 3.

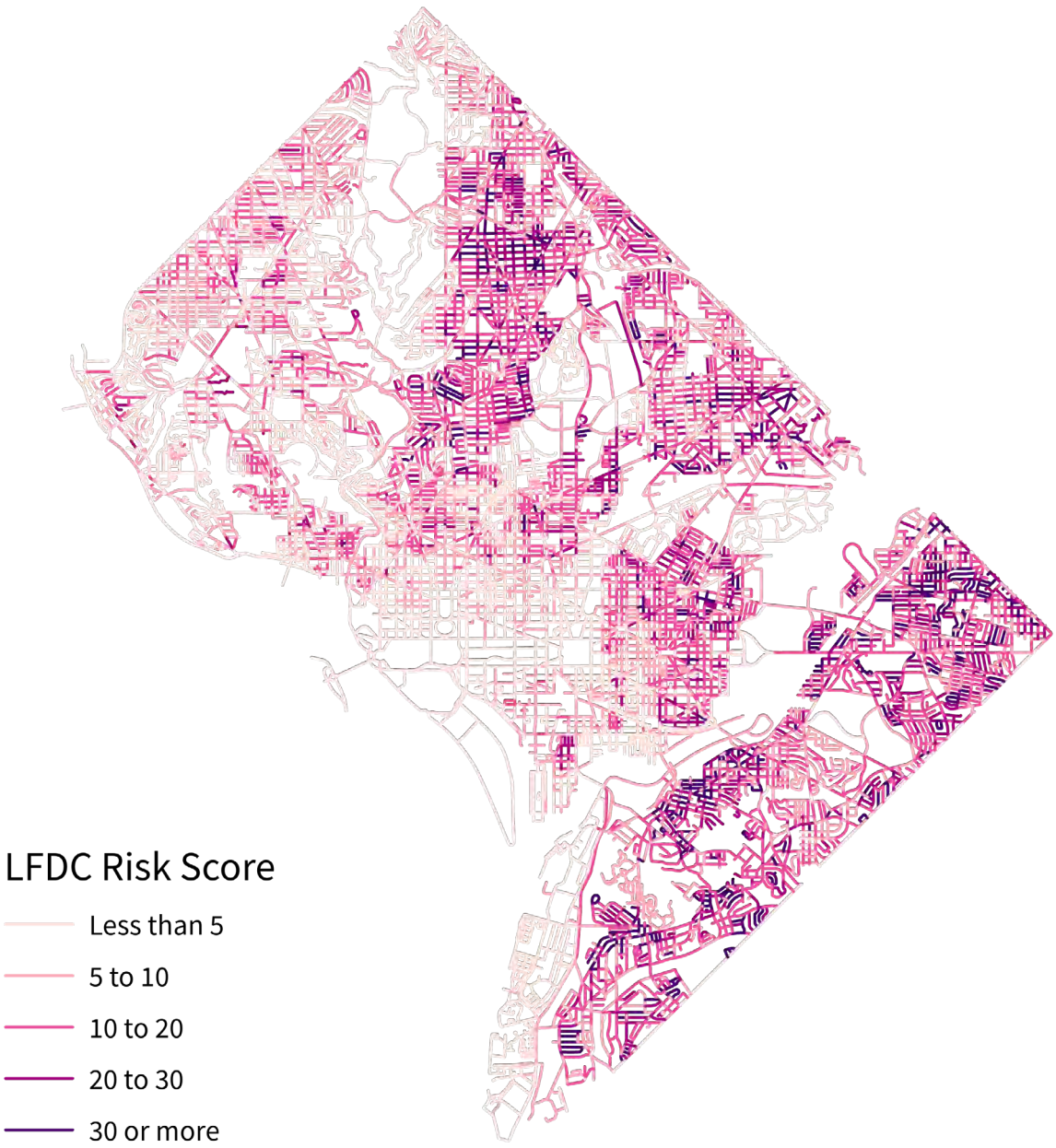
Map 3A: **Model Parameters: Children 5 years or less**



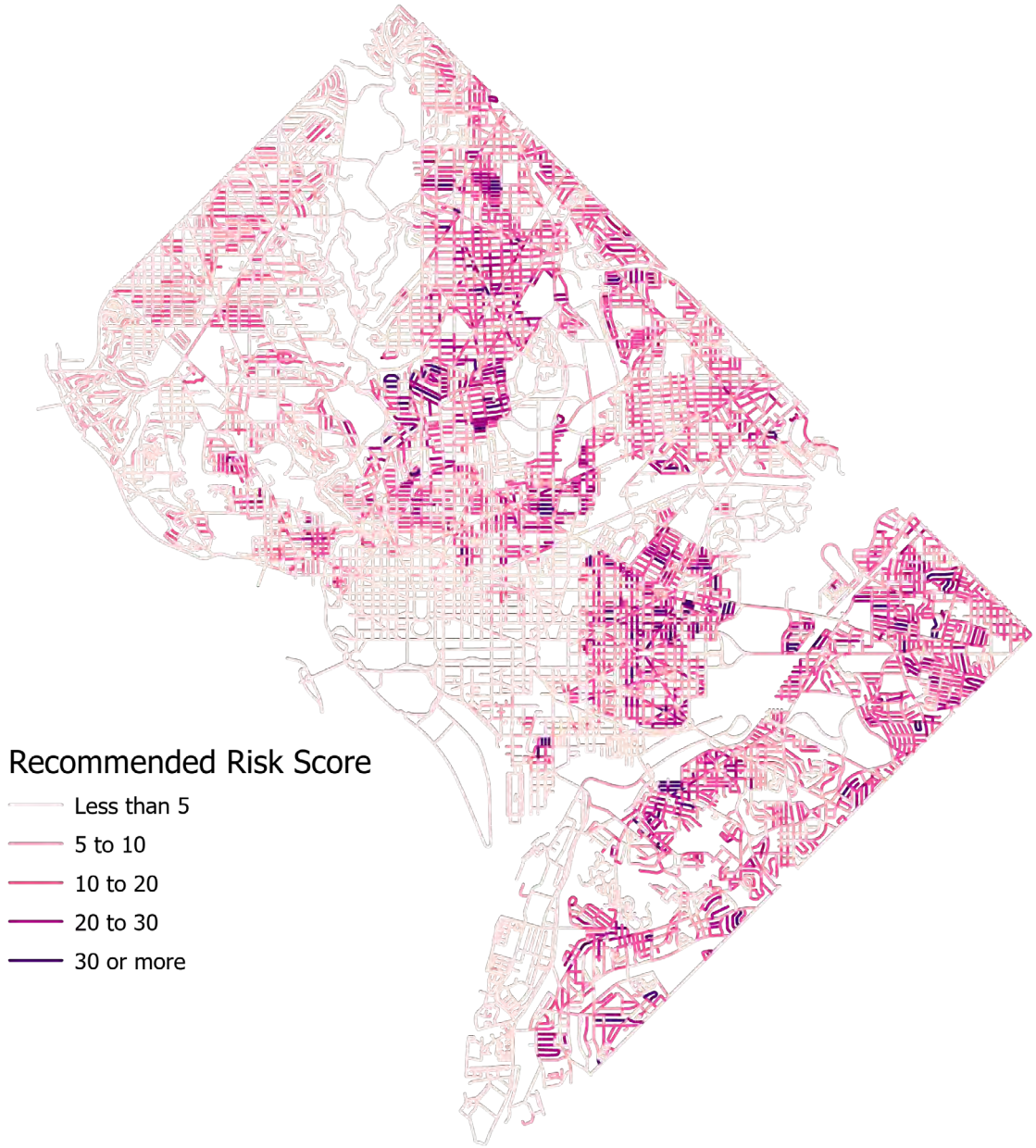
Map 3B: **Model Parameters: Replacements per 100ft**



Map 3C: **Lead Free DC (LFDC) Model Total Risk Score**

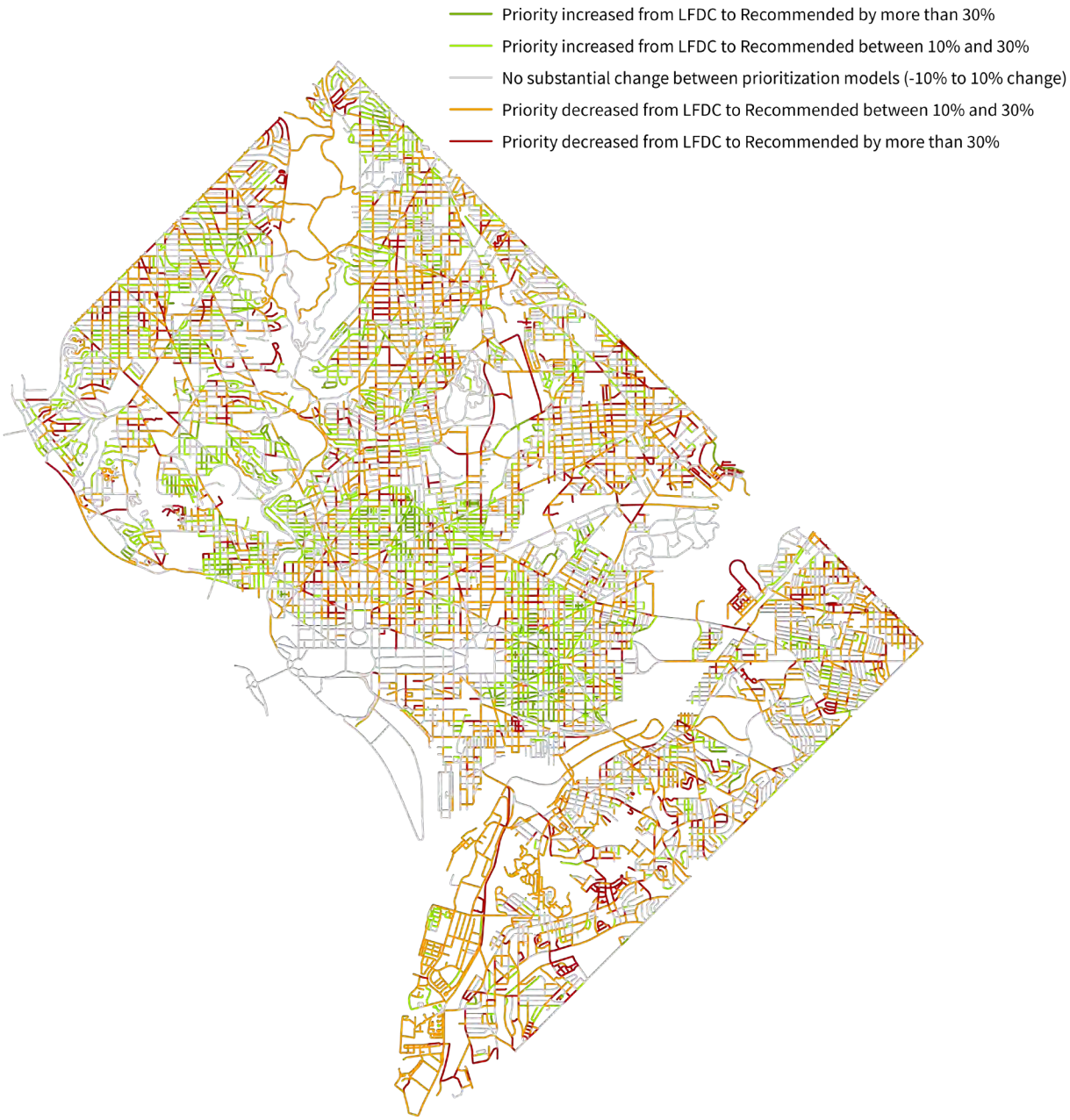


Map 3D: **Recommended Model Total Risk Score**



Map 4 below highlights the difference in prioritization score between the recommended prioritization model and the LFDC model. Percentages were generated by ranking all risk scores in each model then comparing their relative decile. A movement up or down in decile corresponded roughly to a year difference in LSLR scheduling assuming a ten-year plan, which is explained in more depth in the Program Timelines section. These changes shift the prioritization model to better prioritize health and equity in a comprehensive manner. The removal of chlorine and iron sampling parameters shift weight to actual LSL locations, while increasing geographic resolution on the ACS children age 5 and under ensures that blocks with young children are receiving priority.

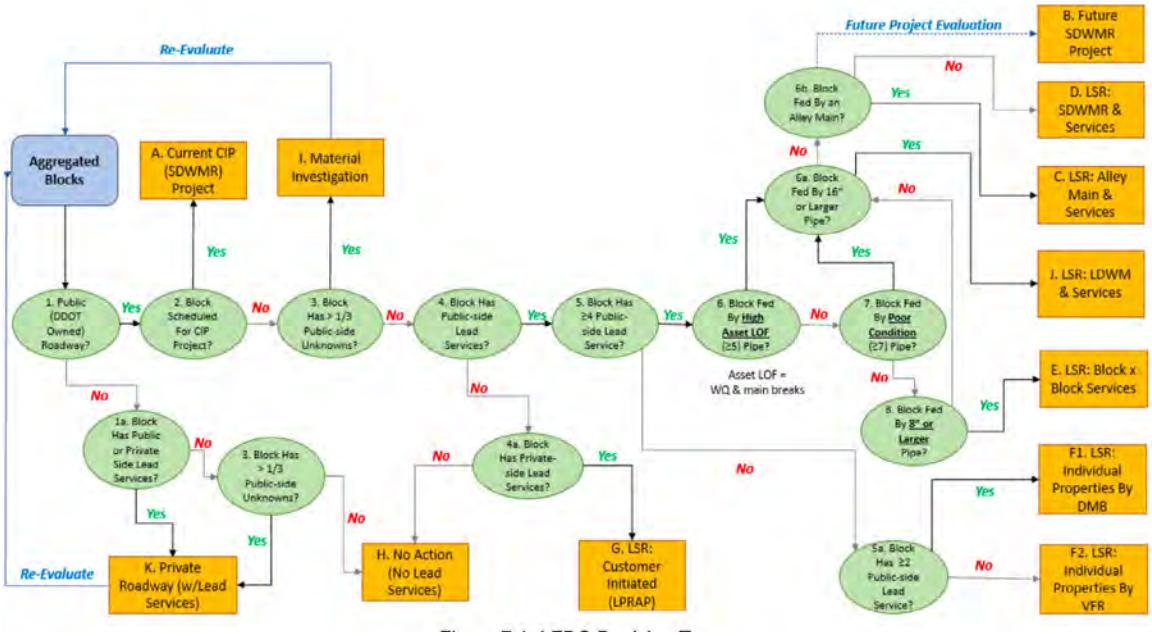
Map 4: Percent Difference between Recommended and LFDC Risk Prioritization



Removal Programs, Funding Sources, and Program Structure

What did DC Water do?

FIGURE 3: LFDC Prioritization Model Decision Tree



Appendix D, Figure 7.1

The LFDC plan breaks LSLR into three overarching programmatic categories:

1. CIP: By Block – LSL Replacements;
2. CIP: By Block – LSLs & Water Main Replacements; and
3. By Premise – LSL Replacements.

The former two categories are replacements initiated by DC Water, while the latter is initiated by the customer. Figure 3 shows the flow chart on how the LFDC Plan assigns service lines from Washington, DC blocks to nine different LSLR programs based on site characteristics. Each yellow rectangle shown in Figure 3 represents a different removal program that falls into one of the three replacement categories listed above. Table 7 shows the number of service lines and blocks in each program as well as its programmatic category.

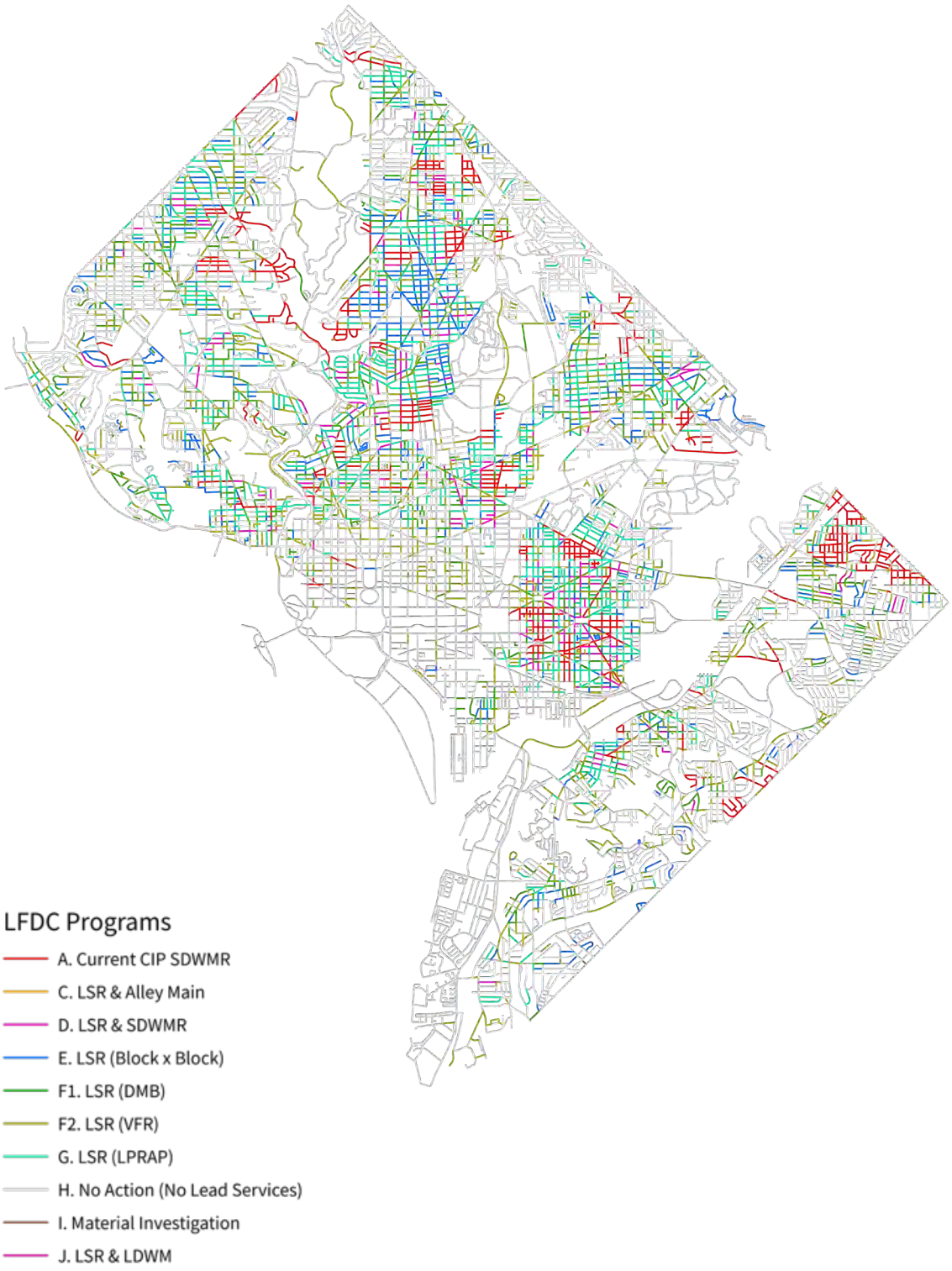
TABLE 7: LFDC Programmatic Break Down

Category	Group	Count of Blocks	Full LSLRs	Partial Private only LSLRs	Public Side Unknowns	Total LSLRs
2	A. Current CIP (SDWMR)	853	1,344	1,378	1,088	3,266
None	B. Future SDWMR Projects	To Be Determined				
2	D. LSR: SDWMR & Services	243	2,025	209	1,008	2,738
2	C. LSR: Alley Main & Services	2	11	0	8	15
2	J. LSR: LDWM & Services	7	63	3	12	72
1	E. Block by Block LSRs	776	4,533	385	5,816	7,826
3	Fl . LSR: Individual Properties by DMB	878	1,520	472	2,431	3,208
3	F2. LSR: Individual Properties by VFR	1,441	903	1,284	2,187	3,281
3	G. LSR: Customer Initiated LPRAP	1,228	0	7,302	536	7,570
None	H. No Action (No Lead Services)	8,155	0	0	1,609	805
None	1. Material Investigation	Reclassified to Other Groups				
None	K. Private Roadways (with Lead Services)	Reclassified to Other Groups				
	Total	**13,583**	**10,399**	**11,033**	**14,695**	**28,780**

Appendix D, Table 8.1

Geographic representations of the LFDC Programs are provided in Map 5 below.

MAP 5: Geographic Representation of the LFDC LSLR Programs



Category 1- By Block – LSL Replacements is comprised solely of bucket E: Block-by-Block LSRs. This program plans on removing 27% of LSLs as defined by the LFDC Plan and will complete full paving of the street after replacement of all LSLs on the block. These replacements are prioritized based on the LFDC Risk Model.

Category 2- By Block – LSLs & Water Main Replacements is comprised of buckets A, B, C, and J. This program will replace LSLs and water mains along each block. The CIP (bucket A) will replace 11% of LSLs, and buckets B, C, and J account for an additional 10% of LSLs.

Category 3- By Premise – LSL Replacements is comprised of buckets F1, F2, and G. This program is customer initiated and accounts for 48.8% of LSLs. These replacements will use individual site paving.

Blocks in Categories 1 and 2 will be checked for all unknowns and historic copper lines. However, the LFDC plan does not currently account for verifying unknowns or historic copper lines on blocks in by category 3. There are approximately 1,200 unknowns and 6,759 copper lines that are not covered in Block by Block programs.

The LFDC plan also does not account for the 805 LSLs that reside in bucket H, No Action (no Lead Services). These LSLs are derived from the estimated 50% of unknowns that are LSLs.

The decision to pave an entire street or pave by individual site is based on two criteria. First is the number of LSLRs on the street. More than three service lines triggers a full-street paving as per the DDOT recommendations. Secondly, the LFDC plan will replace poor condition water mains that are not currently a part of the CIP and the street will be paved afterwards.

Not accounted for in the above table is the 20220331 LFDC Revised Cost Estimate (see Appendix G) to the 2021 LFDC plan. In the revised cost estimate, DC Water accounts for testing 48,163 historic copper, brass, and galvanized lines. These test pits are placed in the non-CIP Block-by-Block program (Categories 1 and 2 except for bucket A). The LFDC plan however does not adjust any LSL counts to reflect the estimated quantity of LSLs found through this testing.

The LFDC Plan mentions a program for emergency replacements without a description of what constitutes an emergency, how emergencies are identified, and how emergency replacements are conducted.

Category 3 is broken into two more programs:

Lead Pipe Replacement Assistance Program (LPRAP). This is a customer-initiated replacement program where only the private side is lead. Many of these sites result from partial LSLR programs that have been implemented over the past 20+ years. The district pays for 50-100% of the private side replacements. This program depends on sufficient outreach to motivate residents to participate, apply for funding, and contribute from their own savings. DC Water anticipates 8,854 services will be replaced using this program. The entire cost of this program is included in the LFDC Plan, even though some replacements are anticipated to be paid by residents.

Voluntary Full Replacement Program (VFRP). This is a customer-initiated replacement program where both the public side and private side are lead. DC Water pays 100% of the public side replacement cost and the property owner pays 100% of private side replacement costs. This program depends on sufficient outreach to motivate residents to participate, apply for funding, and contribute from their own savings. DC Water anticipates around 1,997 services will be replaced using this program. The entire cost of this program is included in the LFDC Plan, even though some replacements are anticipated to be paid by residents.

Washington, DC does not have a mandate to replace all LSLs including those on private property, and does not have a funding source to cover the cost of private side LSLR.

How does this compare to benchmark cities?

Newark takes a block-by-block approach to LSLRs.

- They established an ordinance for the mandatory replacement of LSLs prior to beginning their complete LSLR Program.
- They work simultaneously on all zones helping to promote the message that everyone is important.
- They prioritize replacements by children (e.g. daycares – known and unknown – found by potholing), elderly (homes), and hospitals.
- They passed an ordinance that requires the owner of any building to replace the LSL on their property, allowing them to sign up for the LSLR program or to replace it on their own. Newark was able to use permission to access the property from anyone on or around the property, including a resident, tenant, or neighbor (Appendix K.h).

Detroit

- They complete the majority of LSLRs in conjunction with WMRs that are prioritized based on condition assessments of the water mains. They have a separate program for one-offs based on a running list of customer requests, which they prioritize. Although they have no published criteria, they stated that high lead in water results moves a replacement to the top of the list.
- They allow the owner or tenant to sign an agreement to replace the LSL on private property. If a resident refuses access to the home during a WMR and the LSL must be replaced, Detroit has said they will keep the water off until the LSL is replaced, although they have not had to use this approach in practice.

Cincinnati

- They use a water model and assessment management tool for CIP planning. Since Cincinnati already has a robust 1% WMR program, they focus some of these replacement projects in areas where high concentrations of LSLs remain in service.

What do we recommend doing?

To meet the goal of removing all full and partial LSLs in Washington, DC, the LFDC Plan must account for identifying and removing every LSL in the district. This includes known lead, identifying unknowns, and investigating other service line materials for potential LSLs. Every potential LSL must be included as part of a planned, systematic approach to LSLR before individual services get pulled into priority programs. It is most efficient to do this through DC Water initiated work, which requires new funding and policy support to go forward.

1. Pass an LSLR mandate and provide funding for all LSLRs.

The pathway to ensuring all full and partial LSLs are removed in Washington, DC will be facilitated by an incentive-based approach by the Council of the District of Columbia—mandating LSLR and providing funding for verification and replacement of all potential LSLs so that all residents can readily participate. The mandate compels residents to participate, and the funding removes the largest barrier to participation. Requirements for customers to pay, even when there is capacity for financial assistance, create unnecessary barriers and delays to LSLR. In addition, programs requiring customers to pay or apply for assistance will result in PLSLRs which increases the risk of exposure to lead in water and increases the overall cost of the LFDC Plan. The plan should eliminate as many barriers to participation as possible.

Specific recommendations for the Council of the District of Columbia to establish an LSLR mandate and increase participation include:

- Adopt a model ordinance for LSLR (Appendix K.h).
- Secure funding to cover verification and replacement of all potential LSLs in Washington, DC, incorporating new federal LSLR funding; Washington, DC was allotted $28 million in the first round of infrastructure funding under the Bipartisan Infrastructure Law.
- Expand the definition of “emergency” under DC Law to facilitate free private-side replacements for populations at risk.
- Adopt a policy ensuring all new customers are notified if they have a potential LSL and/or establish property transfer LSLR requirements.
- Provide a simplified online LSLR agreement form that is understandable by target audience. See Examples in Appendix K.b, K.d, and K.e. Other communities like Detroit and Benton Harbor accept a standing agreement that does not expire.

We recommend consolidating all LSLRs into the following four programs:

2. Create a new DC Water-initiated Neighborhood Scale LSLR Program.

This program would complete the majority of LSLRs and service line verifications in a DC Water-initiated neighborhood scale program that is prioritized by the recommended risk model, described in the Prioritization Criteria section of this report, at the Census Block Group scale. The program would encompass any service lines not in the DC Water CIP or in streets with poor quality water mains. Working at the Census Block Group scale, this program will allow DC Water to take advantage of economies of scale, with larger numbers of excavations and LSLRs within a concentrated area prioritized by consequence and likelihood of lead. This program will need to rely on additional external funding sources, such as the new federal LSLR funding. This recommended program is further illustrated in the Program Timelines and Geographies section of this report.

Between 70 and 80% of DC Water's LSLRs would be completed through this new neighborhood-scale LSLR program. Some of the highlights of this recommended strategy include:

- Using equity for schedule prioritization;
- Consolidating work in geographic areas to increase customer awareness and participation while decreasing the cost of multiple mobilizations;
- Streamlining paving needs;
- Accounting for all unknown service lines and verifications of copper and brass service lines, allowing contractors to replace LSLs on the spot when they are identified through the test pitting program; and
- Reducing outreach efforts aimed at convincing customers to initiate LSLR and apply for funding. Customers will still need to sign access agreements to complete the work in their homes.

3. Create a new district-wide DC Water-initiated Individual, High-Priority LSLR Program.

An Individual, High-Priority LSLR Program for critical customers with urgent needs should be available for residents who need an immediate LSLR. While the majority of LSLRs in Washington, DC should occur as part of neighborhood programs, we recommend establishing a program to facilitate meeting urgent community and customer needs. While every potential LSL is otherwise incorporated in the Neighborhood Scale and CIP Water Main Replacement LSLR programs, the Council of the District of Columbia and DC Water should work together to clearly identify and elevate critical customers and cases to immediate one-off replacement. High priority cases to consider for inclusion in this program are:

- Day care centers,
- Multifamily buildings with LSLs and occupants age 5 and younger,
- Homes with children with elevated blood lead levels (EBLLs); and
- Homes requiring emergency service line repairs, and other urgent unplanned needs.

Pre-identified priority customers, like day care centers, should have all service line materials verified and LSLs replaced in the first year of the program, and the list of addresses for the Individual High-Priority LSLR Program should be updated on an ongoing basis. The list should start with the 2018 count of 468-day care centers in Washington, DC. All day care facilities should have confirmed non-lead service lines by the end of 2024. We assumed 10% of LSLRs would be triggered into the Individual High-Priority LSLR Program.

4. Group all LSLRs associated with WMRs together to create the CIP Water Main Replacement LSLR Program.

We estimate about 20% of the total LSLs will get replaced through this program and recommend combining both the CIP program and the water mains DC Water identified as being in poor condition in the LFDC Plan. Additionally, we recommend including and adding all WMR costs to the CIP and separating them from LFDC Plan costs.

The LFDC Model uses a threshold of 4 or more LSLs per block as a condition for DC Water initiated LSLR. Of those blocks with 4 or more LSLs, those with poor water main condition are identified for WMRs at the same time as LSLR. From a water infrastructure planning perspective, any main with a condition rated as poor should be accounted for and planned for replacement through the CIP program. All the WMRs identified in the LFDC Plan meet the criterion of poor quality main regardless of the number of LSLs connected to the water main. The cost of WMR is not an added cost resulting from the LSLR initiative. These WMRs are necessary and will be most cost effective if they happen at the same time as LSLR.

We recommend that DC Water add all poor condition water mains to the CIP so they can prioritize, plan, and budget for these necessary replacements. This may require revisions to the 2% WMR CIP goal.

5. Continue the VFRP program from the LFDC plan.

The scope of the VFRP program is decreased to include only those homeowners and developers who want to pay in full and replace their LSL on their own schedule. DC Water should continue to facilitate these residents connecting their brand-new non-lead service lines to the water mains. Since we do not have data on the current rate of customer initiated LSLRs, the cost of LSLR associated with this program was not identified. Every potential participant in this program is accounted for in the Neighborhood Scale and CIP Water Main Replacement LSLR Programs.

We recommend the decision tree structure in Figure 4 for assigning blocks to the four recommended LSLR programs. The 4 program areas account for and replace all lead, brass, and galvanized service lines, as well as test any historic or unknown service lines to identify and verify material type. These programs would all be initiated by DC Water and do not rely on customers initiating replacement. Table 8 below shows the number of LSLs in each category.

FIGURE 4: **Recommended LSLR Programs**

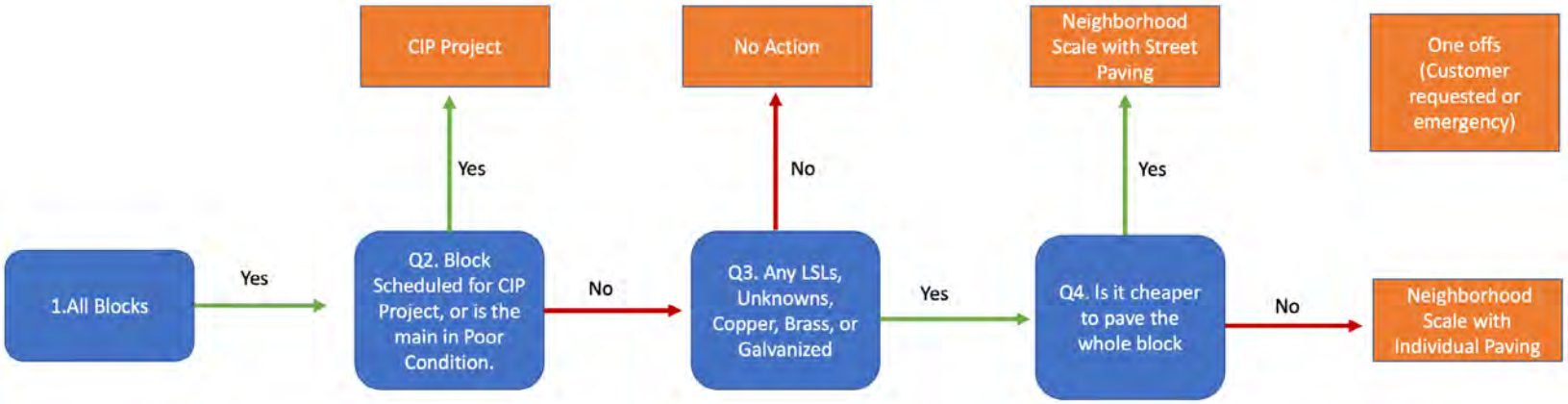


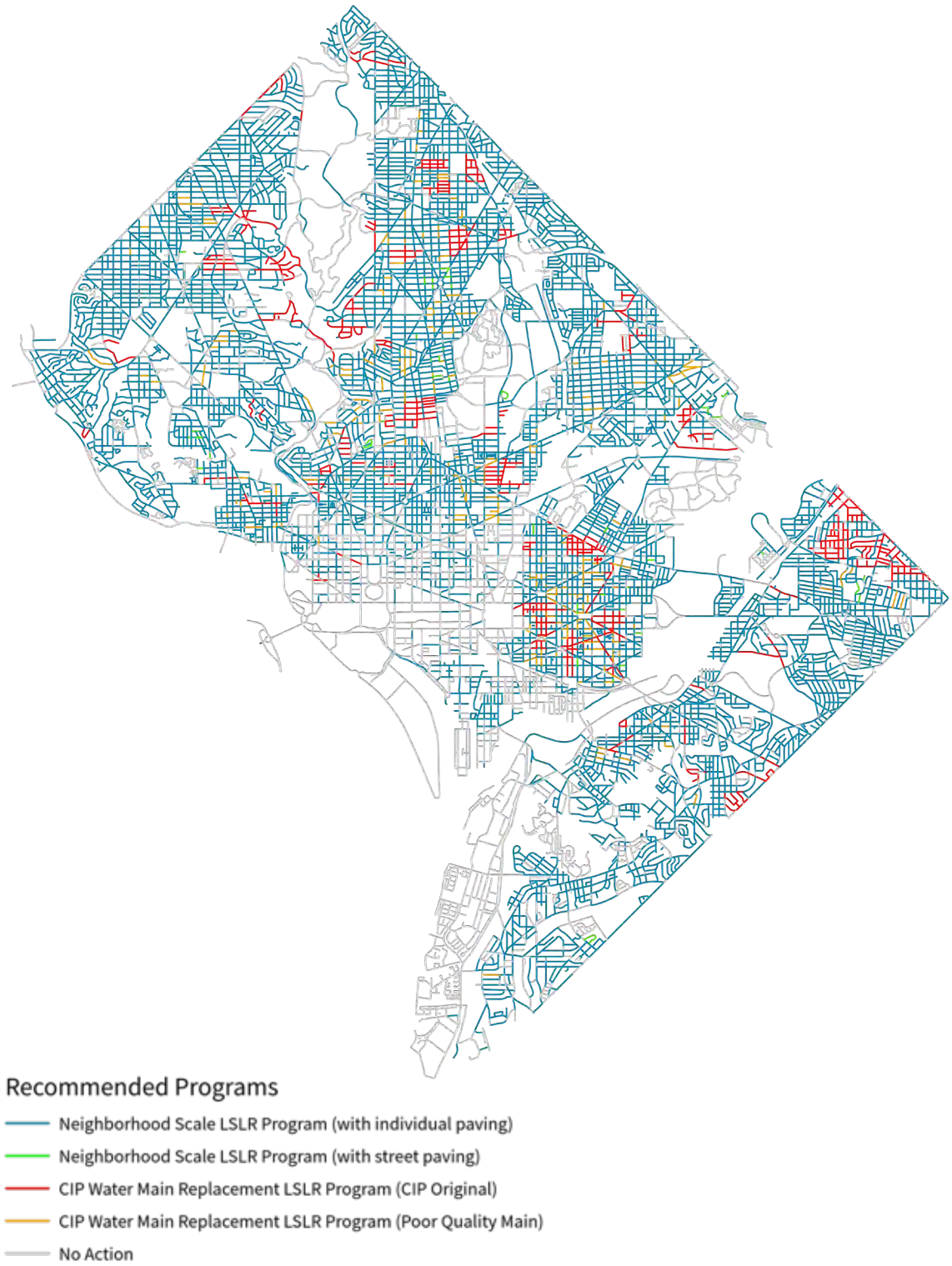
TABLE 8: Recommended Program Breakdown[1]

	Number of Blocks	Full LSLs	Unknown service lines	Historic Copper service lines	Non-Historic Brass service lines	Historic Brass service lines	Galvanized service lines	Full LSLR accounting for unknowns, copper, brass, and galvanized	Private LSL only	Total, Full LSLR + Private LSLR	Percent of all LSLRs
Neighborhood Scale LSLR Program (with street paving)	58	513	1,277	123	81	36	4	1,278	41	1,319	3%
Neighborhood Scale LSLR Program (with individual paving)	12,419	6,356	8,225	37,954	1,802	6,930	562	23,680	9,800	33,480	79%
CIP Water Main Replacement LSLR Program (CIP Original)	855	1,330	957	2,430	121	849	54	2,869	1,436	4,305	10%
CIP Water Main Replacement LSLR Program (Poor Quality Main)	258	2,077	940	1,168	17	303	40	2,980	239	3,219	8%
Total	**13,590**	**10,276**	**11,399**	**41,675**	**2,021**	**8,118**	**660**	**30,807**	**11,516**	**42,323**	**100%**

[1] *Both high priority individual replacements and customer-initiated replacements are not separated in Table 8 as all LSLRs are accounted for as part of the comprehensive plan.*

Map 6 shows the how blocks are assigned to programs in the report recommendations.

MAP 6: Distribution of Recommended LSLR Programs



Program Timelines and Geographies

What did DC Water do?

The LFDC plan ramps up implementation of the three LSLR programmatic categories through projected completion in 2030. The category 1 (CIPERR) program goes block by block according to the prioritization model, but LSLRs associated with WMRs are phased to account for engineering and design time. The customer-initiated programs, which account for about 50% of all LSLRs in the LFDC Plan, are randomly assigned a fiscal year of execution. Table 9 shows how many LSLRs the LFDC plan completes each year in each program.

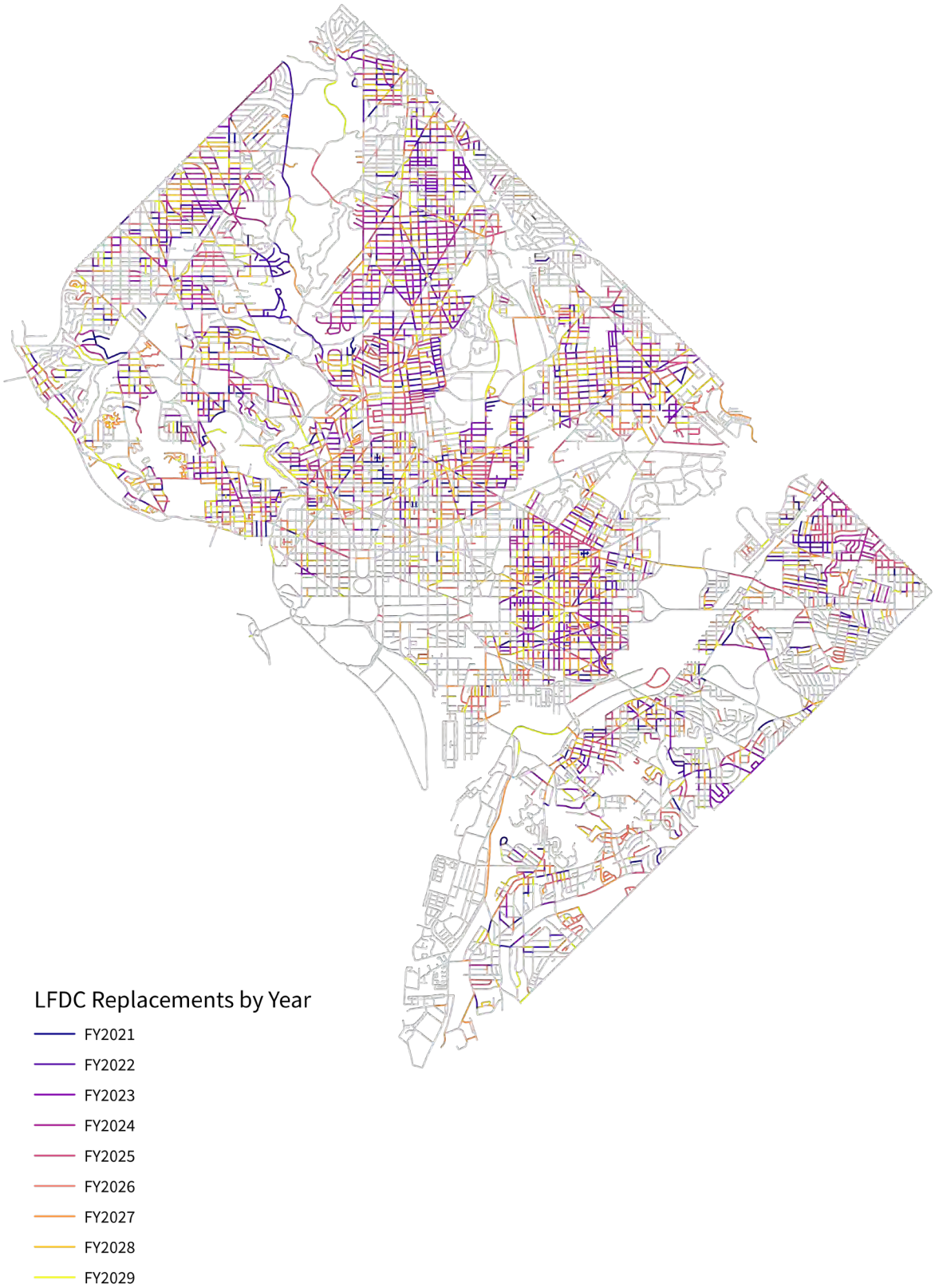
TABLE 9: Number of LFDC LSLRs Per Year[1]

Fiscal Year	CIPERR	VFRP	LPRAP	Annual LSLR Total
FY2021	150	400	250	800
FY2022	1693	300	400	2393
FY2023	2324	200	800	3324
FY2024	3157	183	1234	4574
FY2025	3261	183	1234	4678
FY2026	2344	183	1234	3761
FY2027	1398	183	1234	2815
FY2028	1398	183	1234	2815
FY2029	1398	183	1234	2815
Grand Total*	**17124**	**1997**	**8854**	**27,975**

[1]*LFDC Plan, Page 8*

The LFDC Plan uses the block as the geographic scale of work for all LSLRs. Blocks are completed based on their priority within each program. Map 7 below shows the year each block is completed in the LFDC Plan. As the map shows, many neighborhoods will have work ongoing for many years.

Map 7: **LFDC Plan LSLRs by Year**



What do we recommend doing?

1. Schedule the majority of LSLRs using the prioritization model at the Census Block Group Scale.

To gain local geographic efficiencies, the LFDC Plan should schedule all LSLRs that are not in the CIP according to the prioritization model at the Census Block Group Scale. Table 10 and Map 8 show our recommendations. We calculated the average prioritization scores for each block in the block group to determine a priority score for the entire block group. This approach occasionally masks individual blocks within a block group that have a particularly high-risk score. To maintain equity in the forefront of LSLR scheduling, the top 10% of high-risk blocks should be targeted for LSLR independent of their block group. Contracts can be broken into zones as small as census block groups to ensure opportunities for Disadvantaged Business Enterprise (DBE) companies to win contracts.

Census Block Groups are US Census defined geographies that consist of 600-3,000 people on average. There are 450 Census Block Groups in Washington, DC.

Blocks are geographies defined by DC Water and are a length of street between two intersections/dead ends and the houses on both sides of said street. There are roughly 30 LFDC Blocks in each Census Block Group. Defined in InfoAsset Planner LFDC Model.[6]

Table 10 and Map 8 also shows recommended prioritization of all blocks. High risk and CIP Water Main Replacement LSLR Program blocks are prioritized by individual risk scores, while all other blocks are prioritized by the average risk score of their census block group. DC Water can consider whether CIP projects should be on a different schedule or prioritization based on criteria beyond the LSLR program.

2. Ramp up to complete all LSLRs in approximately 6 years (2024-2029).

The plan should be designed to ramp up so that it can complete LSLRs in approximately 6 years (2024-2029) to achieve the LFDC goal of replacing all LSLs in Washington, DC by 2030. This ramp up schedule accounts for the planning time required to get contracts into place and a year of padding at the end to complete the work in 2030. Table 10 shows the number of LSLRs and the number of blocks that will be completed each year of the plan using the recommended approach. In addition to including the highest scoring census block groups, the first year will include the blocks with the top 10% of individual risk scores being completed independently of the census block group if the average risk score for the block group is not within the top 50% of averaged census block group risk scores.

The annual workload of the plan as shown in Table 10 is based on the number of service lines replaced. As the highest priority blocks have the highest number of LSLs, fewer blocks are addressed in the beginning of the plan than the end. Depending on capacity, DC Water should consider designing the schedule based on a consistent number of blocks per year. Using this approach, 26.9 percent of LSLRs would be completed in year FY2024, completing over 1420 blocks.

In this table the CIP Blocks come from the DC Water CIP plan as presented in the LFDC plan.

TABLE 10: Recommended LSLRs per Year

Year	Neighborhood Blocks	Neighborhood LSLRs	CIP Blocks	CIP LSLRs	Annual Blocks	Annual LSLRs
FY2024	744	5,791	60	1,245	798	7,036
FY2025	1,091	5,804	88	1,255	1,188	7,059
FY2026	1,268	5,799	133	1,258	1,397	7,057
FY2027	1,348	5,804	162	1,219	1,517	7,022
FY2028	1,779	5,799	177	1,292	1,956	7,090
FY2029	2,190	5,803	371	1,255	2,554	7,058
Grand Total	**8,420**	**34,799**	**991**	**7,524**	**9,410**	**42,323**

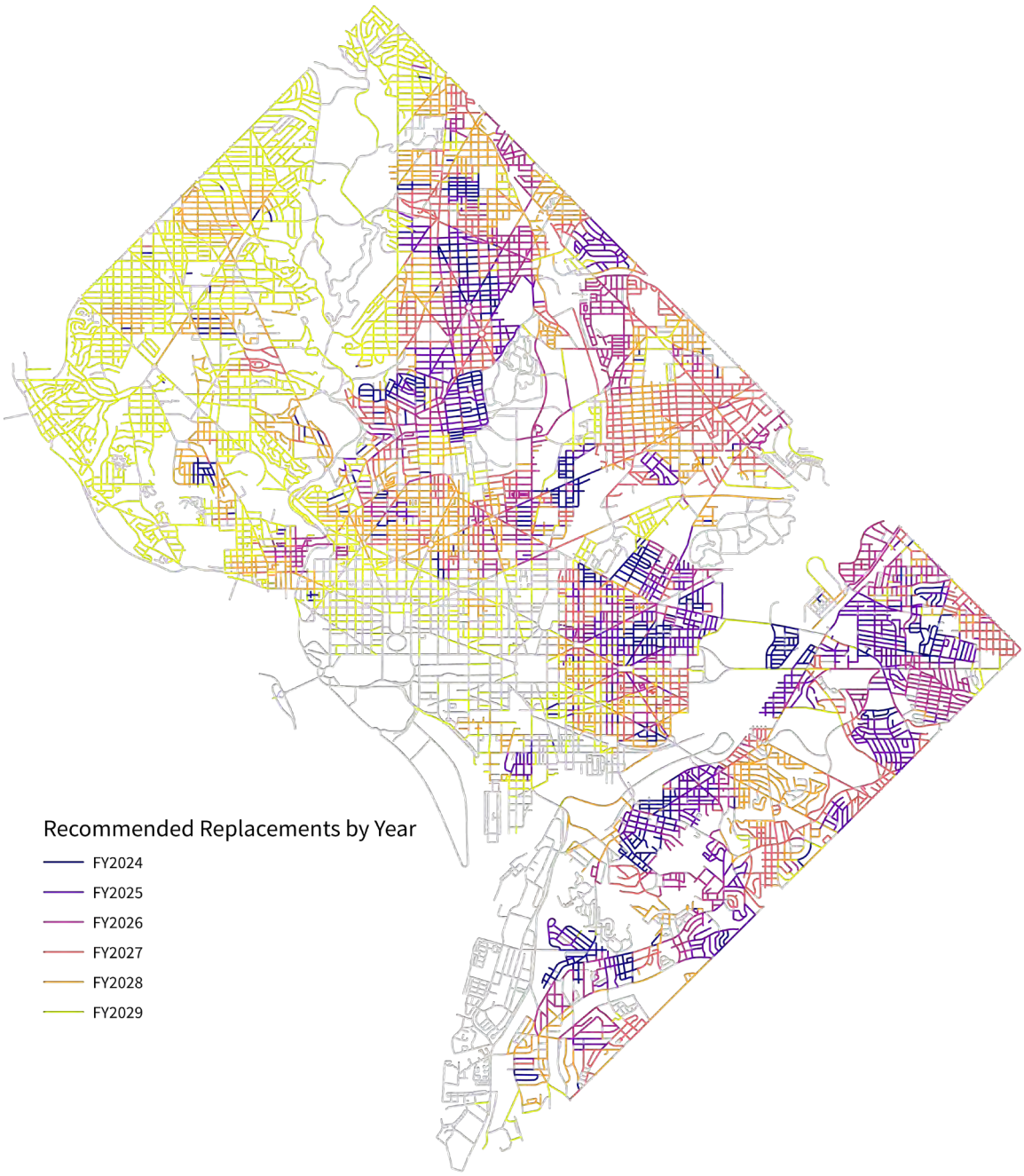
Assuming 200 construction days per year, this results in 36 LSLRs per day. As discussed later in this report, the city of Newark was able to replace 120 lines per day across the city at the peak of their program.

Map 8 shows the year when each block will be addressed, based on the recommendation of a consistent number of LSLRs per year. This plan allows for entire neighborhoods, or census block groups, to be completed at the same time, saving time, resources, and causing less disturbance to residents over the course of the plan.

3. Complete service line verifications and LSLRs at all day care centers during the first year.

Complete service line verifications and LSLRs at all day care centers during the first year as part of the new Individual High-Priority LSLR program. Add additional priority sites per program criteria on a rolling basis, and complete 10% of total LSLRs through this program. The LFDC Plan included about 10% of anticipated LSLRs in its Emergency Replacement program.

MAP 8: Recommendation for LSL Replacements by Year Using the Recommended Prioritization Model at the Census Block Group Scale



Construction Costs

What did DC Water do?

DC Water provided the document "20200331 LFDC Revised Cost Estimate.xlsx" in April 2022 and this section provides a description of the cost analysis in that Excel Workbook (Appendix G). DC Water breaks out program costs for the following programs:

- Capital Improvement Plan (CIP)
  - Block by Block (BBB)
  - Emergency/Vulnerable Pop
  - Small Diameter Water Main (SDWM)
- Voluntary Full Replacement Program (VFRP)
- Lead Pipe Replacement Assistance Program (LPRAP)

The cost of each program was calculated as follows:

1. The number of LSLs in each program is calculated from the service line inventory using the InfoAsset Planner LFDC Model[6] decision tree (Figure 3)
   - Note: this does not include an estimate of brass and galvanized service lines that must be replaced
2. Number of historic copper, brass, and galvanized records to be verified via test pitting are provided based on March 2022 inventory
   - Note: While the cost of test pitting verification was accounted for, the replacement of any service lines found to be lead was not.
3. Two test pits are calculated for every LSL and historic record to be verified
   - Note: Two test pits are used to verify both sides of the curb stop and both sides of the water meter, both of which are typically buried in the front yard.
   - Note: the water service specification provided by DC Water states that contractor cannot charge for test pits at LSLs that are verified and replaced.
   - Note: This does not account for test pits at unknown service lines not found to be lead (50%).
4. Final Pavement Restoration in Public Space is taken from centerline mileage of BBB and small diameter WMR programs
5. Small diameter water main replacement (SDWMR) is included in the LFDC cost estimate for the BBB and SDWM programs
   - Note: The LFDC plan includes two programs involve LSLR and SDWM replacement: The first incorporates the full cost of SDWM replacement in the BBB program. The second, the CIP-SDWM program, does not include restoration or SDWM costs as they are funded by the CIP program.
6. Test pitting costs, public side and private side replacement costs, and foundation penetration and connection to first fitting costs are provided by program, taken

from previous contracts. Costs range significantly based on program due to factors such as number of replacements, size of contractor, etc.

  - Note: We identified some irregularities in calculations and opted to recalculate as part of our analysis as described below.
  - Note: Foundation penetration and connection to 1st fitting is included in all private side replacement cost estimates per contract documentation provided.

7. LSLR, Test pit, SDWMR, and Restoration costs are calculated by multiplying quantities by unit costs by program.
8. A 10% contingency is applied, and the construction subtotal calculated.
9. Planning/Permitting at 3% and Design at 10% of the construction subtotal is calculated, and permit fees are calculated based on number of LSLRs.
10. Program management at 10%, Outreach and Stakeholder Engagement at 10%, Construction management at 5% and Data management at 5% of the construction subtotal is calculated.

Overall Notes:

- This program does not include costs for any filter distribution. Some public outreach materials state that a 6-month filter supply is provided when each LSL is replaced.
- The water service specification and standard drawings do not clearly state how far inside the home the LSL must be replaced. It is not clear what length inside the home is included in this cost estimate.
- DC Water states that the programmatic cost estimates do not include personnel costs. Those costs are significant and must be considered to get an accurate total.

LFDC Cost Estimates:

Table 11 is a breakdown of LFDC plan cost estimates by program. These costs are taken directly from the LFDC plan "20200331 LFDC Revised Cost Estimate.xlsx" (see Appendix G) without adjustment.

TABLE 11: LFDC Program Costs as presented in Appendix G

Program	Total
CIP-BBB	$362,573,012.86
CIP- Emergency/Vulnerable Pop	$69,603,532.11
CIP-SDWM	$109,167,432.95
VFRP	$47,778,004.89
LPRAP	$91,193,820.96
Grand Total	**$680,315,803.76**
Grand Total With SDWMR Program Costs	$1,089,576,480.50

Below are three LFDC programs broken out by two pie charts: one that shows how costs are distributed within the program, the other shows the calculated unit costs of a FLSLR in each program that ignores programmatic costs not directly related to a LSLR (i.e. test pitting copper, SDWM replacement etc.).

FIGURE 5A: CIP-Block by Block (BBB) Program Cost Breakdown ($362,573,012)

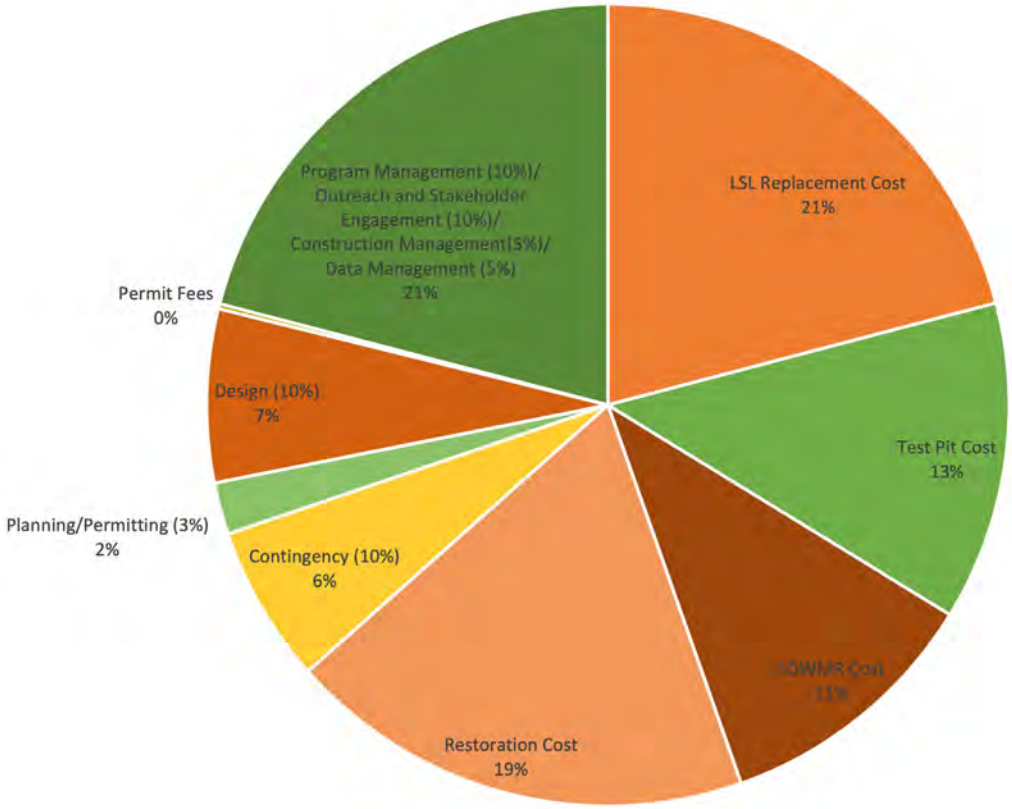


FIGURE 5B: CIP-Block by Block (BBB) Full LSLR Cost Breakdown ($24,535)

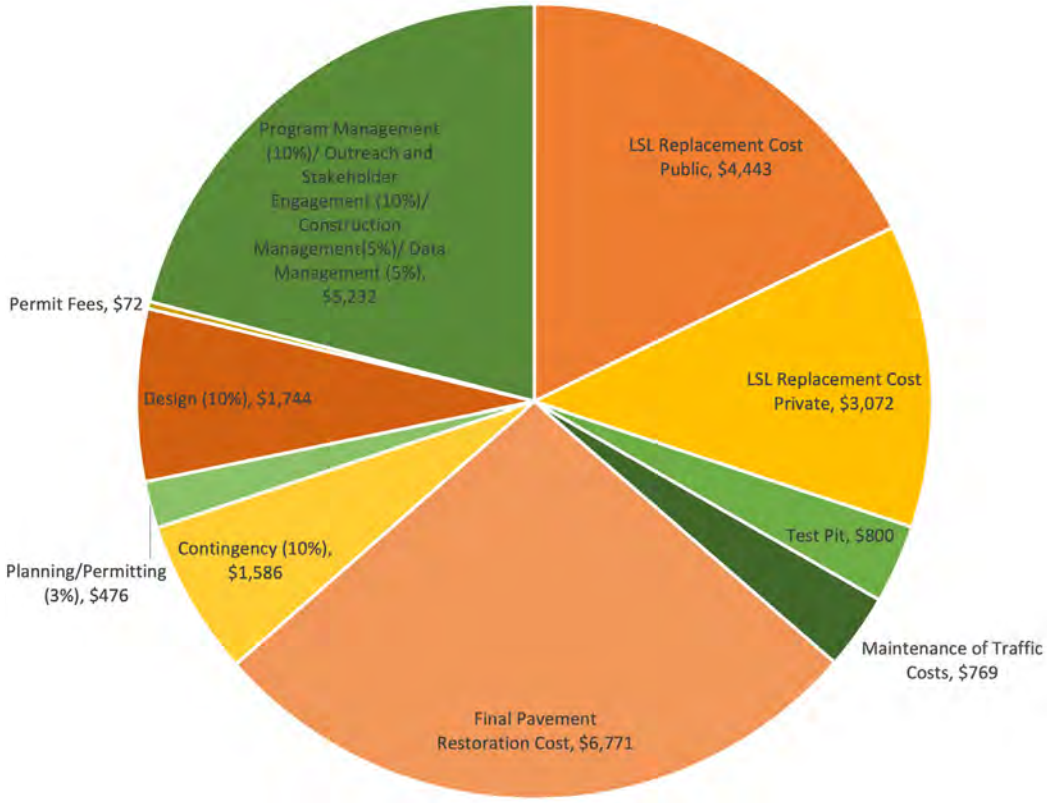


FIGURE 6A: CIP-Emergency/Vulnerable Program Cost Breakdown ($69,603,531)

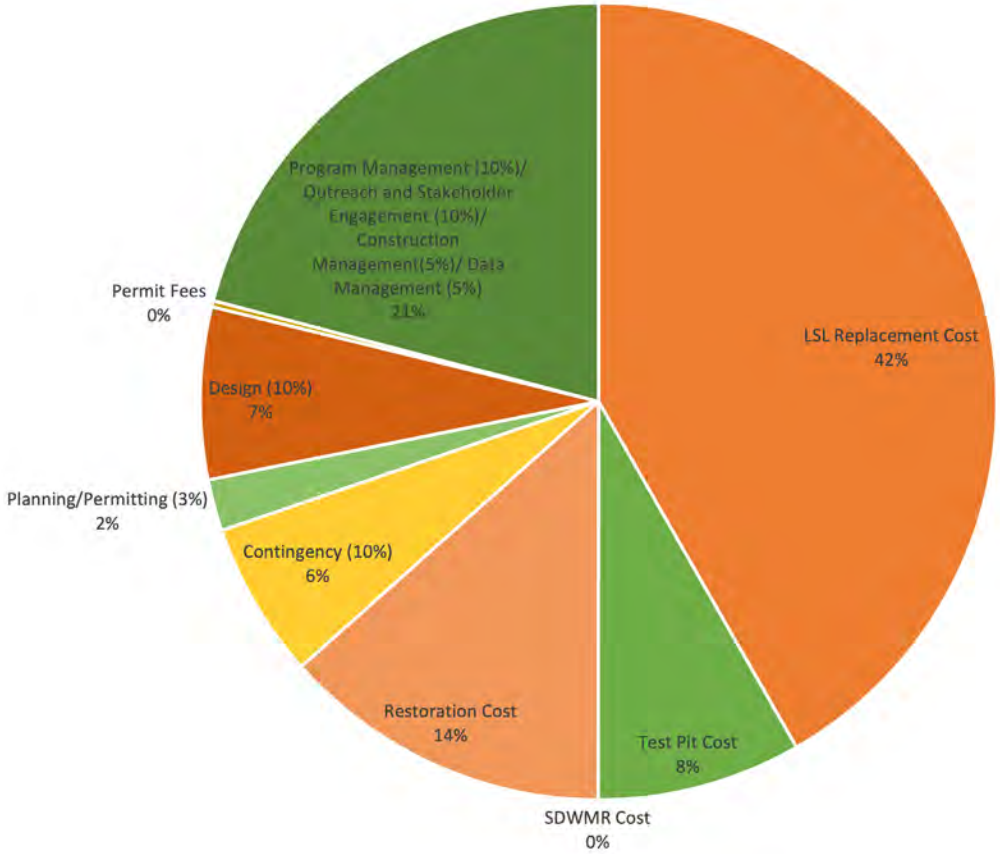


FIGURE 6B: CIP-Emergency/Vulnerable Population Full LSLR Cost Breakdown ($18,774)

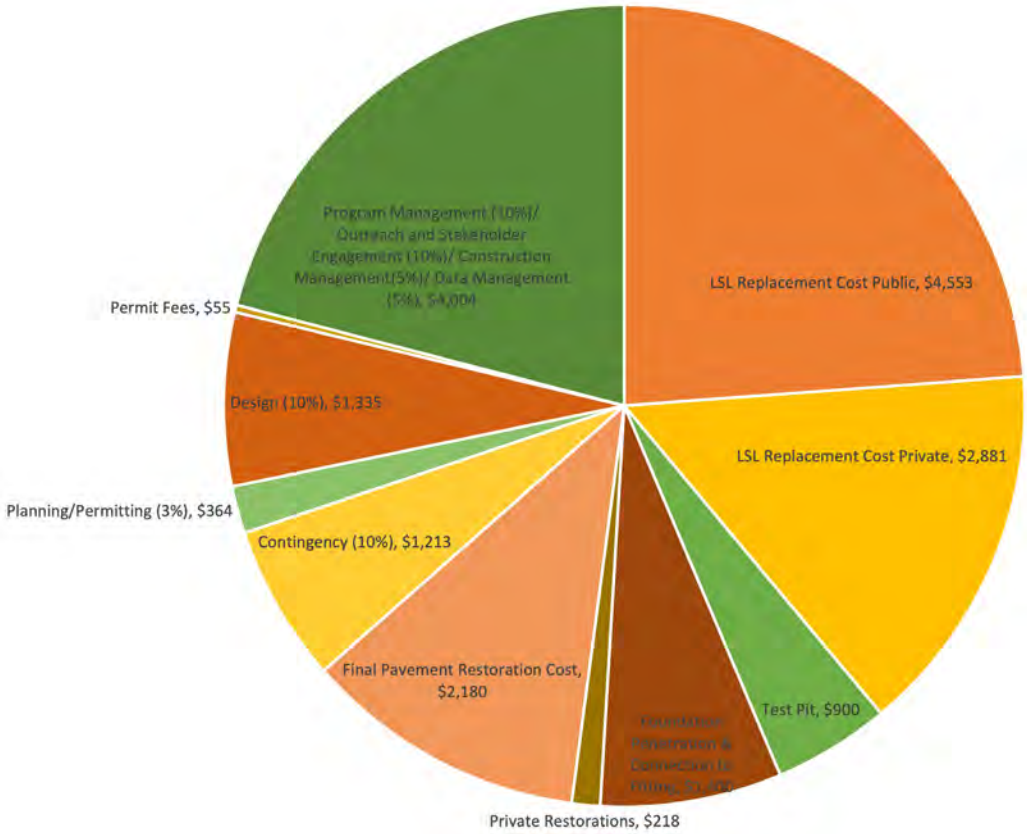


FIGURE 7A: CIP-SDWM Programs Cost Breakdown - Excluding CIP SDWMR Funded Cost ($109,164,432)

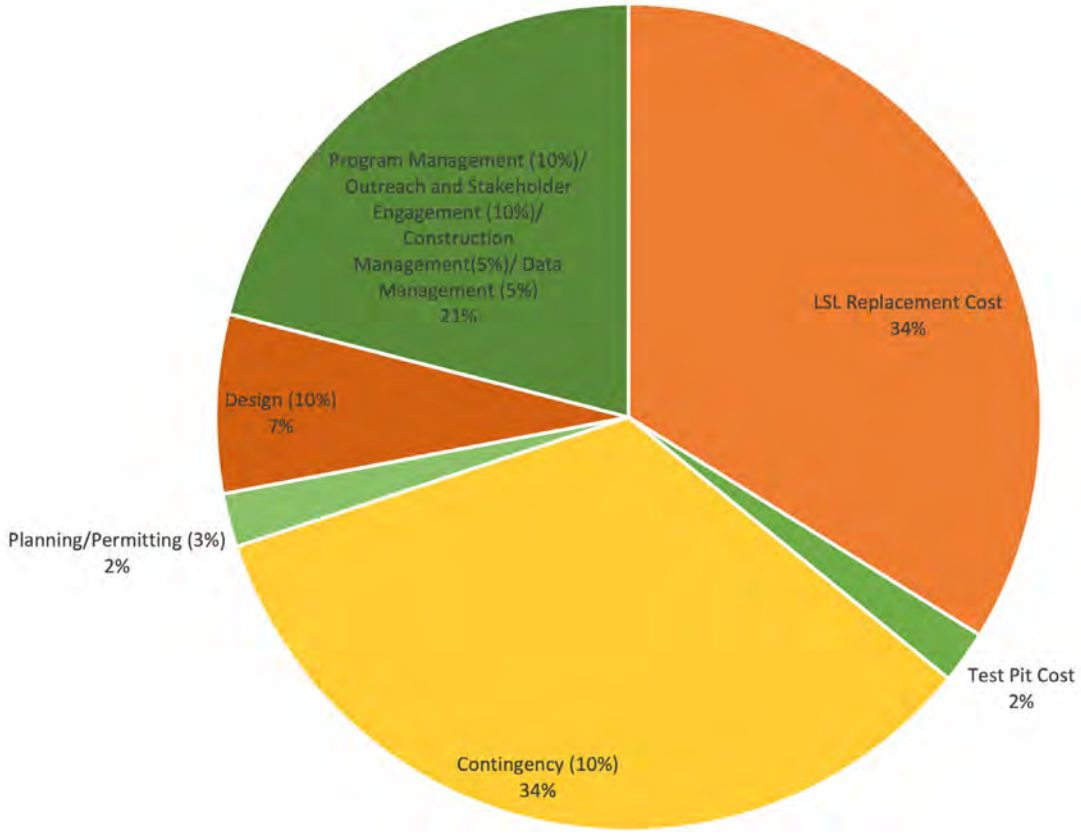
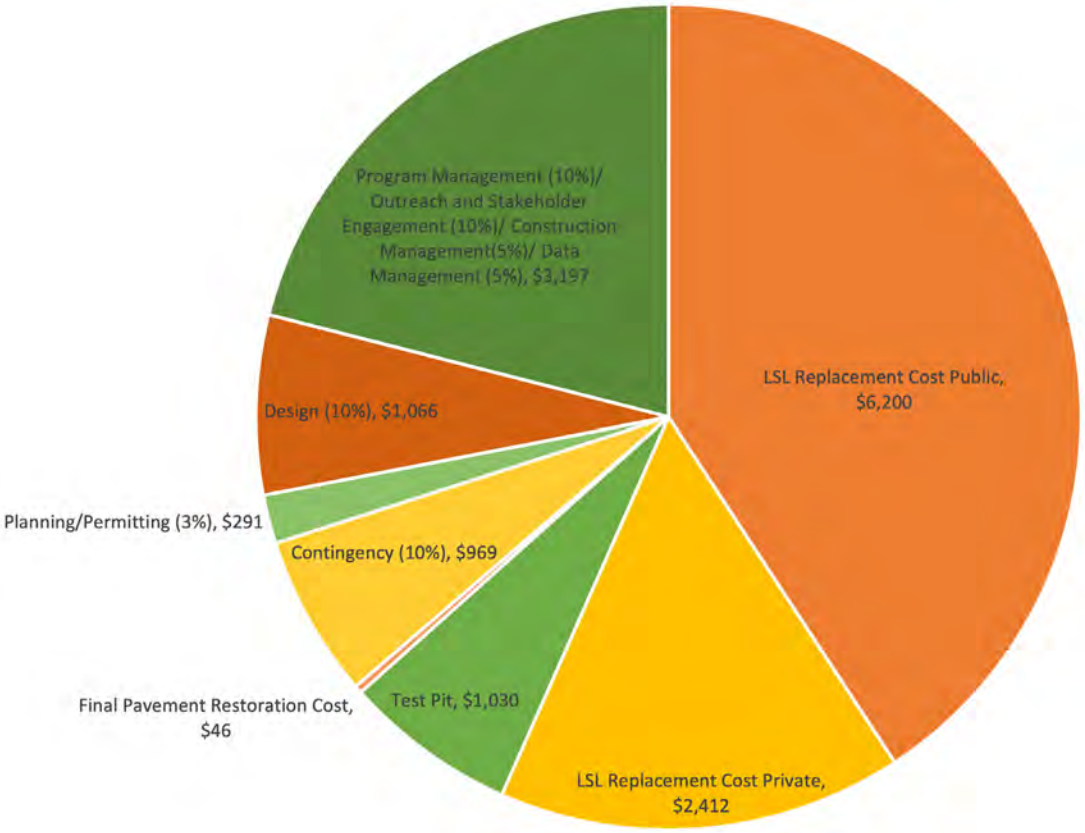


FIGURE 7B: CIP-SDWM Full LSLR Cost Breakdown ($14,949)



The CIP-BBB program has a high restoration cost due to the full street paving that occurs. Additionally, 11% of the cost of the program (not including the additional contingency, program management, etc. costs) is devoted to SDWM replacements. The LFDC plan includes all test pitting of historic copper, brass, and galvanized service lines in this program which accounts for 13% of the cost.

The CIP-Emergency/Vulnerable Population program uses individual restoration costs which are proportionally cheaper per LSLR than street paving and therefore a smaller percent of the total cost of the program. Test pitting is just for the individual LSLRs not any identification of unknowns or copper.

The CIP-SDWM program does not include restoration or SDWM costs as they are funded by the CIP program. The remaining costs include LSL replacement, test pitting, and other programmatic costs. Even without restoration costs the LFDC plan estimates around $15,000 for a replacement. Note: the contingency cost as 34% of the total program appears to be an excel error in the "20200331 LFDC Revised Cost Estimate.xlsx" spreadsheet (see Appendix G).

How does this compare to benchmark cities?

Denver, Newark, Cincinnati, and Detroit provided some limited information regarding the cost of LSLR in each city. Denver provided the most robust cost data, shown in Table 12 below. Contracts and costs can vary widely between cities due to city specific requirements, building density, and cost of living.

TABLE 12: Denver Water LSLR Cost Data For 2021 Construction Year

Type of Replacement	Approximate average cost per replacement
Main to meter	$5,000-$7,500
Meter to property	$2,800-$5,000
Planned FLSLR as part of a WMR	$8,000-$10,000
Neighborhood based LSLR without WMR	$9,000-$11,300
Emergency FLSLR	$8,000-$10,000
Cost per pothole	$280
Cost estimate includes:	
Field inspection (i.e., potholing and interior material verification)	X
Mobilization	X
Utility coordination & locates	X
Street paving	X
Site restoration	X
Record keeping	X[a]
Outdoor flushing only	X
Flushing per AWWA FLSLR standard[10]	X[b]
Outreach program to individual affected residents	X[c]
Permit fees	X

[a]*Included for DW crews, but not for contractors.*
[b]*Interior flushing protocols are inconsistent among contractors and DW crews.*
[c]*Includes door-knocking and in-person coordination, but does not include mailings/postage*

In a personal communication from Cincinnati, they stated that their engineering department projects $1,500 per LSL. The cost of private LSLR has decreased from $5,000 in 2018 to $3,000 as reported in early 2022. Detroit has observed that inflation and work shortages during the COVID pandemic has driven LSLR costs up during 2021, increasing from $5,000 per emergency replacement to $8,300 per emergency replacement in 2021, while their LSLRs associated with WMR programs stayed under $5,000.

TABLE 13: LSLR Cost Benchmarking

Source of LSLR Cost Data	Planned FLSLR (with WMR)	Individual FLSLR	Building side only (e.g., meter or property line to building)	Water main side only (e.g., water main to meter or property line)
EPA LCRR Final Economic Analysis[a]	$3,991	$4,989	$3,222	$3,824
AWWA LCRR comments[b]	$5,204	$6,106	$4,767	$4,191
Denver, CO[c]	$9,000	$9,000	$3,900	$6,250
Newark, NJ[d]	--	$7,000	$6,130	$4,980

[a]Range is presented in the Economic Analysis;[10] average is used here.
[b]Source: American Water Works Association[11].
[c]Source: A. Woodrow, personal communication, March 8, 2022.
[d]Source: Newark presentation[12]

Pittsburgh, Denver, Newark, and Cincinnati have all reported that LSLR costs have decreased since the beginning of each of their programs as contractors and programs become more efficient in their work. For example, Denver's LSLR bids in 2021 were 12% lower than in 2020.

How Did We Calculate Recommended Program Costs?

We made several updates in the cost estimate workbooks to ensure clarity and consistency. We then calculated the cost of the recommended plan and then evaluated the total and relative cost per FLSR to determine whether the remaining costs make sense compared to the work required. We then completed an evaluation of the current and potential future paving costs if the Council of the District of Columbia changes paving regulations associated with LSLR work. Table 14 presents the results of these evaluations and recommendations.

TABLE 14: Construction Costs Used for Recommended Cost Estimate

Cost Element	Corrected Cost	Calculation source[1]	LFDC Cost	LFDC Source[2]
Public side LSLR with Main Replacement	$1,525	"SDWM 11A-15B" AW45	$6,200	'SDWM 11A-15B'!AX26-K12
Public side LSLR without Main Replacement	$5,752	"BBB- Capitol Paving," L29.	$4,497	Summary M10:M11
Private side only LSL Replacement	$3,062	Average of corrected "Summary," N10:N12	$2,829	Summary N10:N14

[1] "20220331 LFDC Revised Cost Estimate_corrections" (see Appendix F).
[2] "20220331 LFDC Revised Cost Estimate" (see Appendix G)

We used DC Water's SDWMR bid tabs to recalculate the public and private side LSLR with main replacement costs. For each of the contracts that DC Water used in their original calculation, we used the same fields from each contract to calculate the total spent on water services for each contract: cost of copper water service, meter box, curb stop, penetration through building wall, private side property agreement, and half of bid allowance. The total number of curb boxes or meters per bid sheet was used as the total number of estimated service replacements per contract. Using the total estimated cost for service replacements and the total number of service replacements expected across the set of selected SDWMR projects, the average FLSLR with a WMR was calculated as $5,632. Using DC Water's average public side LSLR as 27% of the total cost and average private side LSLR as 73% of the total cost, the average public side LSLR with SDWMR came to $1,525.

For public side LSLR without WMR, the cost of public side LSLR was calculated using the Spiniello and Capitol Paving bid sheet line-item totals, averaged across the total number of services estimated on each of the bid sheets, resulting in $5,752. This is similar to, but higher than, the public side LSLR cost from the Emergency/vulnerable Pop program of $5,453.

The average of private side replacement costs from the Spiniello/Capitol Paving bids, the emergency replacement program, and the SDWMR bids were used to arrive at an average private side LSLR cost of $3,062.

We used the average test pitting cost of $337 from the SDWMR bids, as this consolidated strategy of test pitting while working down a WMR is most like the neighborhood scale program we recommend.

We apply a 10% efficiency measure for the Neighborhood Scale LSLR Programs to reflect the efficiencies gained by consolidating many replacements and test pits in the same geographic area. We used a 10% efficiency estimate, which is reflected in the work that Denver has done. Denver's work shows a 10% lower average cost of neighborhood based LSLR without WMR compared to emergency LSLR. Our analyses can be found in Appendices E and F. We did not include a price escalation for inflation in our estimate. The benchmarking cities mostly found that costs decrease over time as contractors become more efficient in their work, and Denver found this to be true for 2021 even as inflation was increasing.

What do we recommend doing?

1. Include the cost of test pitting all unknowns, historic copper, and historic brass service lines. Plan for replacing the 50% of unknowns, 20% of historic copper, and 47% of historic brass that are estimated to be lead, brass or galvanized service lines. Plan for replacing all remaining non-historic brass and galvanized service lines.

These changes increase the number of needed replacements from 27,975 service lines to 42,323 service lines.

2. Update other cost percentages.

Table 15 shows the cost percentages applied in the LFDC Plan and resulting dollar values, percentages applied in our cost analysis and resulting dollar values, and the rationale for the recommended changes. As shown in the table, even though our recommendations substantially decrease programmatic costs, the recommended program is still very generous and likely includes additional opportunities for cost savings. Our recommendations use a total 19% of construction costs to estimate programmatic costs, resulting in 15% of the total recommended program cost. For comparison, Denver's programmatic costs, including outreach and education, are roughly 15% of the total cost of their program (Woodrow, Personal communication, July 13, 2022).

3. Explore strategies for reducing the cost of LSLRs in the Neighborhood Scale LSLR Program.

To estimate the LSLR cost of the Neighborhood Scale LSLR Program, we relied on the contract bids that DC Water used to estimate the cost of their CIP-BBB program but updated the unit costs to reflect the units on the bid sheets. The resulting unit cost of $13,625 is higher than for benchmarking cities and cost benchmarking shown in Table 13. The two LSLR contracts these costs come from were issued as change orders without public bidding so LSLR could ramp up as fast as possible, which may contribute to the higher unit prices. New bids for contracts designed for the recommended programs may have lower unit prices.

We recommend that DC Water pursue innovative strategies for pushing down the cost of Neighborhood Scale LSLR, such as those used in Newark that were successful in both driving down cost and increasing speed of replacement. To keep prices low, contracts were bid out every other day, by zone or area. This approach allowed companies to see each other's bids and revise as feasible to win the next round of contracts. The prices went down with each public bid opening. In addition, benchmarking cities Denver and Cincinnati both found that prices decreased over time as contractors become more efficient with repeat work. We anticipate that the cost of the Neighborhood Scale LSLR Program will be lower than estimated here.

TABLE 15: LFDC and Recommended Programmatic Costs Used to Estimate Overall Construction Costs

	LFDC Plan % Cost	Recommendations % Cost	Rationale
Contingency	10% $73.4 m	10% $34.7 m	No Change
Efficiency	0 $ --	-10% -$29.4 m	The substantial consolidation of projects by geography and time will result in lower project costs like those experienced in Denver and Detroit.
Planning/ Permitting	3% $14.3 m	3% $10.4 m	No Change
Design	10% $47.5 m	0% $ --	Design costs for WMR projects are included in the WMR cost. None of the bid sheets for previous LSLR contracts includes a line item for design. LSLR design is typically limited to simple plan drawings that should already be accounted for in the planning/permitting line item above. The LFDC Plan includes $1000-1700 per LSLR.
Program Management[1]	10% $47.5 m	5% $20.1 m	The recommended program management costs are still very generous, coming in at $2.5 m annually. Assuming 200 construction days per year, this would provide for a program management staff of at least 16 overseeing about two LSLRs per person every construction day.
Outreach and Stakeholder Engagement[1]	10% $47.5 m	5% $20.1 m	10% of the recommended LSLR program would result in a $34.7 million outreach program for LSLR alone, or a $4.3 million annual budget. The 2022 operating budget for marketing and communications for all of DC Water is $2.8 million.[14] A 5% outreach and stakeholder engagement budget will provide $2.5 million annually, nearly doubling DC Water's outreach budget to implement a generous LSLR outreach and engagement program.
Construction Management[3]	5% $23.8 m	3% $11.5 m	This generous construction management budget provides for $1.9 m annually, providing at least 12 construction inspectors reviewing about 3 LSLRs each per construction day.
Data Management[1]	5% $23.8 m	3% $12.1 m	The data management program cost is slightly higher than construction because data management is required for filter tracking. This budget would allow for at least 10 staff for data management, whose primary role is data QA/QC because contractors will be responsible for primary data entry. This is likely much higher than necessary.
Total of staffing programs	43% $204.4 m	19% $74.2 m	Includes Planning/Permitting, Design, Program Management, Outreach and Stakeholder Engagement, Construction Management, and Data Management.
Annual FTE Equivalent[2]	171	63	According to the DC Water 2022 budget, approximately 1,100 people are employed by DC Water.[14] Although this budget includes non-staff costs, like outreach and software, it is helpful to make these types of comparisons to explore the order of magnitude of these programs.

[1]Assumes 8 years of programmatic implementation for 6 years of LSLR, including ramp up and down.
[2]FTE calculated with assumed average DC Water salary of $110,000,15 plus 40% estimate for fringe benefits for a total of $155,000.
[3]Construction management planned for 6 years to cover anticipated construction period.

4. Include the cost of providing certified lead reducing filters to all residents with potential LSLs.

Post-LSLR lead in water data published in the Water Research Foundation Reports,[16, 17] demonstrates the importance of residents using certified lead reducing filters for all drinking and cooking water prior to LSLR replacement and six months post replacement. Although provision of filters is mentioned in some DC Water outreach documents, the cost of filters is not included in the LFDC Plan costs. To provide this level of public health protection, we add in the cost of providing filters for five years for every potential LSL in Washington, DC ($249 per service). This cost is based on current retail cost and is an overestimate. If DC Water purchases certified lead reducing filters in bulk, there will likely be substantial savings. Further, based on the recommended schedule, 66% of LSLRs will be replaced in the first four years of plan implementation. Providing filters in advance of LSLR ensures all residents have an immediate source of reliable very low lead water in every home with a potential LSL. DC Water outreach materials (Appendix J.a and J.c) and research conducted by DC Water have identified the importance of using filters up to six months post LSLR due to the risk of a temporary lead increase following the LSLR.

5. Consider policy changes to reduce paving costs.

The LFDC CIP-BBB program is the most expensive program at a cost of $362.5 million dollars. It also has the highest cost per service line at $24,535. Approximately $10,360 of the cost of a LSLR is attributed to the restoration cost (restoration+ programmatic fees). In comparison, the emergency/vulnerable population program only spends $4,741 in restoration and restoration related programmatic fees. The difference in cost comes from street paving. The CIP-BBB program follows DDOT paving regulations which suggest paving entire streets when replacing 4 or more utility services on that street (4 replacements affecting approximately 30 ft in length).[18] This regulation does not account for the length of the block and therefore is adding significant costs to the LFDC Plan. Table 17 in the Overall Assessment Section displays both the calculated cost of LSLR using the DDOT regulation on street paving and for the most cost-effective method to conduct restoration. Because pavement cost alone may not be the best metric for aesthetic and equity purposes, we suggest DC Water, Council of the District of Columbia, and DDOT work together to develop an appropriate metric for triggering street paving. We suggest exploring the number of LSLRs per 100 ft of road for this metric.

OVERALL ASSESSMENT

What is the cumulative impact of our recommended program changes?

Table 16 quantifies and summarizes the cost savings and additions identified through our analysis and recommendations discussed in the sections above.

Table 16: Costs of Recommended Revisions Compared to 2022 LFDC Revised Cost

Corrections to 20220331 LFDC Revised Cost Estimate	Difference
Update AA12 to correct calculation error in applying 10% contingency	-$47,530,653
Remove Test pit charges for Service Lines that are determined to be Lead per contract specifications	-$60,628,934
Analysis of Recommendations	
Move all SDWM Replacement costs to CIP	-$169,318,277
Adjust restoration to most cost-effective method cost: full street paving or individual site restoration	-$148,394,279
Account for efficiencies of scale for neighborhood scale replacement for non-water main replacement projects	-$29,398,712
Adjust Design, Engagement, Management, and Data Costs	-$90,125,122
Adjust Service Line replacement costs per DC Water bids	$32,350,860
Account for test pitting all Unknowns and Historic Brass in addition to Historic Copper	$18,284,697
Add filters for all potential LSLs and 6 months post replacement	$24,145,432
Account for Individual High-Priority LSLR Program	$8,524,177
Account for replacing LSLs found from Historic Brass and Copper test pits	$143,822,464
Account for replacing all brass and galvanized service lines	$34,895,254

Figures 8-10 display estimated cost breakdowns for each of the three recommended LSLR programs and the estimated cost breakdown for an individual LSLR completed through each of the 3 programs. Based on implementation experience in benchmark cities, we anticipate that the cost of LSLRs completed via the Neighborhood Scale LSLR program can be reduced further via competitive bidding and contractor experience, thus bringing down the overall cost of the plan even further.

FIGURE 8A: Recommended Neighborhood LSLR Program Cost Breakdown ($385,702,037)

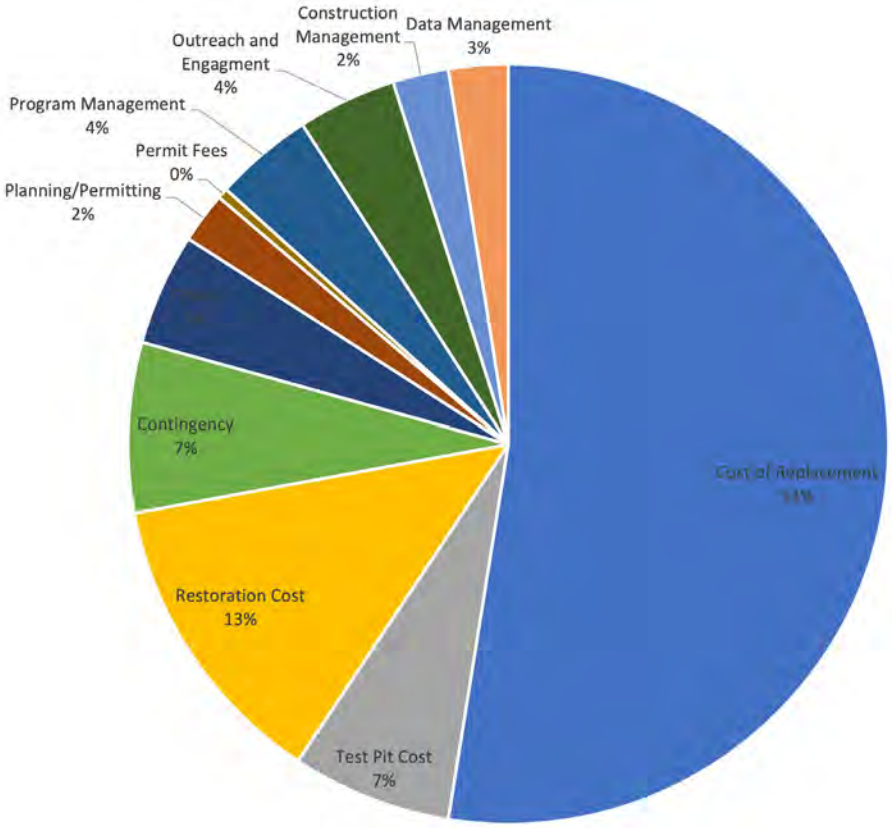


FIGURE 8B: Recommended Neighborhood Scale LSLR Program Full LSLR Cost Breakdown ($13,625)

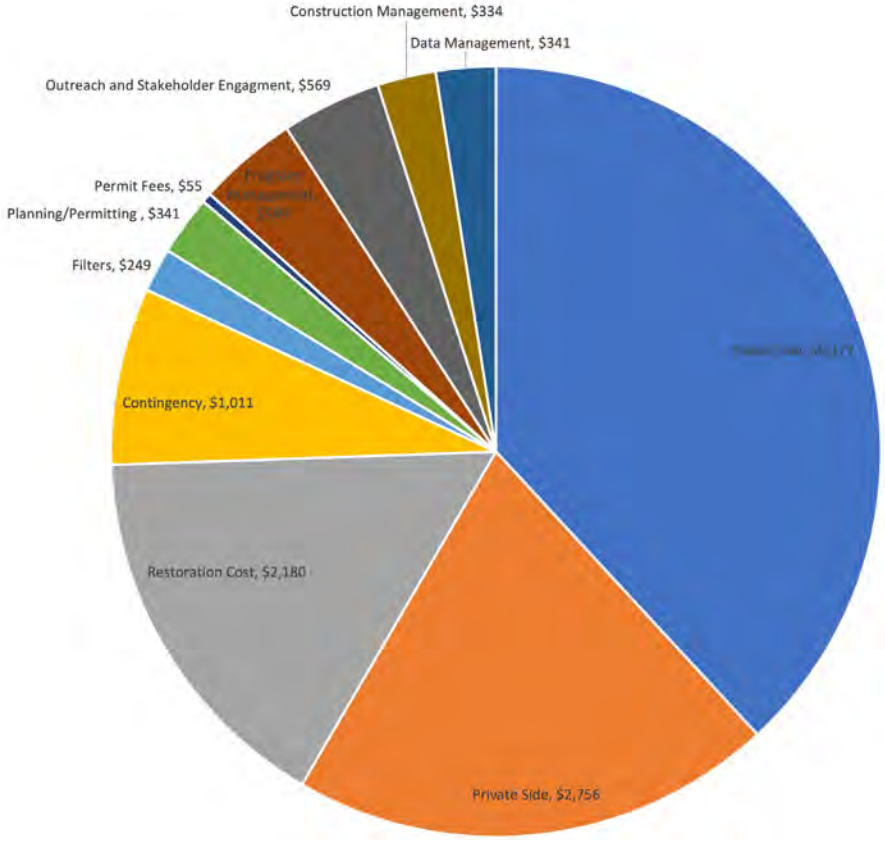


FIGURE 9A: Recommended High-Priority LSLR Program Cost Breakdown ($49,071,131)

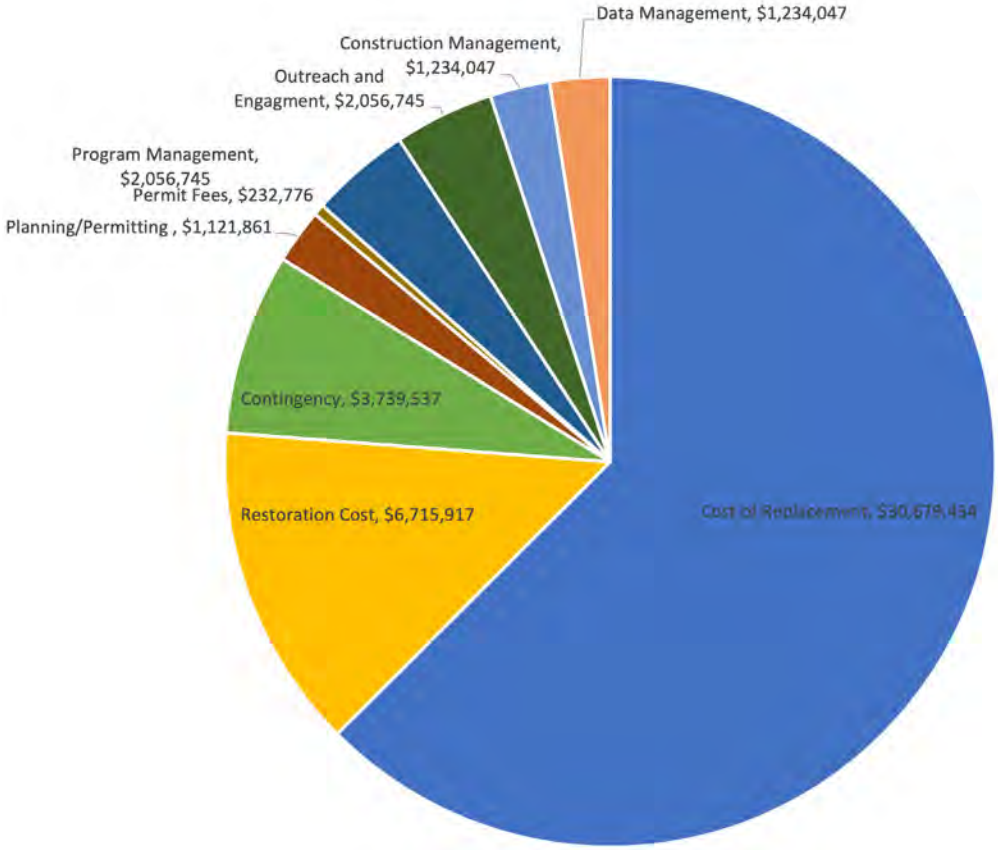


FIGURE 9B: Recommended High-Priority LSLR Program Full LSLR Cost Breakdown ($14,365)

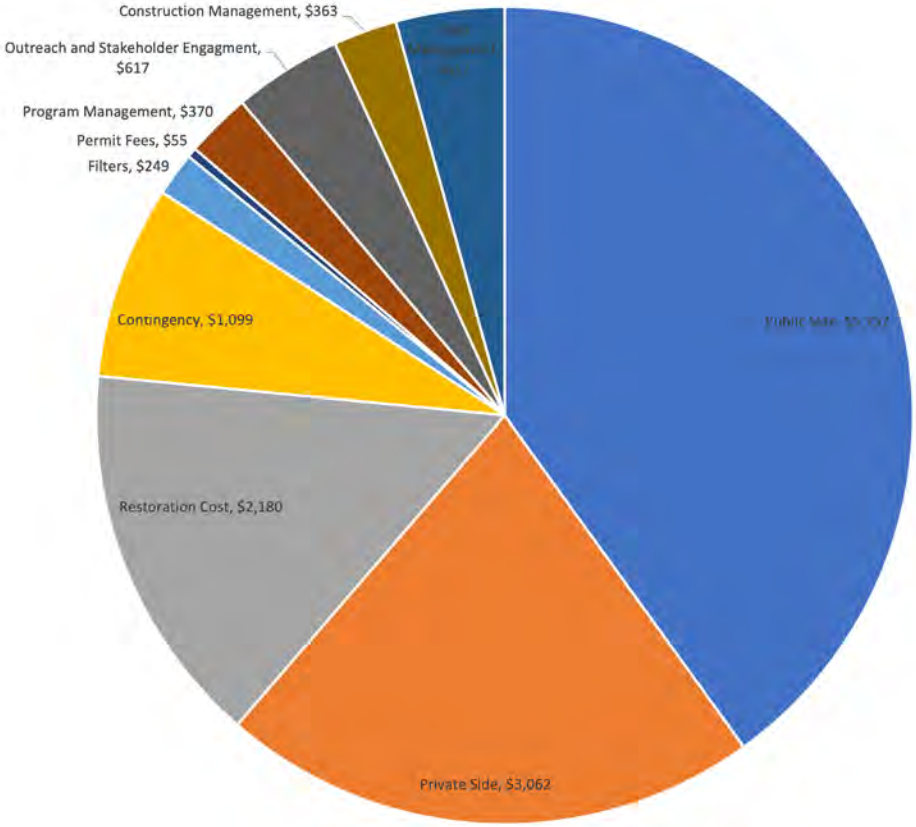


FIGURE 10A: CIP Water Main Replacement LSLR Program Cost Breakdown

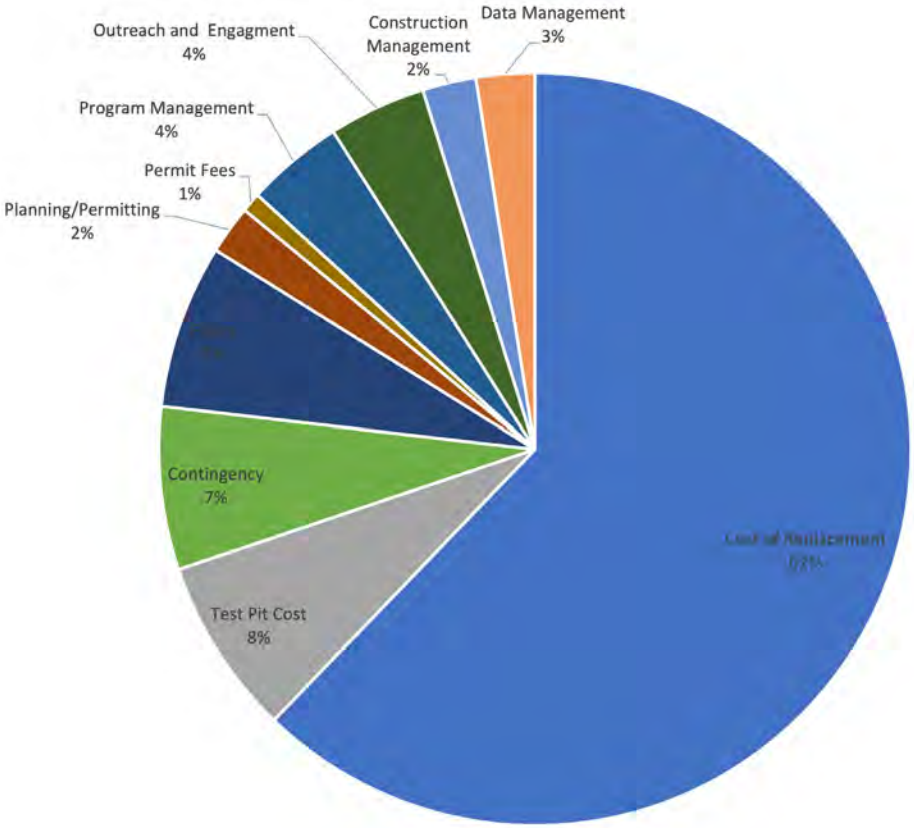


FIGURE 10B: Recommened CIP Water Main Replacement LSLR Full LSLR Cost Breakdown ($6,375)

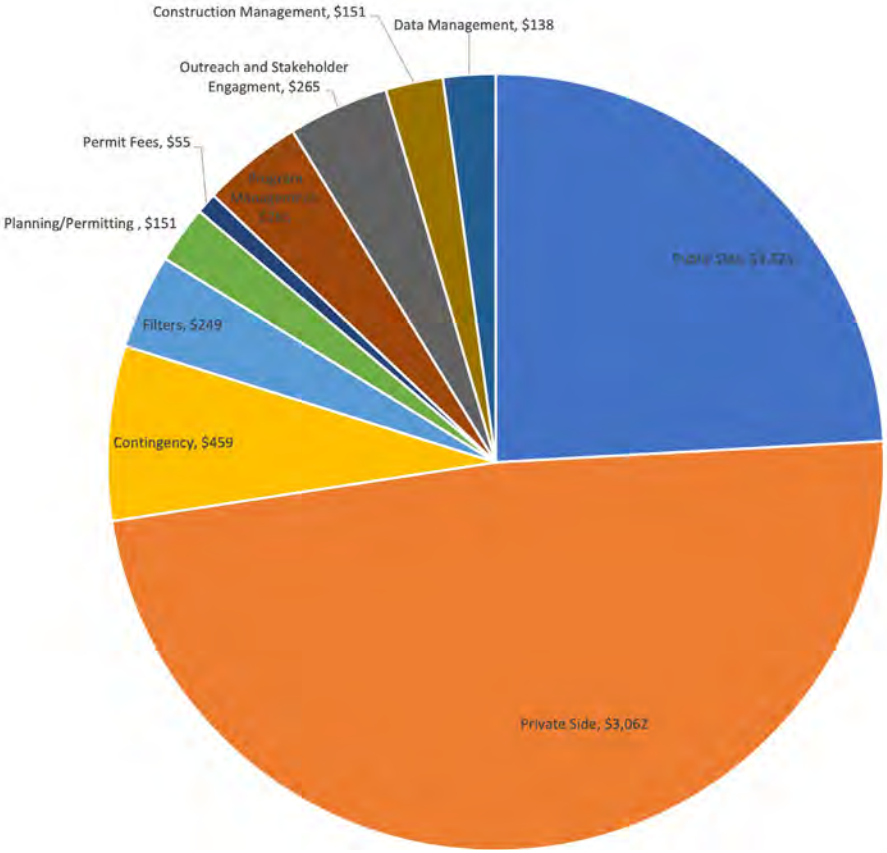


Table 17 provides the recommended total plan cost as described in this report, and additionally shows the cost of WMR described by DC Water in the LFDC Plan and their CIP.

TABLE 17: Recommended Plan Cost

Program	Number of Test Pits	Number of LSLRs	Recommended Program Cost	Miles of WMR	WMR Cost
Neighborhood Scale LSLR program	77,809	31,319	$386,000,000	-	$0
CIP Water Main Replacement LSLR Program	8,875	6,771	$45,000,000	97	$338,000,000
Individual High-Priority LSLR Program	-	4,232	$49,000,000	-	$0
Total:	86,684	42,323	$480,000,000		

Grand Total Low Estimate*		**$480,000,000**
Grand Total High Estimate*		**$628,000,000**

**The low and high estimates are calculated using optimized street paving versus street paving as suggested by District of Columbia Department of Transportation regulations.*

Our LFDC Plan Recommendations are designed to achieve the following:

- Account for identification and removal of all potential lead, brass and galvanized service lines;
- Prioritize critical customers and equity;
- Consolidate programs and timelines to generate cost efficiencies;
- Provide certified lead reducing filters to all potential LSL locations to provide an immediate source of safe drinking water for all residents; and
- Encourage and increase public participation through lower costs, fewer participation barriers, and increased public engagement.

While Table 17 provides an overall summary of the recommendations in this report, Table 18 provides a comparison of the costs and planned outcomes for the LFDC Plan and the recommended plan.

The cost estimate for the LFDC Plan is $680 million (Appendix G), which includes $540 million for LSLR and $141 million for WMR (see Table 18). An additional $193 million for currently planned WMR, $15 million for future planned WMR, and $201 million for future estimated WMR is presented separately but included with the LFDC Plan cost estimate.

Our recommendations for the LFDC Plan, using our analysis and recommended strategies, have a total cost estimate between $480 and $628 million. The recommended changes to the LFDC Plan provide for the replacement of all LSLs by 2030, and they account for the replacement of 14,348 more LSLs than the original LFDC Plan. The recommendations include service line verification for all unknowns

and unverified historical records, addressing a total of 8,867 more potential LSLs compared to the LFDC Plan (number of LSLRs plus services planned for test pitting). Our recommendations add the provision of certified lead reducing filters to provide an immediate source of safe drinking water to all residents with potential LSLs until all LSLs are removed. Further, our recommended programs continue the essential test pitting, outreach, and program and data management practices included in the LFDC plan that are critical for project success.

While we recognize the $349 million need DC Water has included for currently identified WMRs ($141 million for poor quality main WMR, $193 million for currently planned WMR, and $15 million for future planned WMR), we recommend that these WMRs be included in the CIP budget rather than the LFDC budget. These replacements are necessary for maintenance of DC Water infrastructure, and LSLR will be least expensive if completed at the same time, but these are expenses DC Water must plan for even in the absence of a LFDC Plan. Therefore, we recommend funding the WMRs that DC Water identifies as necessary, but we do not include WMR costs in the recommended LFDC Plan cost estimates presented here.

To successfully implement the recommended plan, the Council of the District of Columbia will need to eliminate the bifurcation of LSLR programs and the distinction between funding options for partial LSLs and full LSLs. The current LFDC distinctions of funding sources, funding eligibility, and program administration decrease the efficiency of the LFDC plan. DC Water will need new funding for removing private side LSLs and policy support to implement these recommendations. Breaking down these distinctions and merging programs to function at the neighborhood scale will greatly improve efficiency and the timeline for removing all LSLs.

Table 18: Comparison of LFDC and Recommended Plan Costs

Program Costs	LFDC Plan Costs	Recommended Plan Costs	Delta
LSLR Program			
CIP-Block-by-Block not including main replacement	$222,000,000		
CIP-Emergency/Vulnerable Pop	$70,000,000		
CIP-SDWM not including main replacement	$109,000,000		
Voluntary Full Replacement Program	$48,000,000		
Lead Pipe Replacement Assistance Program	$91,000,000		
LSLR Program Total- not including cost of main replacement	*$540,000,000*	**$480,000,000**	*$60,000,000*
Recommended High Estimate w/ Paving per DDOT Regulations		$628,000,000	($89,000,000)
Water Main Only Replacement			
CIP-BBB Poor Quality Main SDWMR included in the LFDC Plan[1]	$141,000,000	$141,000,000	
CIP Current Planned Water Main Replacement[2]	$193,000,000	$193,000,000	
Total LSLR and Current Planned WMR	$874,000,000	$814,000,000	$60,000,000
Recommended High Estimate w/ Paving per DDOT Regulations		$896,000,000	($23,000,000)
CIP Future Estimated WMR[3]	$216,000,000	$15,000,000	
Grand Total LSLR and WMR	**$1,089,000,000** **27,975 LSLRs** **76,138 services** **accounted for** **97 miles WMR** **0 water filters** **76 miles unidentified WMR**	**$829,000,000** **42,323 LSLRs** **85,665 services** **accounted for** **97 miles WMR** **5 years water filters** **0 miles unidentified WMR**	**$260,000,000**
Recommended High Estimate		$912,000,000	$177,000,000

[1]CIP-BBB Poor Quality Main SDWMR as presented in LFDC Plan includes 80% of 25 miles of water main and 100% of 25 miles of restoration costs, includes contingency, planning, design, program management, outreach, construction management, data management.
[2]CIP Current Planned Water Main Replacement as presented in LFDC Plan does not include contingency, planning, design, program management, outreach, construction management, data management.
[3]CIP Future Estimated Water Main Replacement includes 4 miles of identified water main costs, and 76 miles of unidentified water main and restoration costs. The recommended LFDC Plan Costs include 4 miles of these identified water main costs.

Additional Recommendations

Through the course of this evaluation and benchmarking work, several needs, strategies, and opportunities were identified that do not derive directly from the analysis but are important strategies the Council of the District of Columbia and DC Water should implement and/or consider as they move forward with the LFDC Plan. These are identified in this section.

Improve Water Service Specifications to Protect Public Health and Improve Clarity and Consistency

- Mandate that all materials used in LSLR have third-party certification markings demonstrating materials are in compliance with the final *Use of Lead Free Pipes, Fittings, Fixtures, Solder, and Flux for Drinking Water*[19] regulation.
- Per the *AWWA Full Lead Service Line Replacement Standard C810-17,*[10] the water should be shut off prior to beginning the replacement work. A best practice is to keep the water off until the customer signs off on water restoration. The current DC Water specification has a two-hour limit on the water shutoff. Keeping the water off until the household plumbing is flushed should be a higher priority, while keeping the work time as close to two hours as possible.
- Every LSLR should be completed within one business day. If an emergency prevents this, the water should remain off until the FLSLR has been completed.
- The Water Service Specification should include in-home flushing per AWWA C810-17[10] to be completed by the contractor at the time water service is restored. The contractor should provide flushing services inside the home unless customer refuses and signs. The contractor should be required to hand an infographic explaining and describing the in-home flushing instructions per AWWA C810-17 to the resident at the time they confirm that water service is restored.
- Create clear messaging around the importance, purpose, and urgency of flushing and whether or not this service was performed during LSLR (See example from Detroit in Appendix K.a. and K.c. for examples)
- Contractor should provide documentation to the resident and owner of replaced/non-LSL every time they leave any service location, in addition to all contract recordkeeping requirements.
- The specification should not allow reinstalling any automatic meter reading (AMR) type meter greater than or equal to 1” diameter if it does not meet the revised definition of “lead-free” under the RLDWA.
- Although indicated on the design drawings, it would be helpful to clearly specify the size and location of water service test pits in the water service specification because it is the accurate results of the required test pit that determine whether the service will be replaced.
- Update all standard drawings to include public health protection onsite details,

including 1) turn off water before work begins, and 2) restore water service to the house only after in-home plumbing is flushed, information is shared with the resident, and a 6-month supply of certified lead reducing filters is provided to the resident. This would appear with standard notes re: storm water control and tree protections.

- There are many inconsistencies between DC Water standards, contract descriptions, permit documents, and public outreach. DC Water should do a comprehensive review and update of all water service-related specifications, standard drawings, public notice and outreach for consistency with the recommended LFDC Plan and Standard Operating Procedures. Key issues to include or address are:
    - Turn off water before work
    - Identify and replace water service in the same working day to protect public health
    - Contractor conducts flushing procedure as described in AWWA C810-17[10]
    - Don't turn on the water until flushing is complete and contractor delivers a 6-month supply of certified lead reducing filters to the resident.
    - As described only in standard drawings, the dimensions of test pits are approximately 3' width x 5' length x 6' depth. The Water Service Specification should positively state the purpose and intention of the test pit: to reveal 2 ft of service line on either side of the curb box and again on either side of the meter pit to identify all service line materials in those pipe segments and observe any fittings that may have been installed during previous service line maintenance.
    - Specify in the contract the distance inside the house the service line must be replaced. In other communities this has been defined as to the first fixture, to the shutoff valve, or 18" inside the home. It is essential to define this requirement in water service specifications.
- Thoroughly review all outreach documents for consistency with revised specifications and SOPs. Ensure that only the current outreach documents are included in all LSLR contract documents.
- Continue to revise and improve specifications, standard drawings, and SOPs with lessons learned as program advances.

Improve Communication to Increase Participation

Communications and outreach are critical for reducing barriers and building plan support and trust from community members. All the outreach approaches described in the LFDC Plan are needed and important. These should be updated, enhanced, and multiplied as described below.

To improve communication and eliminate barriers to participation to meet the LFDC Plan goals:

1. Both the Council of the District of Columbia and DC Water should provide more transparent information about the LFDC Plan, including costs, schedules, and maps;
2. DC Water should simplify all paperwork for residents as much as possible. Opportunities include providing both online and paper forms, eliminating financing applications, cutting down complex legal jargon as much as possible, and relying on diagrams whenever appropriate. Examples from other water utilities are included in Appendix K;
3. DC Water should update all outreach materials to be easily understandable and consistent with LSLR programs and contracts;
4. DC Water and contractors should conduct outreach through multiple media formats, repeat them frequently, and widely distribute all updated LFDC materials until the last LSL is replaced;
5. DC Water and contractors should provide multiple methods for residents to ask and have questions answered, including frequent community meetings;
6. DC Water should expand neighborhood level outreach, including neighborhood liaisons from each impacted neighborhood;
7. DC Water should provide written documentation to the resident and owner of every property with a replaced or confirmed non-lead service line;
8. DC Water should revisit their Refusal List to identify when ownership changes at a property on the Refusal List and contact the new owner for replacement.

Future Strategies to Consider in Washington, DC

Benchmarking cities provided several policy strategies that the Council of the District of Columbia should consider when ramping up the LFDC Plan:

Permits and Code Enforcement

- **Denver** coordinated redevelopment with the City's permitting office to evaluate taps for lead or galvanized material. If found, a requirement was placed to bring tap up to code. The utility completes around 400 to 500 LSLR's per year through this cooperation with the city.
- **Newark** allowed blanket permit for opening permits, but details had to be provided for traffic around highway openings.

Contract administration, training and oversight

- **Newark** recommended their approach of hiring an engineering firm to provide oversight of the entire LSLR program. In Newark, their prime engineering firm then hired 3 small women and minority owned firms to help with Construction Administration of the project. These subcontractors provided oversight and coordination with community groups.
- **Newark** required all contractors and all engineering consultants to attend all community meetings with the water department director and elected officials so all questions could be answered on the spot.
- **Detroit** prepared Standard Operating Procedures that clearly state the roles of contractors and the water utility throughout the entire LSLR process and includes them in contract documents to decrease ambiguity.
- **Denver** held 4-day training sessions with contractors, consultants, field workers, and water field liaisons with meter inspections and trouble shooting. Additional training was conducted for field staff to review collecting data correctly, field work, and dealing with customers.
- **Newark** held regular coordination meetings across all contractors in multiple zones to troubleshoot challenges, address issues consistently, and share best practices.

Contract structure and timelines

- **Newark's** program changed considerably after one contractor originally had 9 months to replace 1,000 lines, but they ended up completing ALL lines in 180 days. This experience led them to give contractors requirements to complete 10, 15, or 25 services/day based on company size, not including test pits/potholing. Their timeline per contract went from 9 months to 180 days to 120 days. Their block at a time approach for replacements worked best and was most productive. At the peak of their replacement program, they were replacing 120 lines per day across the city.
- To ensure that all LSLs were replaced and there is no incentive to skip potential lead lines, they do all their potholing at the same time as LSLR. If no lead service is found, contractors charged $0.01 or $1.00 for the pothole and moved on. If a replacement had to be done, the cost of potholing was rolled up into replacement and not charged as a separate line item (same as DC Water contracts).
- To keep prices low, contracts were bid out every other day, by zone/area. This approach allowed each company to sharpen their pencil with each public bid opening, and the prices went down with each bid. Each of the bids were published for 20 days.
- The city has the right to terminate a contract for cause if contractor isn't meeting services/day requirement.
- Like Newark and Benton Harbor, consider incentives if LSLRs are replaced in advance of schedule, as long as all contract requirements are met.
- Comprehensive contract enforcement and recordkeeping are essential if incentives are to be used.

Community outreach and education

The following benchmarking cities implemented strategies to help build public trust and understanding of LSLR programs:

Newark

- Hired residents of the community to help going door to door, giving recognition and creditability to the program
- Used local community groups, non-profits, churches/religious institutions, billboards, website, and lawn signs ("I had my line replaced" or "I signed up to have my line replaced")
- Provided tablets, laptops, and paper options to collect agreement forms at community events
- Installed electronic signs/billboards in neighborhoods

Cincinnati

- Hired and trained qualified plumbers and contractors to perform the work, believing that if the plumbers understood and supported the program, they would be more willing to motivate the property owners to participate in the program
- Developed and invested in a community outreach campaign to inform the public about their program and the reasons to replace the "unseen" LSLs
- Hired a dedicated and well-trained internal team to develop a comprehensive community outreach plan and implemented the following tactics to improve team communication and efficiency:
    - Involved community ambassadors to extend new community outreach initiatives
    - Created SOPs
    - Hosted a Citizens Water Academy to educate citizens about the value of water and importance of LSLR
    - Conducted regular communications about the program on Next Door and other social media
- Involved their Executive Team, Legal, Engineering, Distribution, Water Quality, Customer Service, and the Communications Team in communications from the start, allowing all parties to have a vested interest in the process
- Worked with schools and pediatricians to help amplify positive messaging
- Accounted for and created a plan to include the hard-to reach-population understanding that not everyone is online and grassroots approaches are critical

Additional community outreach and education efforts DC Water may want to consider include:

Create a Community Ambassador program:

- Community organizers are seen as trusted messengers to encourage participation.
- Community meetings to have neighborhoods show interest and accelerate work. Visible outdoor meetings - meet people where they are.
- Use the Ambassador Program to get more consent forms returned

Implement a grass roots plan:

- Outreach
- Yard signs
- Block meetings

Develop online tools to keep residents informed before, during and after LSLR programs:

- Improve program accessibility through more information and self-serve options
- Create a dashboard information tracking program that continuously follows and posts LSLR progress within designated residences and neighborhoods
- Create videos and pictures to give customers piece of mind, improving perceptions of digging and property restoration
- Streamline customer communications by aligning universal LSLR information regardless of who performs the replacement
- Provide a checklist that clearly outlines what residents need to do before and after LSLR, and the actions for which either DC Water or the contractor are responsible.
- Provide educational materials and filter kits in bulk to participating building managers and/or leasing offices of larger multi-unit buildings, with distribution handled by the building manager when the new occupants move in.
- Ensure all outreach materials online and distributed in the community reflect the current LSLR programs; remove older documents and materials from circulation.

APPENDICES

A. Business Processes for Service Line Material Updates
B. Safe Water Engineering Clarifications to Business Processes for Service Line Material Updates
C. Weston Report
D. InfoAsset Planner LFDC Model Development Memo
E. Safe Water Engineering DC LSLR Cost Estimates
F. 20220331 LFDC Revised Cost Estimate_corrections.xlsx
G. 20220331 LFDC Revised Cost Estimate.xlsx
H. DC Water's Water Service Lines Specification
I. DC Water's Water Service Standard Detail from WaterDetails
J. DC Water Outreach Materials
    a. Managing Expectations Booklet
    b. DC Water service line replacement agreement
    c. Flushing instructions from E6-170080
K. Samples from other water utilities:
    a. Detroit post-LSLR flushing instructions
    b. Detroit Lead Service Line Replacement Handouts
    c. Newark Flushing Instructions
    d. Benton Harbor Replacement agreement form
    e. Newark Replacement agreement form
    f. Detroit LSLR SOP
    g. Benton Harbor Water service standard
    h. Model Ordinance (NRDC): Mandatory Replacement of Lead Service Lines
    i. Denver Water Lead Reduction Program Plan
    j. Denver Water Lead Reduction Program Plan Executive Summary
L. Comments from DC Water on the Draft Report
M. Response to Comments from DC Water on the Draft Report

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ATTACHMENT

A

Business Processes for Service Line Material Management

1. Data Dictionary

   a. *Service Line Inspection and Replacement, CIS Update Process Documentation, Version 9.0* (12/2/2015)

      i. Service line material types

Pipe Material Description	**Data Option Start Date**
BRASS – All Brass	Historic
COPPER – All Copper	Historic
GALVANIZED All Galvanized	Historic
LEAD – Lead (Any Segment)	Historic
NONLEAD – Non-Lead (Combination)	Historic
CASTIRON – All Cast iron	Historic
DUCTILE – All Ductile iron	Historic
NLD - not lead based on date of installation of the TAP/service Line.	Historic
GALV_BRASS Mix: Galvanized Iron and Brass	September 2019
GALV_CU Mix: Galvanized Iron and Copper	September 2019
LEAD_BRASS Mix: Lead and Brass	September 2019
LEAD_CU Mix: Lead and Copper	September 2019
LEAD_GALV Mix: Lead and Galvanized Iron	September 2019
LEAD_PLAST Mix: Lead and Plastic	September 2019
PLAST_BRAS Mix: Plastic and Brass	September 2019
PLASTIC Any plastic material (PVC, CPVC, black)	September 2019
BRASS_CU Mix: Brass and Copper	March 2021
GI_Lead Galvanized Iron pipe with lead (lead is or was upstream of existing galvanized iron pipe)	March 2021
GI_Lead_Bras Mix: Brass and Galvanized Iron pipe with lead (lead is or was upstream of existing galvanized iron pipe)	March 2021
GI_Lead_Cu Mix: Copper and Galvanized Iron pipe with lead (lead is or was upstream of existing galvanized iron pipe)	March 2021

      ii. Source of data for service line material types

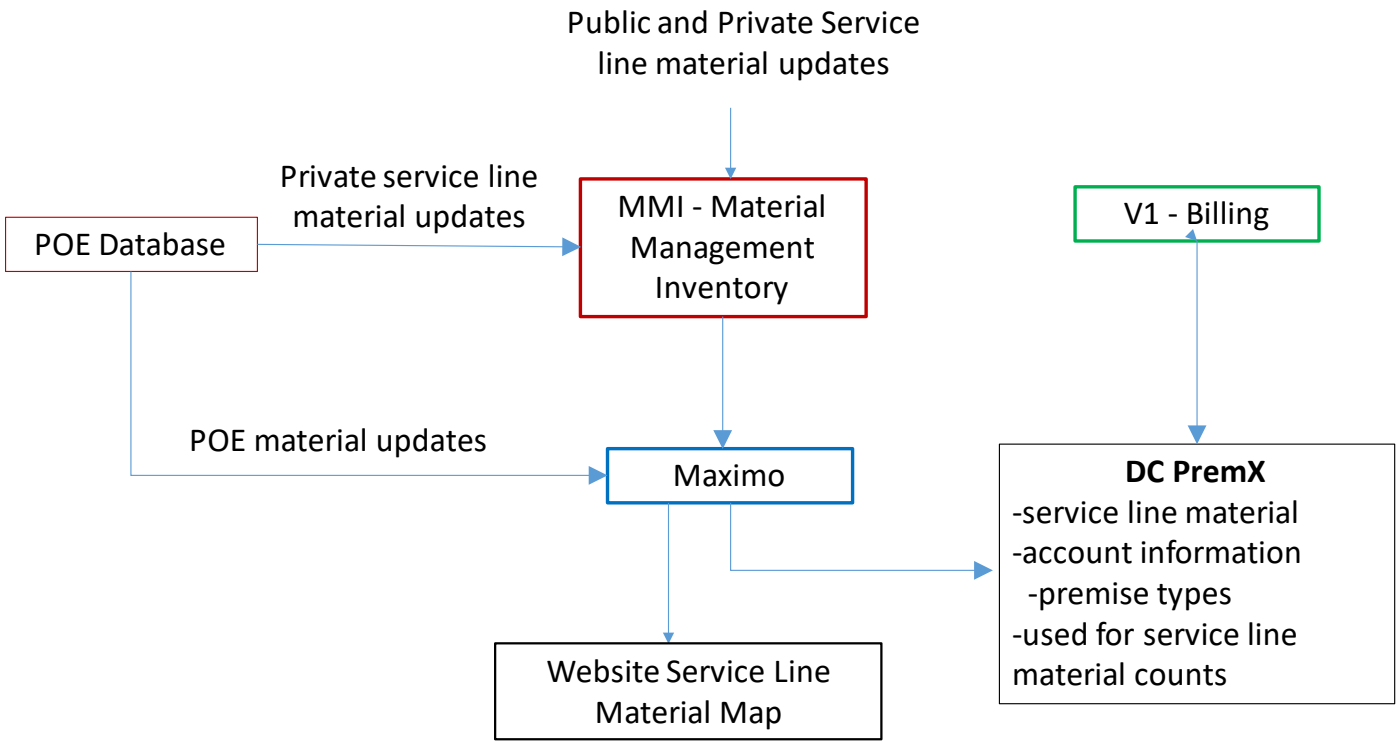
Historic Types
REP - from service line replacement field reports.
INS - one end of a public segment was observed or both ends of a private segment are observed.
OBS - one end of the private side has been observed by DETS, DWS, DSS, or their contractors.
TAP – a new tap has been installed and/or the service line has been abandoned.
LAB - Lab testing performed.
CUS – the customer reports the private side was replaced.
EPA – data from the Weston Report.
CIS – original TAP cards.
AMR – provided by United Metering from initial AMR conversion.
NLS - not lead based on size of service line.
UNK– the source of information is unknown
PRM – Permits
ASB – As Built
Added September 2019

POE - Point of Entry
POE_PUB - Estimated from POE and Public
POE_REP - Estimated from POE & LSR
PUB_REP - Estimated from past LSR
PUB_INS – Estimated from inspection on public side
WQ – Estimated from WQ testing
Added after Sept 2019
MET – Meter inventory of >=3" meter size
GIS – Estimated from GIS water main installation date
PRMDOC – Permit Documents
YB – Year Home was Built (DC Property Tax Database).

b. Point-of-entry (POE)
    i. Pipe breaking through the wall or floor into the building. Plumbing code requires one pipe between connections so the pipe material should be the same from the house to the first connection in the yard, either the meter or the property line if a curb-stop was installed.

2. Databases
    a. CIS – Customer Information System which contains all billing and customer account data was used from 1980 to 2018.
        i. Rick Paisely maintained tracking log until service line material data was fully transferred to Maximo in 2018. The upload files were saved in I:\WASAWIDE\Customer Service Lead Tracking\EPA Lead Service Tracking\Inspection and Replacement Update Files

    b. V1 – Replaced CIS in 2018
    c. MMI – Materials Management Inventory Access DB; stores service line construction activities including pipe materials, segments, and length of pipe replaced.
        i. Tracking database created in 2004 and updated to MMI in 2006
        ii. Maintained by Michael Walsh
        iii. Data sent from MMI to Maximo monthly
    d. POE Access Database – records all customers' pictures and reports of POE material.
        i. Created in 2016
        ii. Maintained by WQ&T
    e. Maximo – the repository for all service line material types and the source of data as of 2019, following the transition of CIS to V1.
    f. DC Water's Service Line Map – website that displays the Maximo data with "description" translations for the source of data. Maintained by IT.
    g. Current data flow:


Public and Private Service line material updates
Private service line material updates
POE Database
MMI - Material Management Inventory
V1 - Billing
POE material updates
Maximo
DC PremX
-service line material
-account information
-premise types
-used for service line material counts
Website Service Line Material Map

3. Updates to MMI
    a. See LSR Workflow chart for details of data input flow.
    b. Service line replacements conducted through DETS water main replacements
        i. Include pipe material viewed when test-pits are dug and existing pipe is visible
        ii. Record pipe material for and length of each segment replaced
            1. Water main to meter
            2. Meter to Property Line
            3. Property Line to House
        iii. Record date of test-pits and pipe replacements (separate records if conducted in different days)
        iv. Record if a meter (and meter number, if available) or jumper was installed. Also, include any other relevant information to be captured and stored in the 'Comments' field.
    c. Service line replacements conducted by DWS and DSS during emergency repair work
        i. Record pipe material for visible sections
        ii. Record length and section replaced
        iii. Record if a meter (and meter number, if available) or jumper was installed. Also, include any other relevant information to be captured and stored (i.e., 'Comments').
    d. Private side material updates obtained via customers' reports
        i. Documentation must be from a plumber or contractor and indicate the section of pipe replaced.
        ii. Homes where DC Water replaced service lines in the 2003-2007 time period and the customer provides documentation of the work or payment to a DC Water contractor is acceptable.
    e. Other projects that record POE when DC Water is inside home
        i. Pressure Reducing Valve (PRV) installations for 4th High and Anacostia pressure zone improvement projects
4. Updates to Maximo
    a. Michael Walsh sends monthly updates from MMI to Maximo
    b. POE data from WQ&T - began asking residents to submit POE information in 2016.
        i. Business Processes for POE Recording (detailed in separate document).
            1. Record all submissions, determine if report (most often pictures) is valid.
            2. Valid pipe material reports are entered in Maximo, POE data field.
            3. Pipe material is extended to private side per rules detailed in POE Business Process.
                a. Valid lead reports will replace existing private side materials (field visits required if existing data is from construction reports). If public side will be changed to "Lead" also if there are no excavation records (REP or INS).
                b. Valid non-lead will populate Null private side
                c. Valid non-lead will not override existing Lead.
        ii. Batch data sent to IT for upload
        iii. Can enter individual POE data into the Maximo Asset screen
    c. New Taps
        i. Approximately October, 2017 Customer Service began recording Public and Private Sides pipe materials as "NLD" and the Origin Source as "PRM" when creating new premises.
        ii. Permits sends a Meter Set Request to Customer Service. WQ&T will update the premise with the service line material data (began July 2020).
            1. Public side material – copper for service lines < 3 inches; ductile iron for service lines 3 inches and greater
            2. Private side – include material if provided in the documentation (drawing sometimes specify the pipe material); otherwise enter "Nonlead".
            3. Material Origin Source - TAP
            4. Public side replacement date – enter the date the Meter Set Request email was sent.
            5. Private side replacement date – do not enter a date.

5. Past Data Cleaning Efforts
    a. 2016 – changes to public and private pipe material and sources of data for publishing Service Line Material Map.

Data Review and Changes to CIS (4/28 - 5/9/16)

1. All public and private service types "CASTIRON" and "DUCTILE" removed for services 2" and less (no pipe material data = "Unknown" category).
    a. Spot check of MMI showed the connections are larger than 2". Will leave all INS material types as currently recorded as they are likely correct as a non-lead material (might not be cast iron, but not lead).
        i. Some RES premises had CASTIRON with CIS as source—removed data (i.e., changed to Unknown). A few had higher lead results in 2003, so cannot assume it should be galvanized iron.
        ii. Private portion, with castiron, changed most to galvanized iron if notes in MMI indicated service between ¾" to 1.5"
2. Public Origin Source=CIS and Public Service Type ="NLD"
    a. Use for tap dates >=1983
    b. Remove Public Service Type and Origin Source for those with tap dates <1983
3. Review Public and Private Service Types of "NLS" to ensure service size is >2" and no typos in service size (ex. 34).
4. Review the Public Service Type "Brass" and Source "INS" to determine if logical.

6. September 2019 Data Cleaning
    a. OIG recommended reducing the number of unknown service line materials. In response, DC Water copied the historic (i.e., non-construction) records from the public side to the private side where the public side had data and private side was null
    b. Data Criteria
        i. Data sources = CIS, EPA, AMR, TAP, INS, OBS
        ii. Premise status = "AC" or "VC"
        iii. Pipe materials not restricted, included: Lead, Copper, Brass, Galvanized, NLD, and NLS
    c. The "Private Origin Source" was copied from the "Public Origin Source", except for INS and OBS.
        i. INS changed to "PUB_INS", described as "estimated from public side inspection"
    d. Public side LSRs and Private side Null
        i. Extended lead pipe material to private side if test pits show lead on public side (following logic that one pipe material was originally installed so *full* service was lead).
        ii. The MMI database criteria for the update are in order of execution and should be used for future occurrences:
            1) *TPPrivatetoBldg* Field filled-in for an address, copy pipe material to Private Side and Private Origin Source is INS.
            2) *POE* field filled-in for an address if the pipe material is LEAD.
            3) If the material-type *TPMetertoPrivate* Field filled-in for an address, update the Private side with pipe material and record the Origin Source as PUB_REP.
            4) If the material-type *TPMaintoMeter* Field filled-in for an address, update the Private side with pipe material and record the Origin Source as PUB_REP.
            5) If the *LSRJV_FY* Field had a value, it was used to add the appropriate material-type to the address (e.g., ***FY*** = 'Lead')
    e. POE reports from 4th High PRV Project.

i. Data were recorded in MMI as "INS" and should be "POE". Removed all non-lead Private side data from Maximo. Followed SOPs for POE data used to update Private Side.

7. 2020 Unknown Verification
   a. Review permit records for service line material information, build dates, and other information that demonstrate either the service line material or that the service line was installed after 1980, the latest known date of a lead service line installed in the District (1991 Weston Report[1]).
   b. Data hierarchy

Credibility	Information	Pipe Material	Source of Data
High	As-builts indicate service line pipe material	[pipe material]	ASB
	As-builts indicate service line installation ≥1983	NLD	ASB
	Documents submitted for permit approval	[pipe material]	PRMDOC
	Documents submitted for permit approval indicate service installation ≥1983	NLD	PRMDOC
	Year home was built and date water service was initiated ≥1983	NLD	YB
Low	GIS shows water main installation of ≥1983 -replacement mains must be further analyzed to ensure services were not reconnected	NLD	GIS

The Public and Private Origin Source should be the source of information with the highest credibility in the above table. For example, if as-builts and GIS support a 1992 build/installation date, then use the ASB code.

   c. Replacement Date / Inspection Date – Enter installation date in "replacement date" field. If date unknown, do not enter any data.

2021 Unknown Analyses and Fill-in

1) Clusters of Unknowns
   a) Find As-builts or Permit Documents to verify water service line installation or water main installation (with new full service lines)
      i) Update service line -- Record address, service line copper for < 3" services, and Public and Private Source Origin as "ASB" or "PRMDOC"
   b) Use GIS water main installation dates to identify water mains installed after 1980.
      i) Research to ensure water services were not reconnected to the new main
         (1) Home build dates of entire block, past Engineering documents
      ii) Update service line – Public Origin Source is "GIS"
2) Tap records
   a) New tap record address with comparable Home build date
      i) Update service line -- Record address, service line copper for < 3" services, and Public and Private Source Origin as "TAP"
   b) New tap record address without comparable Home build date
      i) Review Maximo work order – Permit Dept sometimes uses an old address or simply a nearby address for a new house/development so the address does not match. The Description field and Remarks may have

[1] Figure 4-9 of the Weston Report shows the installation years of lead service lines. The installation declined to less than 5 per year in 1948. Sporadic installations continued until 1977.

different addresses recorded, most have actual measurements for tap location to identify the correct house for the tap.

ii) Look at Google Maps to see if the house address looks new.

iii) Verify a meter is installed and reading (Starr website)

(1) Sometimes the house looks occupied and no meter reading – send these to Tarsha. Developers might not follow process and the service line still has a jumper.

3) Year Build Data and Premise Creation Date

a) Customer service recorded the date a new premise was created between 2008 and Nov, 2017 (conversion to V1 in 2017 produced new procedures which did not continue populating this field). Some premises have dates between 1979 and 2007, however, Rick Paisely does not know how those data were populated. Therefore, Premise Creation dates with year 2008 or later will be used to populate data.

b) The DC Read Property Database lists the year a house was built. This data is also recognized to have some errors.

c) DC Water will update a premise service line material to "Nonlead" with Source Code of "YB" if:

i) The Year Build data is 1983 or later AND the Premise Creation date is $\geq$2008 or NULL and the address does not have an older inactive premise (this could indicate the house was rebuilt on the lot; it is possible the developer or owner connected to the existing water service line instead of installing a new one).

ii) The Year Build data is 1983 or later and Premise Creation date is less between 1979 and 2007:

(1) Customer confirms year build date

(2) POE is Copper or PVC/Plastic

(3) Google Maps view or field visit conducted to ensure the house appearance agrees with likelihood of the dates

iii) The Year Build data is 1983 or later and connection to private development is dated 1983 or later.

Removed "NLD" and "CIS" data (1/26/2022)

A premise with "NLD" as pipe material and source code "CIS" was identified to have Lead pipe, prompting the review of all premises with NLD-CIS data. Removed pipe material data from 55 premises.

ATTACHMENT

B

SWE Clarifications to DC Water's Business Processes for Service Line Material Updates

Below are a short and detailed summary of DC Waters "Business Process for Service Line Material Updates" document. This document details the creation and adjustments to DC Water's service line material databases from 1980 to 2022. Both the short and detailed summaries chronologically order DC Waters Business Processes Updates for ease of understanding. All the language in the detailed summary is taken directly, but reorganized, from the DC Water Business Process document.

Short Summary

1980:

CIS – Customer Information System Created

1990:

Weston Report (Categorizes all service lines)

2004:

Start Tracking Construction Activities

2006:

MMI (Materials Management Inventory Access) Takes over construction tracking activities

2015:

Categorized Historic Data and Types of Materials

2016:

-POE Access Data Base created– records all customers' pictures and reports of POE material
-Cleaned CIS by making sure that and TAP date above 1983 was labeled not lead

2018: CIS replaced by V1

2019 :

-Maximo Created
-All Data brought together
-Updated MMI field processes to make sure pipe material was getting recorded accurately

-POE Public Pipe material is extended to private side per rules detailed in POE Business Process.

a. Valid lead reports will replace existing private side materials (field visits required if existing data is from construction reports). If public side will be changed to "Lead" also if there are no excavation records.
b. Valid non-lead will populate Null private side
c. Valid non-lead will not override existing Lead.

- New taps entered as non-lead

- DC Water copied the historic (i.e., non-construction) records from the public side to the private side where the public side had data and private side was null

2020:

- Review permit records for service line material information, build dates, and other information that demonstrate either the service line material or that the service line was installed after 1980, the latest known date of a lead service line installed in the District (1991 Weston Report[1]).

2021:

-In areas with many unknowns search for permit documents and "as-builts" to determine year mains were installed, also update TAP records when records match.

-If a new premise was built before 2008 on a parcel whose original house was built after 1983

(1) Customer confirms year build date

(2) POE is Copper or PVC/Plastic
(3) Google Maps view or field visit conducted to ensure the house appearance agrees with likelihood of the dates

2022:

Removed "NLD" *(not lead based on date of installation of the TAP/service Line) and* "CIS" data (1/26/2022)

A premise with "NLD" as pipe material and source code "CIS" was identified to have Lead pipe, prompting the review of all premises with NLD-CIS data. Removed pipe material data from 55 premises.

Detailed Summary

1980: CIS – Customer Information System Created

1990: Weston Report (Categorizes all service lines

2004: Start Tracking Construction Activities

2006: MMI (Materials Management Inventory Access) Takes over construction tracking activities

2015: Entered Historic Data and Types

Pipe Material Description	**Data Option Start Date**
BRASS – All Brass	Historic
COPPER – All Copper	Historic
GALVANIZED All Galvanized	Historic
LEAD – Lead (Any Segment)	Historic
NONLEAD – Non-Lead (Combination)	Historic
CASTIRON – All Cast iron	Historic
DUCTILE – All Ductile iron	Historic
NLD - not lead based on date of installation of the TAP/service Line.	Historic

Historic Types -

REP - from service line replacement field reports.
INS - one end of a public segment was observed or both ends of a private segment are observed.
OBS - one end of the private side has been observed by DETS, DWS, DSS, or their contractors.
TAP – a new tap has been installed and/or the service line has been abandoned.
LAB - Lab testing performed.
CUS – the customer reports the private side was replaced.
EPA – data from the Weston Report.
CIS – original TAP cards.
AMR – provided by United Metering from initial AMR conversion.
NLS - not lead based on size of service line.
UNK– the source of information is unknown
PRM – Permits
ASB – As Built

2016:

1. POE Access Data Base created – records all customers' pictures and reports of POE material
2. Cleaned CIS

    1. All public and private service types "CASTIRON" and "DUCTILE" removed for services 2" and less (no pipe material data = "Unknown" category).
        a. Spot check of MMI showed the connections are larger than 2". Will leave all INS *(one end of a public segment was observed or both ends of a private segment are observed.)* material types as currently recorded as they

are likely correct as a non-lead material (might not be cast iron, but not lead).

i. Some RES premises had CASTIRON with CIS as source—removed data (i.e., changed to Unknown). A few had higher lead results in 2003, so cannot assume it should be galvanized iron.

ii. Private portion, with castiron, changed most to galvanized iron if notes in MMI indicated service between ¾" to 1.5"

2. Public Origin Source=CIS and Public Service Type ="NLD" *(not lead based on date of installation of the TAP/service Line.)*
   a. Use for tap dates >=1983
   b. Remove Public Service Type and Origin Source for those with tap dates <1983 (there were places the 1983 rule was improperly applied and they corrected it - would be great to report n for each of these corrections)
3. Review Public and Private Service Types of "NLS" *(not lead based on size of service line.)* to ensure service size is >2" and no typos in service size (ex. 34).
4. Review the Public Service Type "Brass" and Source "INS"*(one end of a public segment was observed or both ends of a private segment are observed.)* to determine if logical.

2018: CIS replaced by V1

2019:

1. Maximo Created
2. New Data are brought together

Pipe Material Description	
GALV_BRASS	Mix: Galvanized Iron and Brass
GALV_CU	Mix: Galvanized Iron and Copper
LEAD_BRASS	Mix: Lead and Brass
LEAD_CU	Mix: Lead and Copper

Pipe Material Description	
LEAD_GALV	Mix: Lead and Galvanized Iron
LEAD_PLAST	Mix: Lead and Plastic
PLAST_BRAS	Mix: Plastic and Brass
PLASTIC	Any plastic material (PVC, CPVC, black)

Data Types
POE - Point of Entry
POE_PUB - Estimated from POE and Public
POE_REP - Estimated from POE & LSR
PUB_REP - Estimated from past LSR
PUB_INS – Estimated from inspection on public side
WQ – Estimated from WQ testing

Updates to MMI

a. See LSR Workflow chart for details of data input flow.

b. Service line replacements conducted through DETS water main replacements

i. Include pipe material viewed when test-pits are dug and existing pipe is visible

ii. Record pipe material for and length of each segment replaced

1. Water main to meter
2. Meter to Property Line

3. Property Line to House

iii. Record date of test-pits and pipe replacements (separate records if conducted in different days)

iv. Record if a meter (and meter number, if available) or jumper was installed. Also, include any other relevant information to be captured and stored in the 'Comments' field.

c. Service line replacements conducted by DWS and DSS during emergency repair work

i. Record pipe material for visible sections

ii. Record length and section replaced

iii. Record if a meter (and meter number, if available) or jumper was installed. Also, include any other relevant information to be captured and stored (i.e., 'Comments').

d. Private side material updates obtained via customers' reports

i. Documentation must be from a plumber or contractor and indicate the section of pipe replaced.

ii. Homes where DC Water replaced service lines in the 2003-2007 time period and the customer provides documentation of the work or payment to a DC Water contractor is acceptable.

e. Other projects that record POE when DC Water is inside home

i. Pressure Reducing Valve (PRV) installations for 4th High and Anacostia pressure zone improvement projects

2. Updates to Maximo

a. Michael Walsh sends monthly updates from MMI to Maximo

b. POE data from WQ&T - began asking residents to submit POE information in 2016.

i. Business Processes for POE Recording (detailed in separate document).

1. Record all submissions, determine if report (most often pictures) is valid.

2. Valid pipe material reports are entered in Maximo, POE data field.

3. Pipe material is extended to private side per rules detailed in POE Business Process.

a. Valid lead reports will replace existing private side materials (field visits required if existing data is from construction reports). If public side will be changed to "Lead" also if there are no excavation records (REP or INS).

b. Valid non-lead will populate Null private side

c. Valid non-lead will not override existing Lead.

ii. Batch data sent to IT for upload

iii. Can enter individual POE data into the Maximo Asset screen

c. New Taps

i. Approximately October, 2017 Customer Service began recording Public and Private Sides pipe materials as "NLD"(*not lead based on date of installation of the TAP/service Line.*) and the Origin Source as "PRM" *(Permits)* when creating new premises.

ii. Permits sends a Meter Set Request to Customer Service. WQ&T will update the premise with the service line material data (began July 2020).

1. Public side material – copper for service lines < 3 inches; ductile iron for service lines 3 inches and greater
2. Private side – include material if provided in the documentation (drawing sometimes specify the pipe material); otherwise enter "Nonlead".
3. Material Origin Source - TAP
4. Public side replacement date – enter the date the Meter Set Request email was sent.
5. Private side replacement date – do not enter a date.

1. September 2019 Data Cleaning (possibly useful references GAO)

a. OIG recommended reducing the number of unknown service line materials. In response, DC Water copied the historic (i.e., non-construction) records from the public side to the private side where the public side had data and private side was null

b. Data Criteria

i. Data sources = CIS, EPA, AMR, TAP, INS, OBS

ii. Premise status = "AC" or "VC"

iii. Pipe materials not restricted, included: Lead, Copper, Brass, Galvanized, NLD (*not lead based on date of installation of the TAP/service Line.)*, and NLS (*not lead based on size of service line.*)

c. The "Private Origin Source" was copied from the "Public Origin Source", except for INS (*one end of a public segment was observed or both ends of a private segment are observed.*) and OBS *(one end of the private side has been observed by DETS, DWS, DSS, or their contractors.)*.

i. INS changed to "PUB_INS", described as "estimated from public side inspection"

d. Public side LSRs and Private side Null

i. Extended lead pipe material to private side if test pits show lead on public side (following logic that one pipe material was originally installed so *full* service was lead).

ii. The MMI database criteria for the update are in order of execution and should be used for future occurrences:

1) *TPPrivatetoBldg* Field filled-in for an address, copy pipe material to Private Side and Private Origin Source is INS.
2) *POE* field filled-in for an address if the pipe material is LEAD.

3) If the material-type *TPMetertoPrivate* Field filled-in for an address, update the Private side with pipe material and record the Origin Source as PUB_REP.

4) If the material-type *TPMaintoMeter* Field filled-in for an address, update the Private side with pipe material and record the Origin Source as PUB_REP.

5) If the *LSRJV_FY* Field had a value, it was used to add the appropriate material-type to the address (e.g., ***FY*** = 'Lead')

e. POE reports from 4th High PRV Project.

Data were recorded in MMI as "INS" and should be "POE". Removed all non-lead Private side data from Maximo. Followed SOPs for POE data used to update Private Side.

2020:

Data Types
MET – Meter inventory of >=3" meter size
GIS – Estimated from GIS water main installation date
PRMDOC – Permit Documents
YB – Year Home was Built (DC Property Tax Database).

1. 2020 Unknown Verification

   a. Review permit records for service line material information, build dates, and other information that demonstrate either the service line material or that the service line was installed after 1980, the latest known date of a lead service line installed in the District (1991 Weston Report[1]).

   b. Data hierarchy

Credibility	Information	Pipe Material	Source of Data
High	As-builts indicate service line pipe material	[pipe material]	ASB
	As-builts indicate service line installation ≥1983	NLD	ASB
	Documents submitted for permit approval	[pipe material]	PRMDOC
	Documents submitted for permit approval indicate service installation ≥1983	NLD	PRMDOC
	Year home was built and date water service was initiated ≥1983	NLD	YB
Low	GIS shows water main installation of ≥1983 -replacement mains must be further analyzed to ensure services were not reconnected	NLD	GIS

The Public and Private Origin Source should be the source of information with the highest credibility in the above table. For example, if as-builts and GIS support a 1992 build/installation date, then use the ASB code.

c. Replacement Date / Inspection Date – Enter installation date in "replacement date" field. If date unknown, do not enter any data.

2021:

Pipe Material Description
GI_Lead Galvanized Iron pipe with lead (lead is or was upstream of existing galvanized iron pipe)
GI_Lead_Bras Mix: Brass and Galvanized Iron pipe with lead (lead is or was upstream of existing galvanized iron pipe)
GI_Lead_Cu Mix: Copper and Galvanized Iron pipe with lead (lead is or was upstream of existing galvanized iron pipe)

2021 Unknown Analyses and Fill-in

1) Clusters of Unknowns
   a) Find As-builts or Permit Documents to verify water service line installation or water main installation (with new full service lines)
      i) Update service line -- Record address, service line copper for < 3" services, and Public and Private Source Origin as "ASB" or "PRMDOC"
   b) Use GIS water main installation dates to identify water mains installed after 1980.
      i) Research to ensure water services were not reconnected to the new main
         (1) Home build dates of entire block, past Engineering documents
      ii) Update service line – Public Origin Source is "GIS"
2) Tap records
   a) New tap record address with comparable Home build date
      i) Update service line -- Record address, service line copper for < 3" services, and Public and Private Source Origin as "TAP"
   b) New tap record address without comparable Home build date
      i) Review Maximo work order – Permit Dept sometimes uses an old address or simply a nearby address for a new house/development so the address does not match. The Description field and Remarks may have different addresses recorded, most have actual measurements for tap location to identify the correct house for the tap.
      ii) Look at Google Maps to see if the house address looks new.
      iii) Verify a meter is installed and reading (Starr website)
         (1) Sometimes the house looks occupied and no meter reading – send these to Tarsha. Developers might not follow process and the service line still has a jumper.
3) Year Build Data and Premise Creation Date

a) Customer service recorded the date a new premise was created between 2008 and Nov, 2017 (conversion to V1 in 2017 produced new procedures which did not continue populating this field). Some premises have dates between 1979 and 2007, however, Rick Paisely does not know how those data were populated. Therefore, Premise Creation dates with year 2008 or later will be used to populate data.

b) The DC Read Property Database lists the year a house was built. This data is also recognized to have some errors.

c) DC Water will update a premise service line material to "Nonlead" with Source Code of "YB" if:

i) The Year Build data is 1983 or later AND the Premise Creation date is ≥2008 or NULL and the address does not have an older inactive premise (this could indicate the house was rebuilt on the lot; it is possible the developer or owner connected to the existing water service line instead of installing a new one).

ii) The Year Build data is 1983 or later and Premise Creation date is less between 1979 and 2007:

(1) Customer confirms year build date

(2) POE is Copper or PVC/Plastic

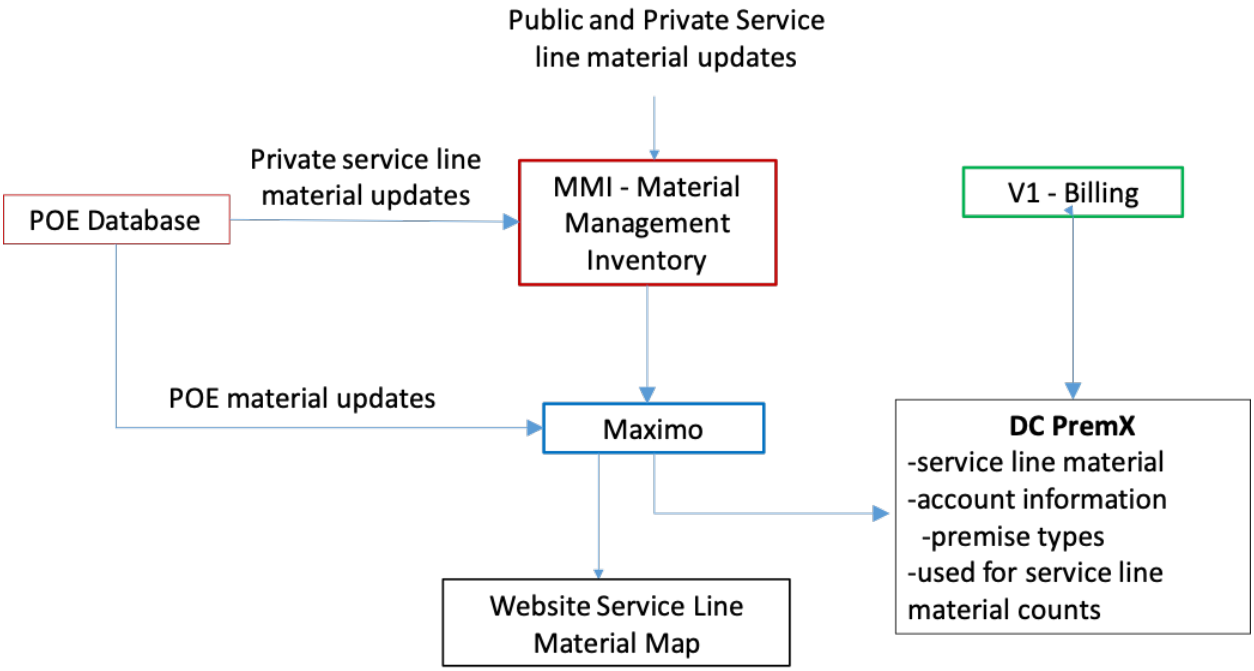
(3) Google Maps view or field visit conducted to ensure the house appearance agrees with likelihood of the dates

iii) The Year Build data is 1983 or later and connection to private development is dated 1983 or later.

2022:

Removed "NLD" *(not lead based on date of installation of the TAP/service Line) and* "CIS" data (1/26/2022)

A premise with "NLD" as pipe material and source code "CIS" was identified to have Lead pipe, prompting the review of all premises with NLD-CIS data. Removed pipe material data from 55 premises.


Public and Private Service line material updates
Private service line material updates
POE Database
MMI - Material Management Inventory
V1 - Billing
POE material updates
Maximo
DC PremX
-service line material
-account information
-premise types
-used for service line material counts
Website Service Line Material Map

ATTACHMENT

C

Ali Sabri

BK Lead 18

Government of the District of Columbia
Department of Public Works
Water and Sewer Utility Administration
Washington, D.C.

LEAD IN WATER STUDY

AUGUST 1990

WESTON MANAGERS DESIGNERS/CONSULTANTS In Association with Delon Hampton and Associates

LEAD IN WATER STUDY

August 1990

Prepared for:

Government of the District of Columbia
Department of Public Works
Water and Sewer Utility Administration
Washington, D.C.

Prepared by:

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31 August 1990

Mr. William Garlow
Acting Chief, Design and Engineering Division
Water and Sewer Utility Administration
Department of Public Works
The District of Columbia
5000 Overlook Avenue, SW
Washington, DC 20032-5397

Subject: Lead in Water Study

Dear Mr. Garlow:

As per our agreement of March 1989 we submit herewith a final report on the Lead in Water Study for the District of Columbia.

In this study we have identified the probable sources of lead in the drinking water system of the District, the extent of the lead service lines in the District, alternatives for reducing the levels of lead at the customers' water faucets, and financial impacts on the district. A database management system for residential service lines has also been developed. A set of findings and recommendations is included in the report. Information presented in this report will form the basis for developing a lead in drinking water reduction strategy for the District.

We have appreciated the opportunity to work with you, your staff, and the other staff in the District.

Respectfully submitted,

ROY F. WESTON, P.E., P.C.

Arun K. Deb

Arun K. Deb, Ph.D., P.E.
Vice President

enclosures as stated

WESTON

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EXECUTIVE SUMMARY

INTRODUCTION

It has been demonstrated by research that there are adverse health effects of high lead levels in humans. Lead toxicity can be especially detrimental to infants, children, and pregnant women. One route of intake of lead in the human body is through drinking water. The current U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) for lead is 50 micrograms per liter (ug/L) of drinking water. EPA is now in the process of revising the National Primary Drinking Water Regulations for lead in drinking water. Most of the lead enters into water from the District of Columbia- (District-) and homeowner-owned lead service lines and from lead solders and brass water faucets in house plumbing systems. Recent Federal legislation has banned the use of lead and lead-bearing material for all drinking water plumbing use.

After discovery of elevated lead levels in first flush water samples from some residences in Washington, D.C., the District retained Roy F. Weston, P.E., P.C., in March 1989 to conduct a study to determine the probable sources of lead in the drinking water system, the extent of lead service lines in the District, and alternatives for reducing the levels of lead at customers' water faucets.

PROJECT DESCRIPTION

The District maintains a record of more than 126,000 service line installations dating back to the beginning of this century. This information was converted from its paper format to a computerized database. This allowed for an analysis of the distribution of lead service lines by age and location throughout the District. The analysis showed that lead service line installations peaked during the late 1920s and early 1930s, then dropped off almost entirely. The use of lead service lines jumped again during the period of World War II when materials such as copper were in short supply.

In many cases, however, the service line material was not indicated in the records. Thus, a methodology was developed to predict whether a particular address possessed a lead service line based upon the location of the address and the year in which the service line was installed. Using this methodology there are approximately 28,000 actual and probable lead service lines remaining in the District.

The U.S. Army Corps of Engineers is responsible for providing treated drinking water to the District. The District maintains responsibility for distributing the water to homeowners. Water quality sampling in the distribution system for lead and other water quality parameters is performed regularly by the Corps of Engineers. Both the raw (untreated) water and the treated water

contain very low levels of lead, typically less than 5 ug/L or 5 parts per billion. Specific water quality characteristics (chiefly pH, temperature, and alkalinity), as well as the age and condition of the service line, will govern whether lead will leach from the lead service line. An analysis of water quality data indicated that the water supply in the District is mildly corrosive.

Water quality samples also were taken from the kitchen faucets of more than 2,400 homes by the District and the consultant as a part of this study. The results of these analyses indicate that lead concentrations at the faucet are not always attributable to the presence of lead service lines. The factors contributing to high lead concentrations at the customer's faucet are:

- Lead leaching from brass faucets.
- Lead-based solders.
- District- and homeowner-owned lead service lines and connections.

The following steps are suggested to reduce the amount of lead ingested from water at the homeowner's faucet:

- Provide public education to consumers on simple ways to reduce lead intake through drinking water. These include using only the cold water faucet for cooking and drinking purposes, and flushing of water from the faucet prior to use.
- Continue to replace lead service lines throughout the District. The highest priority should be given to replacing those lead service lines that have been shown through water quality sampling to cause high lead levels at the faucet.
- Encourage homeowners to replace their portion of the lead service line.
- Modify the treatment process at the water treatment plants to reduce the corrosiveness of the water and thus reduce the amount of lead that leaches into the water from household plumbing systems.

FINDINGS

The following are the important findings in this study:

- The sources of lead in customers' water are brass faucets, lead-based solders, and District- and homeowner-owned lead service lines and connections.
- Potable water in the District is mildly corrosive.

- At present there are 8,271 Known Lead Service Lines and approximately 19,890 Probable Lead Service Lines in the District's water distribution system.

- Lead concentrations in water in the distribution system are typically less than 5 ug/L.

- Approximately 2,900 houses with Known Lead Service Lines or Probable Lead Service Lines have been identified to have lead concentrations of more than 20 ug/L.

RECOMMENDATIONS

The following recommendations are made:

- A public education program as outlined in the report should be developed to alert homeowners to the possible effects of lead ingestion in general, and to instruct them in specific ways to reduce their exposure. A comprehensive program addressing both lead paint and lead in drinking water would be more effective than approaching each issue individually.

- The District should continue to replace its portion of lead service lines, while encouraging homeowners to replace theirs as well.

- The replacement priority developed in this study should be followed, and the lead service lines at addresses in Replacement Categories 4 and 3 (a total of 2,898 service lines of high priority) should be replaced over a 2-year time frame at an estimated cost of $8,375,220.

- The District should conduct additional water sampling of water at the faucets in homes identified as having lead service lines to identify those lead service lines that are contributing to high lead levels at the faucet. This will provide a means to prioritize lead service line replacements after completing replacements of service lines in Replacement Categories 4 and 3.

- Additional sampling data and lead in blood data should be integrated into the database management system and used to revise the lead service line replacement priority developed in this study.

- Treatment processes at the water treatment plants should be modified to increase the pH of water above 8.0.

- The District should consider appropriate legislation requiring total lead service line replacement by homeowners as part of all real estate transfers.

PROJECT OVERVIEW

INTRODUCTION

It has been demonstrated by research that there are adverse health effects of high lead levels in humans. Lead toxicity can be especially detrimental to infants, children, and pregnant women. One route of intake of lead in the human body is through drinking water. The current maximum contaminant level (MCL) for lead is 50 micrograms per liter (ug/L) of drinking water. The U.S. Environmental Protection Agency (EPA) is in the process of revising National Primary Drinking Water Regulations for lead in drinking water. Most of the lead enters into water from lead service lines and from lead solders and brass fixtures in house plumbing systems. Recent Federal legislation has banned the use of lead and lead-bearing material for all drinking water plumbing use.

The District of Columbia (District) has a considerable number of lead service lines. After discovery of elevated lead levels in first flush water samples from some residences in Washington, D.C., the Director of the District's Department of Public Works, John E. Touchstone, putting the city in the vanguard of cities addressing lead in water problems, directed Roy F. Weston, P.E., P.C., in March 1989 to conduct an extensive study to determine the probable sources of lead in the drinking water system, the extent of lead service lines in the District, and alternatives for reducing the levels of lead at the customers' taps.

DATABASE MANAGEMENT SYSTEM

The District does not have a complete record of the materials of service lines. In order to determine the extent of lead service lines, a database was compiled from several sources within the District containing information on service line material, date of installation, and water quality measurements by address. The database was set up on IBM-compatible personal computers using dBASE IV software. Data were obtained from the following data files and combined into a single database from which an estimate of the distribution of lead service lines was obtained:

- Tap File
- Meter File
- Maintenance File
- Planning Commission File
- Lead Service Replacement Program File
- Meter Relocation Program File
- Street Replacement Program File
- Project Locator Data File
- Permit Ledger Program File
- Corps of Engineers File

The Tap File, considered as the primary data for all water service lines in the District, was used in interaction with other data files. Figure 1 shows the schematic interaction of various data

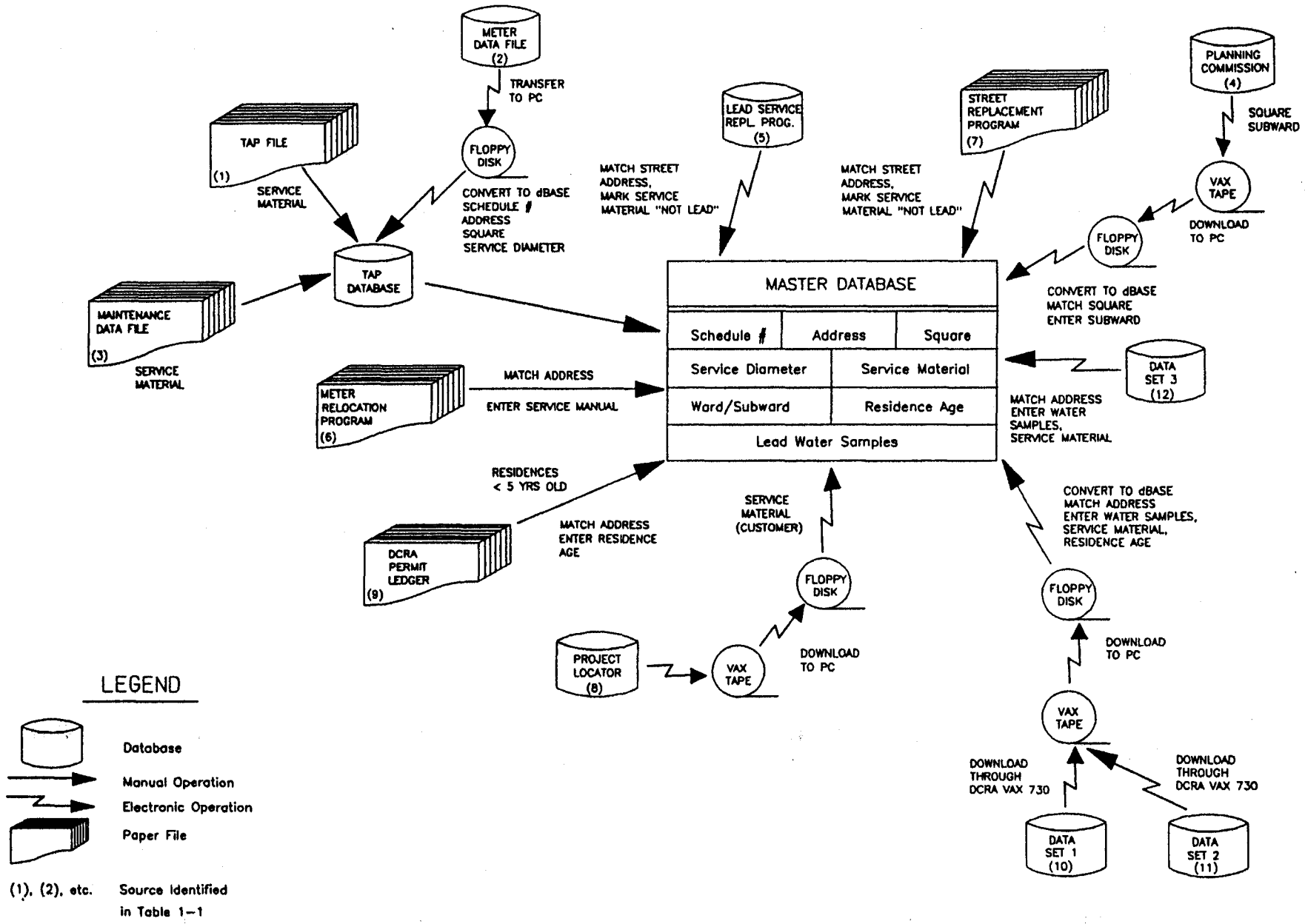


FIGURE 1 SCHEMATIC OF INTERACTION OF VARIOUS DATABASES

files with the Tap File. This database compiled records of 126,099 residential service lines in the District. Out of the 126,099 service lines, the service line material was identified for 81,356 connections, with known lead services lines for 8,987 service connections. This database was used to examine the history of lead service line installations in the District. The majority of early lead service line installations were done prior to 1911, and during the 1920s and early 1930s. Lead usage then dropped off to a fairly insignificant amount in the mid-1930s, then peaked again for about 5 years during World War II.

In order to gain information on the past practice of installation of lead service lines in the District, some members of the Association of Plumbing, Heating, and Cooling Contractors were interviewed. Their records did not indicate any significant installation of new lead service lines since late 1940s. Figure 2 shows the distribution of installation of known lead service lines in the District. This figure also confirms that there was no significant installation of lead service lines after 1946.

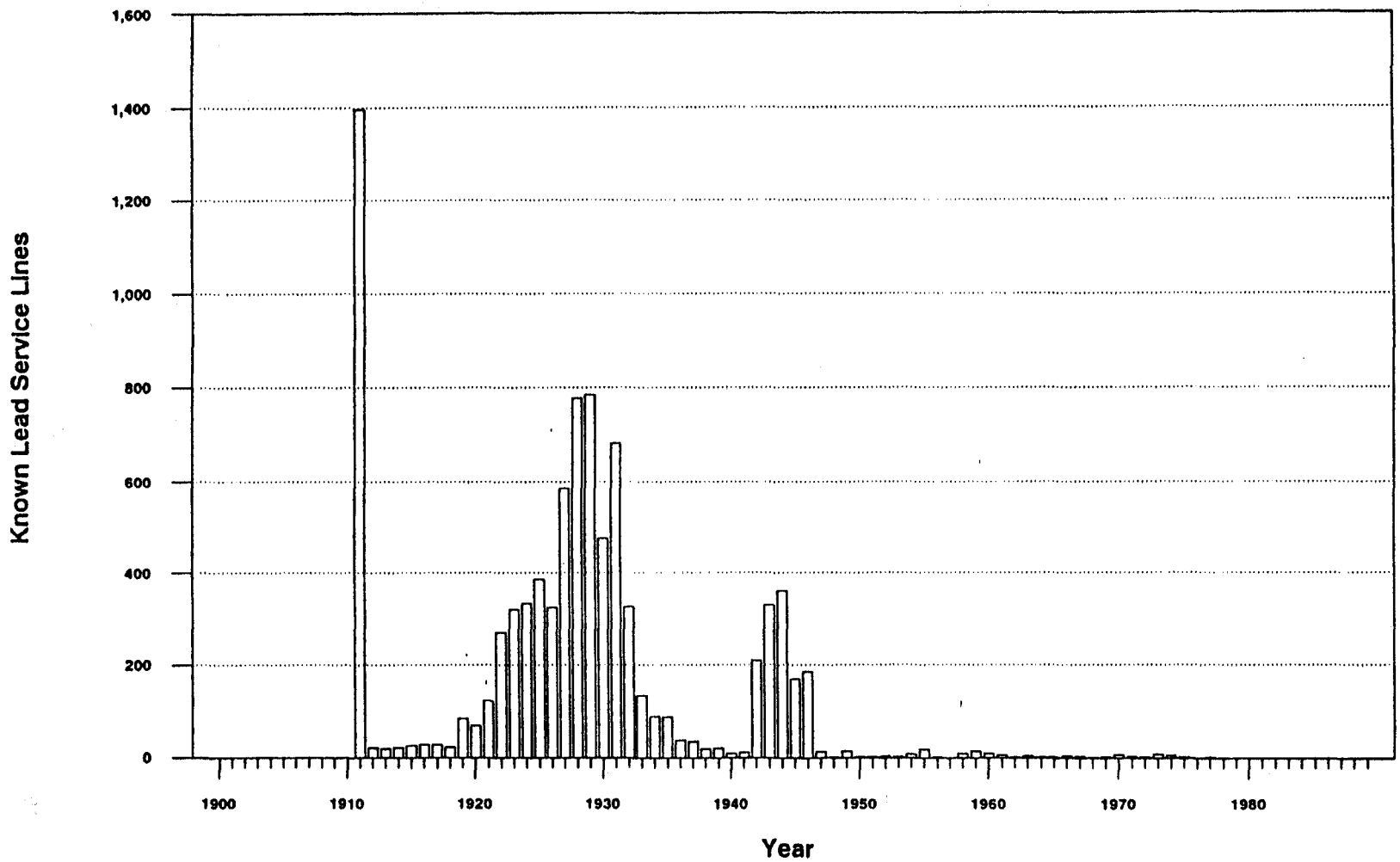
The final Tap File Database was shown to have a variety of uses within the District. Simple data retrieval and analysis programs were developed, and District personnel were trained in their use. Possible future uses of the database were outlined, with further development to occur once the specific uses of the database are determined.

METHODOLOGY FOR IDENTIFYING LEAD SERVICE LINES

There are 44,734 service lines in the District with no recorded line materials. In order to estimate the number of lead service lines among the unknown material service lines, a methodology was developed. The databases developed were used extensively in this methodology to determine the number and distribution of lead service lines in the District.

The basic premise of this technique is that a house located near another house that has a lead service line is also likely to have a lead service line, provided that the service lines were installed at the same time. To analyze the records in the database, houses were considered to be in "proximity" if they were located in the same square. To ensure that these houses all had service lines installed at approximately the same time, the installation date for each was also considered.

The 81,356 records with known service line materials were examined to develop installation date/square combination lead probabilities. The resulting 24,892 combinations were then applied to the 44,734 records with unknown service lines. This was done by examining each of the addresses with an unknown service line, taking the installation date and square for this address, and searching the 24,892 installation date/square combinations for a match. The corresponding lead probability was then assigned to the address with the unknown service line.



Service line installations indicated for 1911 include years up to and including 1911.

FIGURE 2 DISTRIBUTION OF KNOWN LEAD SERVICE LINES FOR THE DISTRICT

An excavation program to excavate test pits at 120 addresses with unknown service line materials was conducted to have their service line material identified. The results of the excavation program were used to calibrate the installation date/square methodology for predicting service line material.

Using this methodology and extrapolation of ratios of known lead service lines with unknown service lines, an estimate of 28,161 possible lead service lines in the District was obtained.

PROCEDURE FOR IDENTIFYING SERVICE LINE MATERIAL

Having examined the various data sources available to the District, it is now possible to outline a procedure for identifying residential homes that have a high probability of possessing a lead service line. A flow diagram of this methodology is given in Figure 3.

WATER QUALITY

The water supply for the District comes from two water treatment plants: the Delcarlia treatment plant and the McMillan treatment plant. Both the plants are operated and maintained by the U.S. Army Corps of Engineers. Corrosion control is practiced at both treatment plants in the form of lime addition. Monthly average values of pH in the water in the distribution system vary from 7.6 during the summer to 8.0 during the spring. Calculated lead solubilities of the treated water of the District range from 0.14 to 0.36 mg/L. Lead solubility is generally high from August to December relative to that from January to July.

Most of the lead in the District's drinking water comes from lead service lines, lead solders, and brass fixtures at the tap. Lead service lines are the joint responsibility of the District and the homeowner. Concentrations of lead in water taken from home faucets are much higher than concentrations in the distribution system. Lead from the plumbing system leaches into water and tends to reach saturated solubility when it remains stagnant in the home plumbing systems between periods of use. However, lead levels found in water taken from home faucets are much lower than those predicted by solubility model analysis.

SAMPLING

The District conducted a preliminary sampling program to evaluate lead in drinking water in the District during 1986 and 1987. Three separate first flush samples (Samples A, B, and C) were collected. Sample A was taken as the first water out of the kitchen tap in the morning, representing lead contribution from lead solder and brass fixtures; Sample B was taken after running the water for 1 minute, representing lead contribution from service lines; and Sample C was taken after running the water for 15 minutes, representing lead contribution from street water mains. The results of known service line addresses have been segregated into known lead and known nonlead service addresses and are shown in Table 1. Averages of

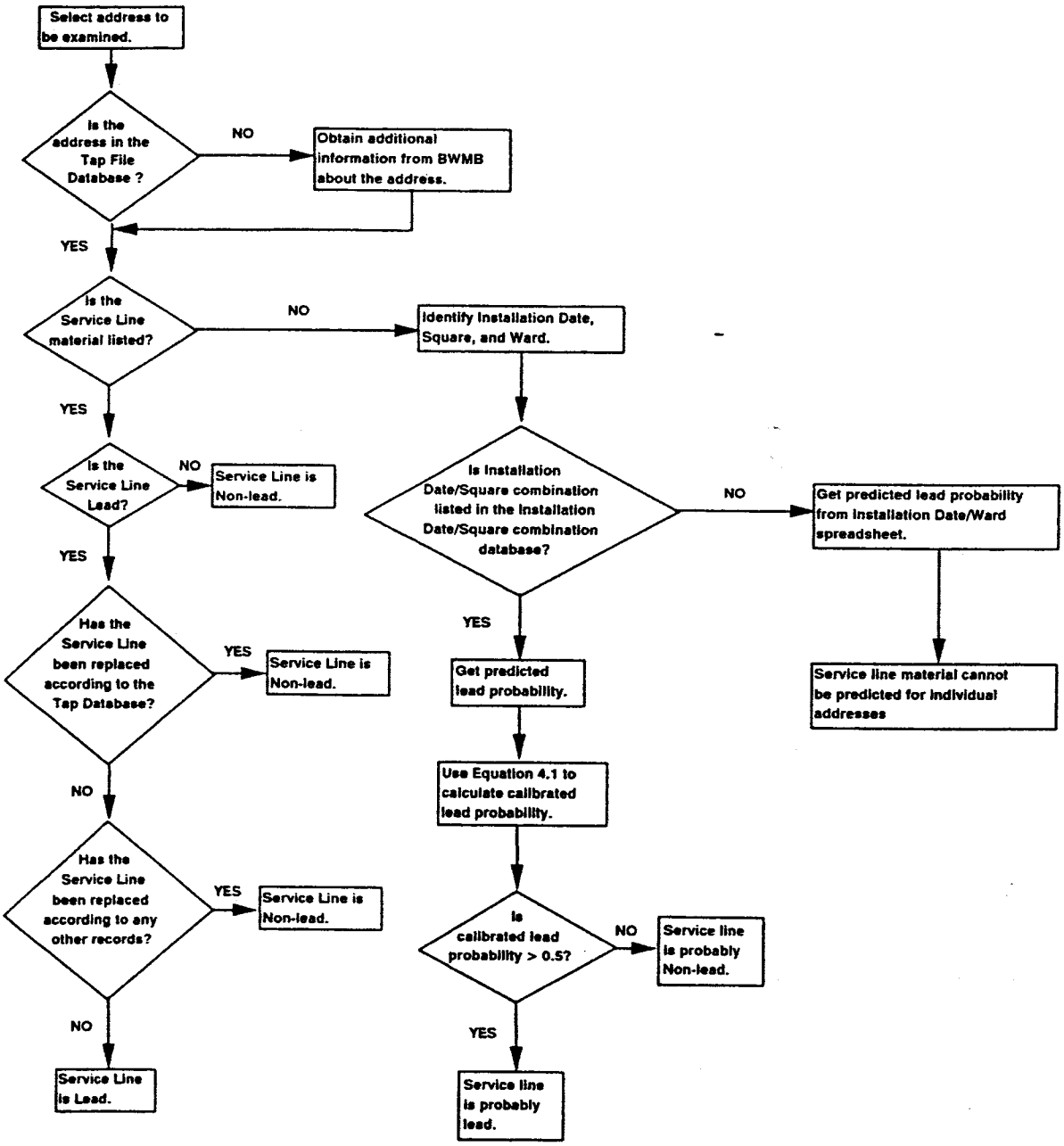


FIGURE 3 METHODOLOGY FOR IDENTIFYING SERVICE LINE MATERIAL

Table 1

Summary of Water Quality Data for Known Service Lines[1]

	Sample A		Sample B		Sample C	
	Known Lead	Known Nonlead	Known Lead	Known Nonlead	Known Lead	Known Nonlead
Avg[2]	20.00	10.75	19.56	8.21	2.00	1.61
Min	<2	<2	<2	<2	<2	<2
Max	390	558	134	308	53	47

[1]All results are in ug/L.
[2]Average values calculated using a value of 1 ug/L for all samples less than the detection limit of 2 ug/L.

Sample A and Sample B of known lead service line houses are significantly higher than the corresponding averages of nonlead service line houses. The average of Sample C is, however, in the same range in both lead service line and nonlead service line houses.

In this study, a separate sampling program was carried out to conduct sampling in 163 homes. Four samples were collected from each home early in the morning before any water was used. Samples were planned to represent lead contributions from faucets, from house plumbing solder, from lead service lines, and from distribution mains. To account for the age of the plumbing and service line material, homes were also assigned to four categories: new homes; homes 2 to 5 years of age; homes more than 5 years old with nonlead service lines; and homes more than 5 years old with lead service lines.

The results indicate that new home (age 0 to 2 years) plumbing systems are reasonably lead-free. Out of 14 homes, 3 homes showed high lead levels in the first sample, indicating the use of brass fixtures or lead solder. Samples from homes in age group 2 to 5 years showed high lead concentrations in the first flush samples, indicating lead contribution from brass fixtures or lead solder. Homes more than 5 years old with nonlead service lines showed lower lead concentrations in the first flush water samples than samples from homes with lead service lines.

ANALYSIS

It was desired to obtain a relationship between the calculated lead solubility and observed lead concentrations in homes served by lead service lines and homes served by nonlead service lines. A regression of the natural logarithms of the observed lead concentrations and corresponding equilibrium lead concentration values was developed. An analysis of 95-percent prediction of observed lead concentrations with equilibrium lead concentrations was performed, and 95-percent concentration levels were found to be about 36 percent of equilibrium lead concentration levels.

TREATMENT ALTERNATIVES

Adjustment of water chemistry at the treatment plant can potentially reduce lead equilibrium solubility of water.

Four treatment options were considered for lowering distribution system lead concentrations: (1) adjustment of pH and alkalinity to greater than 8.0 and 30 mg/L as $CaCO_3$, respectively; (2) precipitation of a protective $CaCO_3$ film; (3) orthophosphate addition alone; and (4) control of pH and alkalinity in conjunction with orthophosphate addition.

The aforementioned alternative treatment options were analyzed, and mean lead levels, 95-percent lead levels, and costs for various options are given in Table 2.

Table 2

Effectiveness and Cost of Various Treatment Options

Treatment Option	Mean Level Level (ug/L)	95% Lead Level (ug/L)	Capital Cost (millions of dollars)	Chemical Cost ($/MG)
1. pH and alk. control	10	55	---	1.00
2. Protective $CaCO_3$	10	55	---	1.00
3. Phosphate addn.	4	29	2	6.30
4. pH and alk. control	3	10	*	78.07

*Not available

As shown in Table 2, Options 1 and 2 can be achieved with minimum cost. However, using these options, it may not be possible to reduce the 95-percent lead level below 55 ug/L. Option 3 can reduce the 95-percent lead level below 29 ug/L. Option 4 will reduce the 95-percent lead level to 10 ug/L. However, sludge handling and disposal costs for this option will be particularly high. Due to anticipated variability of sludge management options, the capital cost for treatment options was not estimated.

FINANCING ALTERNATIVES

The cost of financing of replacement of the District's portion of lead service lines is expected to range between $70 and $80 million. The options available to the District are either to finance through its operating budget (within 20 years) or to finance as part of the District's Capital Improvement Program (within 5 years). An evaluation of the adequacy of the District's current water rate structure and user fee system need to be accomplished to determine the most cost-effective plan of action for the financing.

Financing for replacement of the homeowner's portion of lead service lines also was analyzed. The Community Development Block Grant Program is one potential source of homeowner financial assistance. The other option that was analyzed was a District-appropriated direct grant for low-income homeowners. This option will cost about $9 million to the District for grants to homeowners whose income places them below the poverty level. The District has the option of financing either through the District's Capital Improvement Program, or through its operations and maintenance budget. The determination of the precise financing mechanism to be used is a function of the degree to which the District wishes to or can afford to assist homeowners.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be made about lead in drinking water in the District:

- A large amount of service line data is available to the District from a variety of sources. However, the data sources are scattered among a number of agencies and/or departments. Individual agencies/departments often are not aware of the information available from other sources.

- No proven technology is currently on the market that could be used to identify a lead service line without physical inspection.

- Lead concentrations in the raw water supply of the District and in water in the distribution system are typically <5 ug/L.

- High concentrations of lead in tap water may result from corrosion of lead in brass fixtures, lead-bearing solder, or the District- or homeowner-owned lead service lines.

- The presence of a lead service line did not always indicate elevated lead levels in water at the tap.

- There are approximately 28,000 lead service lines remaining in service in the District.

Based on these conclusions, a number of recommendations can be made to deal with the issue of lead in drinking water. Many of these recommendations are general in nature and should be acted on regardless of the content of the final EPA lead regulations. Those recommendations dealing with the District's specific actions to meet EPA guidelines may need to be modified depending on the final content of the regulations. The recommendations are as follows:

- The Tap File Database should be installed on a computer(s) and used by District personnel to assist in the Lead Service Replacement Program.

- Data from the Meter Relocation Program, Street Replacement Program, and Lead Service Replacement Program should be used to keep the Tap File Database current.

- A public education program should be instituted to teach customers how to reduce their exposure to lead in drinking water.

- Treatment processes at the water treatment plants should be modified to increase the pH of water above 8.0, and water quality samples should be taken at homes that had high lead levels (as identified by previous sampling studies) to determine the effectiveness of pH adjustment.

- If pH adjustment proves ineffective in reducing lead levels at the tap, orthophosphate addition at the water treatment plants to reduce the solubility of lead in water in the distribution system should be considered.

- Homeowners willing to participate in an ongoing water quality sampling program should be located. These homes would then be used for long-term monitoring to assess the effects of the different lead reduction strategies implemented at the water treatment plants, as well as for compliance monitoring for the EPA lead rule.

SECTION 1

INVESTIGATION OF WATER DISTRIBUTION SYSTEM RECORDS

1.1 INTRODUCTION AND OBJECTIVES OF THE STUDY

It has been demonstrated by research that there are adverse health effects of high lead levels in humans. Lead toxicity can be especially detrimental to infants, children, and pregnant women. One route of intake of lead in the human body is through drinking water. The current maximum contaminant level (MCL) for lead is 50 micrograms per liter (ug/L) of drinking water. In 1988, the U.S. Environmental Protection Agency (EPA) proposed a modification of Primary Drinking Water Regulations for lead. This draft modification has a two-part regulation consisting of an MCL of 5 ug/L for lead at the water distribution source and a requirement for water in the distribution system to have a pH of at least 8.0 and carbonate alkalinity of 30 mg/L or more. EPA is now in the process of finalizing National Primary Drinking Water Regulations for lead in drinking water. Most of the lead enters into water from lead service lines and from lead solders and brass fixtures in house plumbing systems. Recent Federal legislation has banned the use of lead and lead-bearing material for all drinking water plumbing use.

The District of Columbia (District) has a considerable number of lead service lines. After discovery of elevated lead levels in first flush water samples from some residences in Washington, D.C., the District contracted Roy F. Weston, P.E., P.C., in March 1989 to conduct this study. The main objectives of this study are to determine the probable sources of lead in the drinking water system, the extent of lead service lines in the District, and alternatives for reducing the levels of lead at the customers' faucets.

The remainder of this section describes the data collection and database development that served as the foundation of the study. Section 2 presents a discussion of the sources of lead in water in general, a detailed analysis of the lead chemistry of the District's water, and various methods of reducing consumers' lead intake through drinking water. Sections 3 and 4 focus on identifying lead service lines in the District. Section 3 describes state-of-the-art remote sensing equipment that was examined for its applicability in locating lead service lines. Section 4 presents the methodology that was used to estimate the number and location of lead service lines throughout the District. A prioritized lead service line replacement program is presented in Section 5, with the financial implications of such a program described in Section 6. The water quality sampling done as part of this study is described in Section 7. Section 8 presents three strategies for dealing with lead in drinking water. Finally, Section 9 lists several conclusions and recommendations drawn from the study.

The remainder of Section 1 is described as follows. Subsection 1.2, Distribution System Data on Lead Service Lines, lists the various sources of data that were combined to create a database from which an initial estimate of the distribution of lead service lines was obtained. Subsection 1.3, Database QA/QC Program, describes the rigorous program that was followed to minimize the number of transcription errors for the database. Subsection 1.4, Use of Lead Material in Plumbing, contains the results of the investigations into the plumbing codes and summarizes the interviews that were conducted with area plumbers and District employees. Subsection 1.5, Lead Water Quality Data, describes the work that was performed for the collection of water treatment plant data and the analysis of sampling program data. This subsection also contains the analysis of the sampling procedures and protocols that have been followed in the past by District agencies, as well as an analysis of the relationship of distribution system lead levels to the water treatment plant parameters. Subsection 1.6, Service Connection Data, presents the initial distribution of the lead service line data collected, and the distribution of the newer residences that could be at risk for lead solder leaching into the drinking water. Subsection 1.7, Water Quality Sampling Data, presents the distribution and statistics for all residences that have been sampled and tested for lead in drinking water.

1.2 DISTRIBUTION SYSTEM DATA ON LEAD SERVICE LINES

This subsection describes the various data files and sources of distribution system data that were investigated. The following data files were analyzed to obtain information regarding location of lead service lines in the District:

- Tap File
- Meter File
- Maintenance File
- Planning Commission File
- Lead Service Replacement Program File
- Meter Relocation Program File
- Street Replacement Program File
- Project Locator Data File
- Permit Ledger Program File
- Corps of Engineers File

Table 1-1 lists each data source, its location, the form in which the data were found, and the purpose for which the data were used. The Tap File, considered as the primary data file for all water service lines in the District, was used in interaction with other data files. Figure 1-1 shows the schematic interaction of various data files with the Tap File.

Table 1-1

Distribution System and Water Quality Data Sources

Source No.	Name	Source Location	Data Form	Purpose
1.	Tap File	Bureau of Water Measurement and Billing	Index Cards	Obtain Tap Information Starting Tap Numbers 67000 Through 188000
2.	Meter Data File	Information Systems	ASCII Files	Obtain Tap Information of First 67,000 Taps
3.	Maintenance Data File	Bureau of Water Measurement and Billing	Index Cards	Lead Service Line Determination
4.	Planning Commission Data File	D.C. Planning Commission	ASCII File	Match Wards to Square
5.	Lead Service Replacement Program Data File	Bureau of Water Measurement and Billing	dBase File	Obtain Additional Lead Service Line Information
6.	Meter Relocation Program Data	Bureau of Water Measurement and Billing	Paper	Obtain Additional Lead Service Line Information
7.	Street Replacement Program Data	Water and Sewer Utility Administration Office	Paper	Obtain Additional Lead Service Line Information
8.	Project Locator Data File	Information Systems	ASCII File	Obtain Additional Lead Service Line Information
9.	DCRA Permit Ledger Data	DCRA Permit Office	Paper	Obtain Housing Data Less Than 5 Years Old
10.	Data Set 1	DCRA	DecMate	Lead in Drinking Water Data
11.	Data Set 2	DCRA	DecMate	Lead in Drinking Water Data
12.	Data Set 3	DCRA	dBASE File	Lead in Drinking Water Data

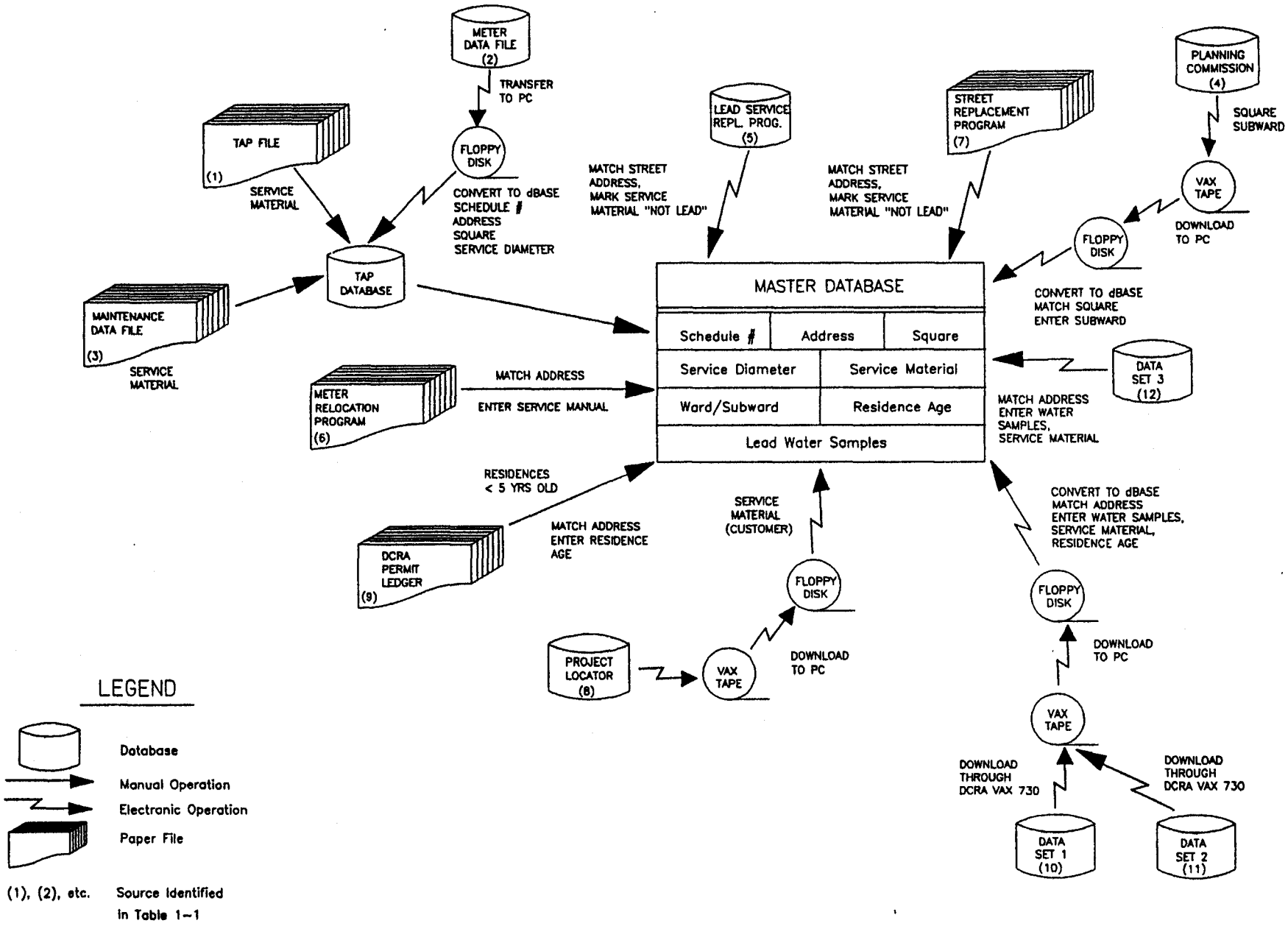


FIGURE 1-1 SCHEMATIC OF INTERACTION OF VARIOUS DATABASES

1.2.1 Tap File

The major source of information for lead service lines was the Tap File, which is a collection of index cards stored in the Bureau of Water Measurement and Billing (BWMB) offices at the Bryant Street Pumping Station. The database created from the Tap File records formed the base with which all of the other information sources were interacted.

This file contains cards that are submitted every time a water main is tapped for a new water service connection. All residential taps are recorded in this file, ordered by schedule number, which is a sequential, unique number assigned to every tap. Approximately 188,000 schedule numbers have been issued by the District.

The data collection effort began on 18 April 1989. Three data entry personnel obtained the information that was to be entered into the database from each index card. The tap cards typically contained the following information:

- Schedule number.
- Address.
- Square.
- Lot.
- Date of connection.
- Property owner and plumber names.
- Size of service line.
- Location of curb-cock.
- Location and size of main.

A database was set up on IBM-compatible personal computers using dBASE IV software. Table 1-2 shows the composition of the Tap File Database record.

Several data handling problems were encountered during the data entry effort:

- The first 67,000 tap records were no longer in the Tap File. According to BWMB employees, these records were taken from the file several years earlier and merged into the adjacent Maintenance File in an attempt to organize all of the data under one filing system. The Maintenance File (see Subsection 1.2.3) is organized alphabetically by street and by house number within a street as opposed to the Tap File's ascending schedule number order. The missing Tap File cards were, therefore, scattered throughout the much larger Maintenance File, effectively out of reach of the data entry staff. A database supplied by the Information Systems group of BWMB (see Subsection 1.2.2) supplied the schedule number, address, and square information for the missing tap records; the remaining information was gathered by the data entry staff through the Maintenance File, as described in Subsection 1.2.3.

Table 1-2

Tap File dBASE IV
Database Structure

Field Name	Field Width	Data from Tap File Card
SCHEDNUM	6	Schedule Number
DATE	4	Year of Tap
ADDNUM	5	House Number
STRADDR	50	Street Name
QUADRANT	2	Quadrant
PIPESIZE	5	Diameter of Service Line (in.)
PIPEMATL	1	Service Line Material
ABAN-REPL	1	Abandoned/Replacement Service Line
SQUARE	6	Square
WARD	2	Ward (not obtained from Tap File)
Lead Service Replacement Cost	8	Future use
Replacement Priority	3	Future use
Date of Replacement by the District	10	Future use
Date of Replacement by Owner	10	Future use

- The newest residential taps were also not recorded in the Tap File, but for a different reason. BWMB employees stated that the newer taps are recorded directly onto the computer. Therefore, all taps recorded since 1984 were not available for entry from the Tap File.

- A significant number of tap records either did not contain all of the needed information or had confusing information. The most persistent problem was when the original schedule number was crossed out and replaced with a different number. BWMB staff could not always explain the reason for the change. It was decided to let the original schedule number stand unless the index card was moved to the location in the Tap File that corresponded to the new number.

  Missing information included, at one time or another, any of the first nine fields listed in Table 1-2 except for the schedule number. Two of the most consistently missing pieces of information were the line material and square fields. Both fields are extremely important; the presence of the former field, especially if the service line is lead, provides confirmation of the service line and can provide some insight into the service line material for surrounding properties. The latter field is needed to determine in which of the eight wards the property is located.

- Although not unexpected, the condition of many of the index cards had deteriorated to the point where they were illegible. This had the combined effect of slowing the data entry effort and increasing the potential for typing errors. A QA program was designed to minimize the number of obvious errors in the data.

  Tap File data entry was completed during the week of 12 June 1989. The database contained approximately 106,000 records, which represented all records available in the Tap File. Since the Tap File contained schedule numbers 67000 through 188000, so that the expected maximum number of records 121,000, this implies that only 12 percent of the original service lines have been abandoned (and the corresponding tap cards removed from the file). Subsection 1.3.1 contains a more thorough analysis of the database.

  The Tap File Database was not complete at this point. Additional work was performed to obtain the data from the missing 67,000 tap records. In addition, each address in the file was assigned to its appropriate ward.

1.2.2 Meter File

As stated in the previous subsection, the Tap File did not contain the cards for the first 67,000 taps. Obtaining this information was imperative because these locations are the oldest in the District (pre-1915) and are the most likely to have had originally installed lead service lines. The BWMB Meter File contains information used for billing and customer service purposes. Upon reviewing this information, it was determined that the screen contained several useful fields. A meeting was scheduled with a system analyst from the Department of Public Works Office of Information Systems (OIS) group to determine whether the information could be obtained in a form suitable for entering into the Tap File Database.

It was discovered subsequently that the Meter File information consisted of selected fields from the master database that OIS maintains on its mainframe computer. The OIS analyst agreed to supply the data for all active residential addresses throughout the District on floppy disks. These data contained the following information for schedule numbers 000000 through 999999:

- Schedule number.
- House number.
- Street name.
- Quadrant.
- Square.

The missing Tap File information was addressed by creating a supplementary database for all records that had a schedule number less than 67000. Upon investigation of the records, it was discovered that the schedule number for several thousand records in the Meter File was 000000. Neither OIS nor BWMB personnel knew the reason for such an assignment. Several of these addresses were not found in the Maintenance File. It was assumed that these records were either inactive or abandoned service lines, and they were removed from the database.

This supplementary database was installed on the project computers at BWMB. Data entry personnel were instructed to look up each address in the Maintenance File and attempt to fill in the missing data. Subsection 1.2.3 describes the activities that comprised this effort.

It should be noted that only 20,400 of the first 67,000 taps were still active. This is not surprising, since most of these residences were located in the center of the District and as such were probably torn down and replaced by commercial or government buildings, or by open space (especially the Mall) or new roads.

The data present in the Meter File also contained schedule numbers greater than those found in the Tap File. It was initially decided to append this information to the Tap File Database to ensure that

the most recent locations were included. However, this was not done because of four factors:

- Schedule numbers were not contiguous, as would be expected given the recent nature of the tap (post-1984). Many gaps appeared in the schedule numbers that caused concern over the reliability of the information.

- One piece of information that did not appear on the Meter File is the tap date. The date was not important for the first 67,000 schedule numbers because the taps occurred well before the introduction of materials other than lead. The tap date for the newest locations, however, becomes very important because of the potential of relatively new solder contributing to lead in the water of these households.

- Dates of construction were obtained for all residences built since 1984. It is expected that concentrations of lead in drinking water in newer homes may be high where lead solders were used in the house plumbing system. The data file is developed from the Department of Consumer and Regulatory Affair's Permit Ledger data and is discussed in Subsection 1.2.9.

- The Tap File database contained the schedule number, address, and square for all available single-family addresses. Data for the service line diameter and pipe material fields for the first 67,000 taps, as well as the ward location for all addresses, were still needed.

1.2.3 Maintenance File

All water system maintenance activities are recorded in a file called the Maintenance File. The Maintenance File is a very large collection of index cards and small paper records located next to the Tap File at the BWMB office. It contains the sum total of all known water system activity that has been performed at any address in the District. This file is much larger than the Tap File; BWMB personnel estimate that there are 500,000 pieces of paper in the Maintenance File. The file is separated into residential addresses and commercial (or nonresidential) addresses. The residential portion of the file is organized alphabetically by street name. Within the street name, records are organized by quadrant and, within the quadrant, by increasing house number. All work orders that pertain to a house number are arranged chronologically.

It was not originally intended to utilize the Maintenance File in reviewing the water distribution system records. The sheer size of the file is such that any attempts to obtain information on all addresses would be costly and time consuming. Furthermore, this file is the central repository of all information and is in constant use by BWMB personnel, service crews, meter replacement

crews, and several other groups. Any extensive use of this file would severely disrupt the normal routine in the office.

The missing 67,000 tap records discussed in previous subsections required a limited investigation of the Maintenance File to be performed. In order to complete the data collection for the first 67,000 taps, the following data had to be obtained from the Maintenance File for each address in the supplementary Tap File Database:

- Date of tap installation.
- Service line material.
- Service line diameter.

The database was sorted to match the organization of the Maintenance File. Nevertheless, the volume of information available at any address that had to be sorted through greatly diminished productivity. To ensure that the effort was completed on time, the data entry staff were instructed to concentrate only on obtaining the service material for each address, which was the most important piece of information of the three. The staff were then free to look through all of the service orders for each address as well as the tap card, thus increasing the chances of obtaining a definite service line material indication.

Data entry on this file was completed on 30 June 1989. Quality assurance was performed on the supplemental database, and then it was appended to the main Tap File Database to produce the full 126,099-record Tap File Database.

1.2.4 Planning Commission Files

All data analyses for the project were performed on the basis of political wards. The District of Columbia is divided into eight wards, with each ward being further divided into five subwards. This initially presented a challenge, since the only geographical information that appeared in the Tap File was quadrants and squares. A District of Columbia Planning Commission map was obtained that showed the location of all squares and the boundaries of the eight wards in an attempt to determine whether an orderly relationship existed between squares and wards. It was immediately apparent that no such relationship existed; the approximately 7,900 squares often appeared at random in different areas of the District.

Before starting the square-versus-ward matching effort, additional inquiries were made to the Planning Commission staff. This led to the discovery of their mainframe database that, among other relationships, identified the ward location of every square. A Planning Commission programmer provided a floppy disk of this information in a form suitable for inclusion into the dBASE IV software.

The ward-versus-square database enabled staff members to quickly and easily fill in the ward field for any record in the Tap File Database, as long as the record contained the proper value in the square field. The merge was highly successful; over 90 percent of the records now had a ward location. Those records that did not get a ward had tap cards that did not have the square specified, which was fairly common in the older Tap File records.

The completion of this task marked the end of the database creation process. The Tap File Database now contained schedule number, address, tap size, square, and ward information for 126,099 records. Service line material information at this point, however, was limited to those rare occurrences where the plumber who installed the service line happened to note the material type somewhere on the index card. The objective of the remaining distribution system data collection tasks was to modify the database by ascertaining the presence or absence of lead service lines. The various data gathering efforts that the District initiated under past and ongoing programs were investigated, with the objective of detection of any additional lead service line information. The following programs were investigated:

- Lead Service Replacement Program
- Meter Relocation Program
- Street Replacement Program
- Project Locator Program

1.2.5 Lead Service Replacement Program

The first source of database modification information was provided by the District's Lead Service Replacement Program. The program, which has been in operation since June 1986, replaces District-owned, noncopper residential service lines (i.e., the portion of the service line that lies between the main and the curb shut-off valve).

The program operates as follows: a list of probable lead service line locations is maintained through a combination of addresses compiled by the Department of Consumer and Regulatory Affairs (DCRA) Water Hygiene Branch during its water testing program and by subsequent calls by concerned residents and other water consumers. Since the service line material has at this point been identified only by the homeowner, Lead Service Replacement Program personnel first attempt to identify the District side of the service line by checking the work order history in the BWMB Maintenance File. If no information to the contrary is found, the service line is assumed to be lead and is added to the list. The four dedicated Lead Service Replacement Program crews of the Bureau of Water Service (BWS) excavate the service line, replace it with copper, and note the customer's service line material. Whenever the customer's service line is not copper, notification is given to the customer describing the situation and urging him/her to replace it as soon as possible.

The Lead Service Replacement Program, which is headquartered at the Office of BWS, maintains a dBASE database of all addresses that had their service lines replaced since the program's inception. As of the third week of June 1989, when a floppy disk was obtained, the program's database contained 854 records. This ongoing program replaces 20 to 40 service lines per month depending on the weather. Close contact was maintained with program personnel throughout this study, and the main database was updated to ensure the most up-to-date assessment of lead service line distribution.

The Lead Service Replacement Program database contains the following fields of interest:

- House number.
- Street name.
- Quadrant.
- Material type replaced.
- Date.

The objective in using these data was to match each replaced service line with its corresponding entry in the Tap File Database and mark the service line material as being copper. It was desirable to perform this matching and marking function electronically; however, the lack of a simple, unique key field in the Lead Service Replacement Program database made this difficult. The only way to match the data was to attempt to search by a combination street name, house address, and quadrant. The potential for typographical errors in the street name and various inconsistent abbreviations (ST., ST, STREET) limits the success of such a search. The only alternative is to sort the databases the same way, print out the Lead Service Replacement Program database, and manually mark the addresses as having lead service lines and indicating that they have been replaced.

In the future, it is recommended that the Lead Service Replacement Program consider adding the schedule number and square to its database in order to facilitate the updating of the Tap File Database and to provide periodic feedback on the distribution of the remaining service lines. This latter point will ensure that all areas of the District are receiving equal attention from the program.

1.2.6 Meter Replacement Program

The second source of database information modification was provided by the District's Meter Relocation Program. The objectives of this program, which has been underway for approximately 10 years, are to move all water meters to the outside of the building and to standardize on one meter manufacturer. For the purposes of this study, the Meter Relocation Program differs from the Lead Service Replacement Program in several important ways:

- Service lines connected to the meter are not seen by the crews whenever the meter to be replaced is already outside of the building. In this case, the crew only digs deep enough to connect the new meter to the old risers (unless the risers are in poor condition in which case they are also replaced). The service line is not exposed and therefore its type cannot be ascertained.

- Each job is recorded on a paper meter replacement ticket, which is then filed in the BWMB Maintenance File. No computer records are maintained. Finding and recording all past meter replacement activity would have involved searching every address in the Maintenance File. Time, cost, and project scope constraints did not allow this search to be performed.

- Upon investigation of several Meter Relocation Program job tickets, it was discovered that the service line material type was rarely noted.

Since data on past meter relocation activity could not be obtained, it was decided to set up a mechanism that would obtain this information during all future activities. It was recommended to the Meter Relocation Program management to modify its program in the following two ways:

- Instruct all crews to excavate down to the service line so that they could determine the type of service line on both the customer and the District sides.

- Have the crews fill out a simple form (see Figure 1-2) and return it at the end of the day to a central location.

Program management has cooperatively implemented these recommendations. This has resulted in the collection of information on approximately 200 additional identified service lines to date. This information enabled further updating of the Tap File Database and provided valuable input for the statistical analyses.

1.2.7 Street Replacement Program

The third source of database information modification was identified at the first monthly project status meeting at the District's office in Blue Plains. This information, hereafter called the Street Replacement Program, is a result of the District's requirement that all noncopper service lines (as well as other utilities) be replaced whenever a street construction contract is awarded. All available street inspector logs (see Figure 1-3 for a sample) that identified the service line material were obtained.

As was found with the Meter Replacement Program information, the Street Replacement Program information is not computerized;

D.C LEAD STUDY

DATE: 05-26-89.

NAME OF CREW LEADER: C. HARTRIDGE

FULL ADDRESS OF WORK LOCATION	INDICATE TYPE OF PIPE MATERIAL OBSERVED IN THE APPROPRIATE SPACE BELOW							
	FROM BUILDING LINE TO METER				FROM THE METER TO WATER MAIN			
~~1307 E ST. NE~~	IRON.	LEAD.	COPPER.	OTHER	IRON.	LEAD.	COPPER.	OTHER
				3/4				3/4
1307 E ST. NE				BRASS				BRASS
			3/4				3/4	
3935-MASSACHUSETTS AVE. NW NE			COPPER				COPPER	

FIGURE 1-2 SAMPLE METER RELOCATION DATA COLLECTION FORM

Contract No. 87-0029
Recap bid item #7
Replace 2" and smaller water services

Partial No.	Address			Length	Sq. No.	Lot NO.
3	1818	13th	st.	42.42	277	93 - Galv.
3	1820	"	"	45.09	"	92 - Galv.
3	1822	"	"	48.16	"	822 - Galv.
3	1824	"	"	53.74	"	846 - Galv.
3	1826	"	"	64.34	"	845 - Galv.
3	1828	"	"	62.32	"	95 - Galv.
3	1830	"	"	41.57	"	96 - Galv.
3	1832	"	"	41.09	"	74 - Galv.
3	1834	"	"	41.25	"	73 - Galv.
3	1836	"	"	52.75	"	844 - Galv.
3	1838	"	"	64.26	"	843 - Galv.
3	1840	"	"	64.26	"	842 - Galv.
3	1842	"	"	49.42	"	841 - Galv.
3	1844	"	"	50.42	"	840 - Lead.
3	1829	"	"	36.33	"	9 - Copper
Total#3= 759.42						
4	1800	"	"	47.45	"	800 - Galv.
4	1808	"	"	54.64	"	800 - Galv.
4	1810	"	"	58.14	"	77 - Galv.
4	1812	"	"	57.25	"	76 - Galv.
4	1814	"	"	47.42	"	75 - Galv.
4	1816	"	"	50.00	"	94 - Galv.
4	1825	"	"	59.64	"	813 - Lead
4	1817	"	"	47.40	"	808 - Galv.
4	1815	"	"	44.57	240	807 - Galv.
4	1813	"	"	60.92	"	806 - Galv.
4	1811	"	"	48.19	"	805 - Galv.
4	1809	"	"	41.10	"	804 - Galv.
4	1807	"	"	43.32	"	24 - Galv.
4	1805	"	"	43.74	"	23 - Galv.
4	1801	"	"	44.50	"	25 - Galv.
4	1500	"	"	30.92	241	74 - Lead
Total #4 = 779.50						
5	1504	"	"	50.99	"	842 - Lead
5	1506	"	"	49.83	"	88 - Lead
5	1508	"	"	50.08	"	87 - Lead
5	1510	"	"	51.82	"	86 - Lead
5	1512	"	"	51.24	"	85 - Galv.
5	1514	"	"	50.32	"	84 - Galv.
5	1700	"	"	32.07	"	819 - Galv.
5	1711	"	"	29.33	240	102 - Galv.
5	1714	"	"	48.89	241	108 - Tie in/in Basin
5	1716	"	"	51.68	"	107 - Galv.
5	1718	"	"	34.43	"	99 - Galv.
5	1722	"	"	50.42		- Lead
5	1736	"	"	52.50		- Lead
5	1740	"	"	33.25		- Lead.
Total #5 = 636.85						

FIGURE 1-3 SAMPLE STREET REPLACEMENT PROGRAM DATA FORM

moreover, the information is not centrally located. The data were obtained by contacting the inspectors, who then pulled their logs from their personal files. The inspectors were found to be highly organized and extremely knowledgeable.

Since each group of addresses represents a replaced street, almost all of the records to be changed are located on one street and, therefore, will appear together in the Tap File Database. The database was sorted to allow rapid entry of this information. For each address found, the original service line material was marked to match that indicated on the Street Replacement Sheet, and the service line was marked as having been replaced.

1.2.8 Project Locator Data File

The fourth source of database information modification was identified at the 6 July 1989 project progress meeting and presentation. These data, hereafter called the Project Locator Data File, is the end product of an extensive study performed in 1983 to 1984 by the Office of Engineering Services for the BWMB. Project Locator was a house-to-house survey, the objective of which was to improve the quality and accuracy of water billing.

The Project Locator records were located at the OIS office. All of the information was copied to magnetic tapes readable by WESTON's VAX mainframe computer system. Table 1-3 shows the format of each record in the Project Locator Data File.

As can be seen in Table 1-3, the Project Locator Data File uses the 11-digit customer account number as the key (unique) field. The Tap Data File keys on the tap schedule number. Therefore, a second run was requested on the main database from which the Meter File (see Subsection 1.2.2) was obtained in order to build another database that related the customer's account number to the schedule number. The format of this temporary file appears in Table 1-4.

Several steps were required to move the desired data from the Project Locator Data File to the Tap File Database. The first step taken was to strip unnecessary data from Project Locator Data File. After loading the magnetic tapes onto the WESTON mainframe computer, a simple program was written to extract the following information from each record:

- Account number.
- Riser pipe type.
- Service pipe type.

The second step taken was to load the magnetic tape containing the account number versus schedule number onto the mainframe. The third step taken was to download both files from the mainframe to the PC for subsequent loading into the same database program used for the Tap File Database. Once the two files were loaded into dBASE, the temporary account number versus schedule number database was merged with the Project Locator Database.

Table 1-3

Format of Project Locator Data File

DATE: 08/01/83 PAGE: 1 of 5

FILE ID: PLMAST FILE NAME: PROJECT LOCATOR MASTER FTYPE#: 910

RECORD SIZE: 632 FILE TYPE: XD CREATED BY:
DATA LOC: PLDATA,1
I/O TO JOBS: P/L REPORTS UPDATED BY: PL;PLORDR

DESCRIPTION:

This is the master file record layout for the Project Locator System.
The V/I# Column signifies the source of the data element:
P=Program Generated, BLANK=Water Revenue, R=Real Property F=Field Survey

Fld No.	Field Name	Mask	V/ I#	Fld Desc	Fld Len	Fld Mod	Positions From	Positions To
1	SURVEY SHEET NUMBER	CK DIGIT	P	N	7		1	7
2	ACCOUNT NUMBER			X	11		8	18
3	SERVICE ADDRESS			X	41		19	59
	House/Building number			N	4		19	22
	House Number Suffix			X	1		23	23
	Street Name			X	18		24	41
	Street type			X	2		42	43
	Quadrant			X	2		44	45
	Apartment Number			X	5		46	50
	Zip code			N	9		51	59
4	SPECIAL INST CODE	TLU		X	1		60	60
5	SPECIAL INSTRUCTIONS			X	30		61	90
6	METER MANUFACTURER 1			X	2		91	92
7	METER MANUFACTURER 2		F	X	2		93	94
8	METER SIZE			N	3		95	97
9	METER ID NUMBER 1			X	9		98	106
10	METER ID NUMBER 2		F	X	9		107	115

Table 1-3
(continued)

DATE: 08/01/83 PAGE: 2 of 5

FILE ID: PLMAST FILE NAME: PROJECT LOCATOR MASTER FTYPE#: 910

RECORD SIZE: 632 FILE TYPE: XD CREATED BY:
DATA LOC: PLDATA,1
I/O TO JOBS: P/L REPORTS UPDATED BY: PL;PLORDR

DESCRIPTION:

This is the master file record layout for the Project Locator System.
The V/I# Column signifies the source of the data element:
P=Program Generated, BLANK=Water Revenue, R=Real Property, F=Field

Fld No.	Field Name	Mask	V/ I#	Fld Desc	Fld Len	Fld Mod	Positions From	Positions To
11	METER LOCATION			X	60		116	175
12	CURB COCK LOCATION			X	50		176	225
13	RISER MATERIAL		F	X	1		226	226
14	PIPE TYPE		F	X	1		227	227
15	# OF METER REGISTERS			N	1		228	228
16	METER DIAL UNITS		F	N	15		229	243
	lowest dial unit 1		F	N	4		229	232
	lowest dial unit 2		F	N	4		233	236
	lowest dial unit 3		F	N	4		237	240
	number of dials 1		F	N	1		241	241
	number of dials 2		F	N	1		242	242
	number of dials 3		F	N	1		243	243
17	ACCOUNT TYPE			N	1		244	244
18	PROPERTY USE		R	N	2		245	246
19	BUILDING NAME		F	X	25		247	271
20	NUMBER OF UNITS			N	5		272	276

Table 1-3
(continued)

DATE: 08/01/83 PAGE: 3 of 5

FILE ID: PLMAST FILE NAME: PROJECT LOCATOR MASTER FTYPE#: 910

RECORD SIZE: 632 FILE TYPE: XD CREATED BY:
DATA LOC: PLDATA,1
I/O TO JOBS: P/L REPORTS UPDATED BY: PL;PLORDR

DESCRIPTION:

This is the master file record layout for the Project Locator System.
The V/I# Column signifies the source of the data element:
P=Program Generated, BLANK=Water Revenue, R=Real Property, F=Field

Fld No.	Field Name	Mask	V/ I#	Fld Desc	Fld Len	Fld Mod	Positions From	Positions To
21	FIELD AUDITORS INITS 1		F	X	3		277	279
22	FIELD AUDITORS INITS 2		F	X	3		280	282
23	CONNECTION SIZE			N	3		283	285
24	SET (RESET) DATE			N	6		286	291
25	PIPE DATE		F	N	6		292	297
26	TEST DATE		F	N	6		298	303
27	TEST RESULTS			N	3		304	306
28	METER REMOVAL DATE			N	6		307	312
29	METER AUDITORS INITIALS		F	X	3		313	315
30	SQUARE		R	N	4		316	319
31	SQUARE SUFFIX		R	X	4		320	323
32	LOT		R	N	4		324	327
33	OFFICE AUDITORS INITS		F	X	3		328	330
34	DATE FORM ISSUED		P	N	6		331	336
35	DATE OFFICE UPDATE		P	N	6		337	342
36	DATE MD UPDATE		P	N	6		343	348
37	AGENT CODE	TLU		X	4		349	352

Table 1-3
(continued)

DATE: 08/01/83 PAGE: 4 of 5

FILE ID: PLMAST FILE NAME: PROJECT LOCATOR MASTER FTYPE#: 910

RECORD SIZE: 632 FILE TYPE: XD CREATED BY:
DATA LOC: PLDATA,1
I/O TO JOBS: P/L REPORTS UPDATED BY: PL;PLORDR

DESCRIPTION:

This is the master file record layout for the Project Locator System.
The V/I# Column signifies the source of the data element:
P=Program Generated, BLANK=Water Revenue, R=Real Property, F=Field

Fld No.	Field Name	Mask	V/ I#	Fld Desc	Fld Len	Fld Mod	Positions From	Positions To
38	POLICE STREET CODE		PF	N	4		353	356
39	ROUTE			N	4		357	360
40	TALLY			N	3		361	363
41	LICENSED BUSINESS CODE		R	N	3		364	366
42	ADDRESS RANGE		F	X	20		367	386
43	NEW ACCOUNT		F	X	1		387	387
44	HELD ACCOUNTS	1,2,3	F	X	1		388	388
45	HELD REASON		F	X	25		389	413
46	RANK		P	N	4		414	417
47	ALTERNATE ADDRESS		P	X	40		418	457
48	FILLER		P	X	8		458	465
49	REAR FLAG		P	X	1		466	466
50	CORNER FLAG		P	X	1		467	467
51	FILLER		P	N	1		468	468
52	ISSUE COUNT		P	N	1		469	469
53	ERROR FLAG		P	X	1		470	470

Table 1-3
(continued)

DATE: 08/01/83 PAGE: 5 of 5

FILE ID: PLMAST FILE NAME: PROJECT LOCATOR MASTER FTYPE#: 910

RECORD SIZE: 632 FILE TYPE: XD CREATED BY:
DATA LOC: PLDATA,1
I/O TO JOBS: P/L REPORTS UPDATED BY: PL;PLORDR

DESCRIPTION:

This is the master file record layout for the Project Locator System.
The V/I# Column signifies the source of the data element:
P=Program Generated, BLANK=Water Revenue, R=Real Property, F=Field

Fld No.	Field Name	Mask	V/ I#	Fld Desc	Fld Len	Fld Mod	Positions From	Positions To
54	STATE FLAG		P	X	1		471	471
55	RESERVATION FLAG		P	X	1		472	472
56	FILLER		P	X	160		473	632

Table 1-4

Format of Account Number Versus Schedule Number Data File

Field Name	Columns
Account Number	1-11
House Number	12-15
Street Name	16-40
Lot	41-44
Square	45-48
Schedule Number	49-54

The final step in the procedure was to merge the service line material information from the Project Locator Database onto the Tap File Database by matching the schedule numbers in the two databases. To accommodate the service line material information, a new field was created in the Tap File Database entitled "Customer Service." This addition was necessitated by the fact that the service line material entry in the Project Locator effort is what the Project Locator personnel viewed for those residences that had inside water meters and is, therefore, a direct observation of the customer's side of the service line only. The information collected to date has represented direct observation of the District's side of the service line. It was decided to segregate the two pieces of service line material information to avoid making unsubstantiated inferences on the material type of any portion of a residential service line.

1.2.9 Department of Consumer and Regulatory Affairs Permit Ledger

The objective of the final data collection activity was to examine new construction data in order to identify the population that is potentially exposed to drinking water actively leaching lead solder. It was learned that the Department of Consumer and Regulatory Affairs (DCRA) Permit Office was responsible for maintaining the records for all construction permits.

The following information was gathered from a visit to the Permit Office: (1) the information was contained in a bound ledger; (2) the ledger could not be removed from the building; and (3) photocopying was not available. Due to the importance of this information and the lack of another source of the same data, it was decided to transcribe the data by hand for later entry into the computer as the New Construction Database. A sample of this transcription appears in Figure 1-4. The following information was obtained from the ledger for all new construction of single-family dwellings since 1 January 1984:

- House number.
- Street name.
- Quadrant.
- Square.
- Permit date.

The first three pieces of information were used in the project to identify locations for water sampling needed to identify the contribution of brass fixtures and lead solder to lead levels in drinking water. The square information enables the location to be tied into one of the eight wards in the District to provide the distribution of new construction. The permit date provides a reasonable estimate of the service line's age. While the permit date does not coincide with the actual service activation date, it does provide a relative age of the service line compared with other new construction.

NEW CONSTRUCTION: APRIL 1984

Permit No.	Address/Quadrant	Square	Date	Remarks
13300662	4459 Salem Lane, NW	1364	4-3-84	SFD
13300663	4465 Salem Lane, NW	1364	4-3-84	SFD
13300664	4477 Salem Lane, NW	1364	4-3-84	SFD
13300665	4471 Salem Lane, NW	1364	4-3-84	SFD
13300666	4489 Salem Lane, NW	1364	4-3-84	SFD
13300667	4483 Salem Lane, NW	1364	4-3-84	SFD
13300722	2715 M. Street, NW	1214	4-6-84	
13300728	2620 Bowen Road, SE	5869	4-6-84	
13300795	3645 Alabama Ave., SE	5671	4-11-84	Townhouse
13300796	3647 Alabama Ave., SE	5671	4-11-84	Townhouse
13300796	3649 Alabama Ave., SE	5671	4-11-84	Townhouse
13300796	3651 Alabama Ave., SE	5671	4-11-84	Townhouse
13300799	3627 36th Place, SE	5671	4-11-84	Townhouse
13300800	3625 36th Place, SE	5671	4-11-84	Townhouse
13300801	3623 36th Place, SE	5671	4-11-84	Townhouse
13300802	3621 36th Place, SE	5671	4-11-84	Townhouse
13300803	3619 36th Place, SE	5671	4-11-84	Townhouse
13300804	3617 36th Place, SE	5671	4-11-84	Townhouse
13300805	3615 36th Place, SE	5671	4-11-84	Townhouse
13300806	3613 36th Place, SE	5671	4-11-84	Townhouse
13300807	3611 36th Place, SE	5671	4-11-84	Townhouse
13300808	3609 36th Place, SE	5671	4-11-84	Townhouse
13300809	3607 36th Place, SE	5671	4-11-84	Townhouse
13300810	3605 36th Place, SE	5671	4-11-84	Townhouse
13300811	3603 36th Place, SE	5671	4-11-84	Townhouse
13300812	3601 36th Place, SE	5671	4-11-84	Townhouse
13300944	317 Mass. Ave., NE	1749	4-23-84	

FIGURE 1-4 SAMPLE OF DCRA PERMIT LEDGER DATA

This information was used in the effort to determine the contribution of brass fixtures and lead solder to lead concentrations in drinking water. The New Construction Database was sorted into two categories: (1) those addresses that are less than 2 years old, and (2) those addresses that are 2 to 5 years old. Houses that are in the first category should have no lead solder because of the recent ban on using lead solder in potable water service lines. Houses that appear in the second category are considered to be at risk for leaching of lead solder into drinking water. Further discussion on the distribution of these data appears in Subsection 1.6.3.

1.3 DATABASE QA/QC PROGRAM

A rigorous QA/QC program was created and followed for the database that was created from the Tap File index cards. A combination of manual and electronic checking enabled every record to be checked for missing information and keypunch errors.

The keypunch errors were corrected, and, when possible, missing information was filled in by consulting similar records or the knowledge of the project staff members.

The objectives of the QA/QC program are to ensure the following:

- To confirm that data that appear on each card in the Tap File is entered into a corresponding record in the Tap File Database.

- To check the database for keypunch errors. The QA/QC was performed on all the tap records with schedule numbers greater than 67,000. The QA/QC for the data entry task was performed in two stages. One of the staff members was assigned this task and designated as database QA/QC coordinator. The methodology is described in the following paragraphs.

Stage I -- Data Scanning

Each time the Tap File Database was backed up, the QA/QC coordinator would scan the data. The frequency of such data scanning was every 3 to 4 working days. The QA/QC coordinator would scan the data entered since the previous backup for each machine. Normally, the QA/QC coordinator would browse through the data and correct any apparent typing errors on the screen (e.g., "Nwe Jersey Ave." would be corrected to "New Jersey Ave."). Moreover, the data would be constantly indexed and sorted to locate any blank entries.

For each blank entry the QA/QC coordinator would check for an "X" in the UNSURE field. If an "X" were present, the blanks were filled in most cases with the probable entry by checking the fields of adjacent entries (e.g., if the SCHEDNUM field had the following

entries: 92372, blank, 92374, the blank would be replaced with a 92373, the most logical entry).

In addition to the preceding tasks, the QA/QC coordinator would periodically print out portions of the database and methodically check for any blank or improper entries and also compare that portion of the database with the corresponding tap records. If an improper/illogical entry was noticed, the QA/QC coordinator would immediately rectify the mistake. Approximately 8 to 10 percent of the entire database was randomly sampled and checked by this method.

By carrying out the procedure described in Stage I, a random and quick QA/QC of the database would be accomplished. However, since there were approximately 10,000 records entered every week, it could have been possible to overlook some typing errors. To overcome this problem, the Stage II of the QA/QC program was undertaken.

Stage II -- Electronic Checking

The second stage was designed for an extensive QA/QC process by which the entire database was checked. To carry out this step, utility programs were compiled in the dBASE environment. The programs were designed to check for the validity of an entry for each field in every record for the entire database. Whenever a nonstandard entry or an invalid value was encountered, the program would direct the record in question to the printer. The QA/QC coordinator would then scrutinize the hard copy of the printout and make the necessary correction on the hard copy and in the database. The rigorous project QA/QC program enabled the development of an extremely accurate database. However, no database of this size is without errors. Even with 99 percent accuracy, a 126,099-record database will contain more than 1,200 errors. Furthermore, certain types of errors cannot be recognized as such. For example, if the square is supposed to be 1012 and the data entry staff accidentally entered 1013, this error will not be noticed if there is a square 1013.

1.4 USE OF LEAD MATERIAL IN PLUMBING

A second potential source of lead in drinking water involves the leaching of lead solder from the various plumbing connections within the residence. Older plumbing solders contain up to 50 percent lead, while newer "no-lead" solders have reduced lead to no more than 0.2 percent. Although the District of Columbia has banned the use of lead solder in potable water systems since 1987, it is still available on the market for use in heating and wastewater conveyance systems. Consequently, the local use of lead materials in plumbing was investigated by assessing the current District of Columbia Plumbing Code, conducting interviews of licensed plumbers, and interviewing experienced BWMB management and supervisory personnel.

1.4.1 District of Columbia Plumbing Code

The District of Columbia Plumbing Code sets standards for all plumbing work performed by registered plumbers as well as for materials used in design, installation, repair, and replacement of plumbing fixtures intended to receive and discharge water. This subsection focuses on those code provisions that pertain to potable water systems. These provisions described are for installation and permitting for plumbing work, existing plumbing systems, alteration and repair, water service line requirements, and piping system materials.

1.4.1.1 Installation and Permit

This section of the plumbing code provides that all work must be done by a registered master plumber under a duly issued permit. Furthermore, any person granted a license to practice as a master plumber shall post a bond before engaging in this trade.

Every application for a permit to connect with the District's water system, to install service lines attached thereto, or to repair a service line outside the building line must state upon the application form the number and address of the building, premises, or establishment; the square lot or sublot number; the number of stories and the frontage measurement; the purpose for which the water is to be used; and the time at which the tap will be required to be made by the Department of Public Works. The application form required for the connection is the index card that is subsequently inserted by the BWMB into its Tap File. The form, which must be signed by the owner of the building that is to receive the service connection, authorizes the plumber to notify the proper authorities to tap into the water supply system. The only exception to the permit requirement is for repairs involving only the working part of a faucet or valve, the clearance of stoppages, or the replacement of defective faucets, provided that no changes are made in piping to existing fixtures.

1.4.1.2 Existing Plumbing Systems

The code's provision for existing plumbing systems addresses the service requirements for existing buildings. It states that if the authorized occupancies in an existing building do not change, the existing plumbing system may continue to be used unless a change is required by this code or by regulations of other departments of the government of the District of Columbia that affect the health, safety, and welfare of the public.

1.4.1.3 Alteration and Repair

The alteration and repair code provision requires that repairs made to any part of the plumbing system conform as nearly as may be practicable to the regulations for new work of like character. This provision also states that if cumulative additions, alterations, or repairs to an existing water system through timed

or phased work exceeds 50 percent of the total length of the service line in the building's system, the entire system must comply with the codes.

This provision of the code has a direct impact on the potential sources of lead in water distribution systems. The extensive rehabilitation of old buildings throughout the city surely results in more than 50 percent water service line replacement. Therefore, assuming that the code was obeyed, the rehabilitated structure would not contain any lead service lines. Furthermore, if the work is less than 2 years old, the solder should be lead-free.

These rehabilitated structures could not be identified from any of the available records. A second consideration arising from this provision of the code involves those buildings that receive less than 50 percent water service line replacement. In these cases it is possible that only the easily accessible lines have been replaced.

1.4.1.4 Water Service Requirement

General water service regulations require that every building, including separate business establishments having an outside entrance, have an independent water connection with a public or private water main. Also, it is required that installation of every water service line be at a right angle to the lot line common to the property and the public way under which the main lies.

The exceptions to the independent and separate service requirement occur when a building is located in an interior lot behind another building such that service line cannot be established directly from the main or line cannot be installed via an adjacent alley, courtyard, or driveway. In these cases, the code allows the extension of the water service line from the front building to the rear building. This arrangement is then considered to be one service line.

1.4.1.5 Piping System Materials

The District of Columbia Plumbing Code has adopted a modified version of the Building Officials and Code Administration (BOCA) schedules for water service line and water distribution line. Tables 1-5 and 1-6 show the approved water service line materials and water distribution line materials, respectively.

1.4.2 District of Columbia Plumbing Association and Plumbing Practices

The District of Columbia Metropolitan Area has a functional plumbing association, which is based in Washington, D.C. The association is known as Metropolitan Washington Association of Plumbing, Heating, and Cooling Contractors (MWAPHCC). It is a local chapter of the National Association of Plumbing, Heating, and Cooling Contractors. This association, which has been in operation

Table 1-5

Schedule of District of Columbia Approved Water Service Pipe Materials

Material	Standard
- Acrylonitrile butadiene styrene (ABS) plastic pipe	ASTM D1527 ASTMD2282
- Brass pipe	ASTM B43
- Cast iron (ductile iron) water pipe	ASTM A377; AWWA C151
- Copper or copper alloy pipe	ASTM B42; ASTM B302
- Copper or copper alloy tubing (Type K & L)	ASTM B75; ASTM B88 ASTM B251
- Polyvinyl chloride (PVC) plastic pipe	ASTM D2846; ASTM F441;ASTM F442
- Polybutylene (PB) plastic pipe tubing	ASTM D2662; ASTM D2666 ASTM D3309
- Polyethylene (PE) plastic pipe	ASTM D2239
- Polyethylene (PE) plastic pipe	ASTM D2737
- Polyvinyl chloride (PVC) plastic pipe	ASTM D1785; ASTM D2441; ASTM D2672

Table 1-6

Schedule of District of Columbia Approved Water Distribution Pipe Materials

Material	Standard
- Brass pipe	ASTM B43
- Copper or copper alloy pipe	ASTM B42; ASTM B32
- Copper or copper alloy tubing	ASTM B75; B88;ASTM B251
- Polyvinyl chloride (PVC)	ASTM D2846;ASTM F441; ASTM F442
- Galvanized steel pipe	ASTM A53; ASTM A120
- Polybutylene (PB) plastic pipe	ASTM D3309

since the 1890s, is the oldest trade association in the country. Although membership is open to all eligible master plumbers, the existing association comprises only 10 to 15 percent of all the master plumbers in the Washington, D.C., Metropolitan Area.

Several registered master plumbers in the District of Columbia Metropolitan Area were contacted to obtain an understanding of current plumbing practices and how and when they have changed over the years. After making telephone contact, a questionnaire was sent to the plumbers who were willing to participate to determine whether they served the District and to set up a meeting to interview them on plumbing practices.

Response to the questionnaire was poor. Only 4 plumbing firms responded out of the 20 questionnaires that were mailed. In an attempt to obtain greater cooperation, MWAPHCC was contacted for help. The President of the Association, Mr. James Wimmel, provided excellent cooperation by distributing the questionnaires directly to 30 of the members at the Association's monthly meeting. Ten plumbers returned their questionnaires; five of whom agreed to be interviewed.

Appendix A contains the five interviews. The small number of interviews makes it difficult to draw any conclusions as to the overall state of current plumbing practices. Some of the more consistent remarks are presented as follows:

- There was no indication of installation of any new lead service lines since the mid-1940s by those plumbers whose service involved installation or replacement. Some repair work involving lead service lines took the form of either sectional or complete replacement of the existing service lines. Current water service lines are made of copper, brass, cast iron, or some alloys.

- The common use of lead service lines years ago was based on the fact that lead service lines were easy to work with, and the pipe came in rolled lengths and required very few couplings for most installations. Furthermore, lead pipe was less expensive than the other competitive materials.

- With respect to the use of lead solder, it was discovered that whereas the use of the pure lead solder and solder made of alloy of lead and other materials has been discontinued and banned for use in drinking water applications, they are still on the market and can be used in other areas such as drainage, sewer, and vents.

- Inspection of plumbing supply centers and responses from master plumbers confirmed that there are no more lead lines available in the market. The following three categories of lead solder are on the market and in use by plumbers:

- Alloy of 50 percent tin and 50 percent lead used for drainage and sewer service lines.

- Alloy of 95 percent tin and 5 percent antimony (nonlead).

- Alloy of 95 percent tin, 4.5 percent copper, and 0.5 percent silver; the only one approved for water service lines (nonlead).

The two areas of concern with regard to plumbing practices and lead in drinking water are lead service line repairs and the potential for continued application of lead solder in potable water distribution systems. Interviews with the plumbers revealed that, while the know-how needed to work with lead service lines is disappearing, it is still possible that an existing private lead service line can be repaired rather than replaced. These repairs involve cutting the defective section and fitting and soldering a copper sleeve. This practice, while not illegal, can introduce lead into the drinking water due to the disturbance of the protective coating inside the pipe and the possible presence of lead filings generated by the cutting action. The plumbers say that they encourage homeowners to replace all lead service lines in the house. However, economic issues are often the deciding factor, and the owner may choose the less expensive method.

As previously stated, lead solder is still available for use on nonpotable distribution systems. Its use for drinking water lines is illegal. Enforcement of this ban is difficult. Lead solder is much less expensive than no-lead solder, and its fluxing characteristics and ease of use are superior. These two advantages make lead solder attractive to homeowners and plumbers who are either ignorant of the potential hazards or do not have a master plumber license to lose.

1.4.3 Distribution System Maintenance Personnel Interviews

Eight service line crew supervisors were interviewed in an attempt to understand past and current practices on service line replacement and to obtain additional, first-hand information on lead service line distribution throughout the District. Each supervisor was interviewed separately; interviews were brief, lasting only 10 to 15 minutes, to avoid interfering with their work. Appendix B contains all of the interviews. Summary results are presented in this subsection.

Questionnaires that rely on personal experience and recollection tend to produce inconsistent results, especially when the sample size (in this case, eight) is small. It is not possible to use the information obtained by the questionnaires to assign service line distribution probabilities or any related statistical inferences. However, this was never the objective of this effort. Instead, the questionnaires can be used to get an idea of service line

maintenance practices and to obtain empirical information on service line material types.

The eight supervisors interviewed were highly experienced. All but 1 supervisor had more than 10 years of experience; 4 had more than 20 years of experience. None of the supervisors had ever installed a lead service line, and they have been replacing lead service lines for the last 3 to 4 years. Responses on service line material varied somewhat. There was some consensus that lead service lines are more prevalent in the northwest quadrant, although three supervisors thought that the distribution was approximately equal throughout the District.

The opinion of BWS, and the initial results from the tap records, indicates that lead service lines tend to appear most often in the northwest quadrant. The crews attempt to determine the service line material before arriving at the site either by checking the maintenance file or by calling the dispatcher (who then checks the maintenance file). The supervisors stated that they occasionally get an indication of the service line material, and that on those occasions when lead is expected, they actually unearth lead "most of the time." The supervisors also noted that the material of the customer side of the service line (i.e., from the curb stop to the meter) is rarely different from the District side (from the curb stop to the main), although several supervisors thought that the service lines differed about half the time. Information gathered from the Meter Replacement Program crews indicate that both sides of the service line are the same material nearly all the time.

1.5 LEAD WATER QUALITY DATA

Water quality data were gathered from several sources. DCRA provided data on lead in drinking water that it had collected during several sampling efforts. These data provided insight into the lead concentrations in water at the tap. The U.S. Army Corps of Engineers provided water quality data for both water treatment plants and several sampling points located throughout the distribution system.

The following subsections describe the efforts in collecting and organizing these data. Preliminary analyses were performed on the data, which are also described and the results presented. These data are used to develop recommended strategies for reducing the exposure to lead in drinking water and for developing predictive techniques for identifying lead service lines.

1.5.1 Department of Consumer and Regulatory Affairs Lead-in-Water Sampling Studies

Three distinct lead-in-water sampling efforts conducted by the District in 1986 and 1987 were analyzed. The results of this sampling were collected into three databases. For the purposes of this study, the three databases will be identified as Data Set 1, Data Set 2, and Data Set 3. Because of differences among the three

sampling efforts, each will be described separately. The following paragraphs contain a brief summary of each sampling effort, followed by a discussion of the associated database. A detailed discussion of the sampling protocols is given in Subsection 1.5.2. A brief analysis of the data is given in Subsections 1.5.3 and 1.5.4.

Data Set 1 was collected from 156 buildings along Sherrier Place, N.W. Two types of samples were collected: midday and first flush. A 1-liter midday sample was collected by District personnel working door to door. The sample was generally collected at the kitchen faucet, although it was reported that some samples were collected at outside spigots. Three separate first flush samples labeled A, B, and C were collected. These three first flush samples were collected by the homeowner in expandable "cubitainers" provided and labeled by the District. Sample A was to be taken as the first water out of the tap in the morning; Sample B after running the water for 1 minute; and Sample C after running the water for 15 minutes. The three cubitainers were then placed outside the front door of the residence where they were collected by District staff.

The samples were analyzed for lead with a detection limit of 2 ug/L. The results of the sampling were entered into a DecMate personal computer. The data were transferred from the DecMate to an IBM personal computer compatible format via DCRA's Vax 11/730 mainframe computer. This data file was then modified and loaded into a dBASE IV database file.

Several issues had to be resolved after examining this database. First, lead values that were less than the detection limit of 2 ug/L were entered as "less than 2." For the purposes of analysis, a standard convention of assigning a value halfway between zero and the detection limit is generally accepted. Therefore, all values less than 2 in the database were changed to a value of 1.0. Second, two records having the same address (5100 Sherrier Place) were identified. However, as the sample IDs were different for the two records, both records were retained for analysis. Finally, three pairs of records having the same sample ID, either first flush or midday, were located. One of the records, however, had an address of "0 Sherrier Place." It was decided that this record was in error, and it was deleted. The remaining two pairs of records were corrected by deleting the sample ID and associated result from one record of the pair, making sure that at least one sample remained at each address.

Data Set 2 was collected after Data Set 1. Midday and/or first flush samples were collected from 757 addresses. Sampling procedures, analysis, and data entry were identical to that for the Sherrier Place Study.

These data were entered into dBASE IV in the same manner as Data Set 1. Close examination of the data resulted in two minor updates of the database. First lead values less than the detection limit were entered as "less than 2." These values were replaced with

values of 1.0 as in Data Set 1. Next, 10 pairs of records were identified that were exact duplicates. This was corrected by deleting one record of each pair.

Both Data Set 1 and Data Set 2 were included in a report issued by the Water Hygiene Branch (WHB) of DCRA. Data Set 3 consisted of lead-in-water data from sampling performed after the completion of this report. Data Set 3 consisted of two first flush samples collected by the homeowner and sent directly to a laboratory for analysis. Since the sampling protocol for Data Set 3 required discarding the first 1 cup of water from the first flush sample, the results are expected to be different from Data Sets 1 and 2. The laboratory analyzed 1,330 first flush samples.

This last database was received in dBASE IV format. Examination of the data showed several issues needing attention. First, there were 12 records that contained no data; these were deleted. Next, four pairs of records were identified that were identical, except for insignificant differences (e.g., different spellings of last names, different phone numbers, etc). One record of each pair was deleted to solve this problem. Next, 29 pairs of records were identified that had identical sample IDs, but different addresses or different values of lead concentrations. Since there were differences, it was decided to retain both records of the pair in the database.

1.5.2 Review of Sampling Collection Protocols

As described in Subsection 1.5.1, several sets of water samples were collected and analyzed for lead. In some cases samples were collected by DCRA personnel, and in other cases the samples were collected by the homeowners. The method of collecting the samples varied with the type of sample taken (e.g., first flush A, B, or C, or midday).

In all cases samples were collected in cubitainers and preserved with acid. The midday samples collected on 6 November 1986 (Data Set 1) were collected by WHB personnel from 83 homes on Sherrier Place. WHB personnel were instructed to take samples from the kitchen if possible, but the cold water tap was not specifically mentioned. WHB personnel were instructed to run water for 2 minutes prior to sampling if water had been run during the day. If water had not been used, water was allowed to run for 15 minutes before sampling.

If permission to sample from inside a residence was denied, but a sample from the outdoor spigot was granted, then the water was allowed to run for 10 minutes prior to sampling. WHB personnel were instructed to record the name of the person collecting the water sample, and the time and location of the sample.

The first flush samples collected on 8 November 1986 (Data Set 1) from 136 residences on Sherrier Place were collected by individual homeowners. The homeowners were instructed to sample from a cold

water tap first thing in the morning before using any water, but were not instructed to sample from the kitchen. Homeowners were instructed not to sample if toilets had been flushed within 6 hours of the sampling time. The first sample, marked A, was collected immediately after turning on the faucet. The sample marked B was collected after the water was run for 1 minute, and the sample marked C was collected after the water had run for an additional 15 minutes (presumably 16 minutes total). No instructions were given for recording the name of the person collecting the sample, or time or location of sample collection.

For comparison, draft guidance from EPA specifies that samples should be taken from the cold water kitchen tap in single-family homes (U.S. EPA, 1988, "Lead Monitoring Protocol for Drinking Water System," 13 April 1988). It should be noted that this guidance did not exist at the time that the District performed the sampling. A series of four samples are recommended for "Morning First Draw" samples as shown in Table 1-7.

After the samples are collected, the water also should be tested for pH, alkalinity, and residual chlorine. In addition, one sample should be taken from the treatment plant and analyzed for pH, lead, and alkalinity (total and phenolphthalein). The water is then shut off and all plumbing in the house is not used for one-half hour. Then, the one-half hour samples are taken for comparison with the first draw samples as shown in Table 1-8. This "Fixed First Draw" sample is being considered as an alternative to the "Morning First Draw."

Both protocols used to collect water samples in the District in 1986 had some potential problems that could affect the concentration of lead in the sample:

- Instructions to WHB personnel did not specifically request samples from the cold water tap. Samples taken from the hot water tap could result in higher lead concentrations than from a sample taken from the cold water tap.

- Relying upon homeowners to take first flush samples introduces a whole range of potential sampling errors. Some problems related to this were discovered, such as sampling from another residence and not allowing water to flush between samples.

- Homeowners were not instructed to sample from the kitchen, where most water ingested would come from. This could introduce inconsistencies in sample results.

- Homeowners were not instructed to record time or location of sample, or other relevant observations.

The aforementioned criticisms describe potential problems that could affect sampling results. It is not evident from the data

Table 1-7

Recommended Lead Monitoring Protocol
Morning First Draw*

Sample No.	Description	Purpose
1	250 ml taken immediately upon opening the tap without wasting water, then shut off the tap.	Contribution of faucet assembly to lead levels.
2	750 ml taken immediately after Sample No. 1, without wasting any water between Sample No. 1 and Sample No. 2.	Contribution of household plumbing (solder) to lead levels.
3	250 ml sample collected after the water turns cold, or some other indication that the water is representative of the service line.	Contribution of service line to lead levels.
4	250 ml sample taken after water has run for about 3 additional minutes after Sample No. 3, or has otherwise been determined to be representative of water in the main.	Contribution of distribution system to lead levels.

*Samples should be taken after water has been standing overnight for at least 8 hours.

Source: U.S. EPA, Lead Monitoring Protocol for Drinking Water Systems, 13 April 1988.

Table 1-8

Recommended Lead Monitoring Protocol
Fixed First Draw

Sample No.	Description	Purpose
1	250 ml taken immediately upon opening the tap, without wasting any water, then shut off the water.	Contribution of faucet assembly to lead levels.
2	750 ml taken immediately after Sample No. 1, without wasting any water between Sample No. 1 and Sample No. 2.	Contribution of household plumbing (solder) to lead levels.
3	250 ml sample taken after the water turns cold, or any other indication that the water is representative of the service line.	Contribution of service line to lead levels.

Source: U.S. EPA, Lead Monitoring Protocol for Drinking Water Systems, 13 April 1988.

that any of these problems actually occurred. In addition, standard QA/QC samples were collected and analyzed (e.g., duplicates, spikes, replicates) and did not indicate any problems with laboratory procedures. In addition, the large differences between EPA protocols for "Morning First Draw" and "Fixed First Draw," which EPA considers to be roughly equivalent, underscore the point that sampling for lead in drinking water is an imprecise science at best. The sampling protocols used by DCRA fall within the EPA guidelines.

1.5.3 Relationships Between Sample Types

The sampling programs described in Subsection 1.5.1 collected two basic sample types: midday and first flush. The midday sample was a single 1-liter sample. The first flush sample consisted of a set of three distinct 1-liter samples. The two types of samples were collected in different fashions (as described in Subsection 1.5.2), and to examine lead levels in different areas of concern. This subsection describes the expected purpose of each sample type.

The midday sample was meant by DCRA to represent the water intake a consumer would typically be expected to ingest. As described in Subsection 1.5.2, the water was allowed to run for 2 minutes if water had been in use throughout the day, and for 15 minutes if no water had been used previously.

The sampling procedure for the set of three first flush samples is described in detail in Subsection 1.5.2. Sample A would represent the effect of lead leaching into the water from the interior plumbing system. Sample B would be likely to contain water from the service line, and thus give an indication of the amount of lead contributed by the service line. Finally, Sample C would consist of water from the distribution system. It was expected that Sample C would have a low lead concentration. It was also expected that a Sample C would be equivalent to a midday sample.

The set of first flush samples provide the District with a good understanding of both the lead concentrations in drinking water, as well as a general indication of where the lead is originating. Sample A represents what is probably the highest lead concentration a consumer would be exposed to in drinking water from the tap. This sample corresponds to the at-the-tap sampling proposed by EPA in the most recently proposed lead regulations. Sample B should show the contribution of the service line to lead levels at the tap. Finally, Sample C, representing water in the distribution system having minimal contact with the service line and interior home plumbing, will provide a baseline against which Samples A and B can be compared.

It is important to note, however, that due to differences in interior plumbing arrangements, Sample B may not always represent water from the service line. The only way to verify that the sample was from the service line is to inspect the interior plumbing, calculate the volume of water held there, and then flush

this amount from the tap prior to sampling. Since this was not possible in all cases, the sampling protocol called for a 1-minute flush prior to sampling, which in most cases will result in a service line sample.

The midday sample represents distribution system water, which is expected to have low lead concentrations. It is not indicative of the worst-case situation that results from lead leaching into the water from household plumbing systems (including lead service lines). It does, however, show localized differences in lead levels within the distribution system.

1.5.4 Relationship of Lead Levels to Treatment Plant Parameters

Water quality data were obtained in dBASE format from the U.S. Army Corps of Engineers (COE) for both the Dalecarlia and McMillan water treatment plants. The data also included sampling results for 10 sampling points located throughout the distribution system. Data available included values for alkalinity, pH, hardness, temperature, and lead concentrations from October 1984 through May 1989. Water quality data prior to October 1984 were obtained in paper format, but were not included in this analysis. A more detailed analysis of water quality is presented in Section 2.

The first parameter considered was lead concentration. The proposed lead regulations call for quarterly sampling from each point of entry to the distribution system for water systems serving more than 3,300 people. A system is considered to be in noncompliance if the Maximum Contaminant Level (MCL) of 5 ug/L is exceeded in any one sample. An examination of the water quality data from the District's two water treatment plants shows that the lead concentration exceeded the proposed MCL in two samples taken since October 1984. The two occurrences are as follows:

Location	Date	Lead Concentration (ug/L)
McMillan WTP	5/3/85	12.3
McMillan WTP	6/3/85	13.4

The next water quality parameter evaluated was pH. The proposed lead regulations will require water systems serving more than 3,300 people to take and analyze 20 water samples per quarter to determine compliance with certain "no-action" levels. Water systems that exceed these "no-action" levels will be required to reduce the corrosiveness of their water through treatment. The "no-action" level for pH calls for no more than 5 percent of the samples to have a pH less than 8.0. These samples are to be taken from the cold water kitchen tap of homes considered to be at high risk for lead or copper problems, including:

- Residences at the ends of the distribution system (i.e., dead-ends or areas of low or no flow); and either
- Residences that have lead solder that is less than 5 years old in their plumbing systems, or
- Residences with lead service line connections and or lead interior plumbing.

The pH data from the 10 sampling points in the distribution system were examined for compliance with the "no-action" level for pH. Out of a total of 5,214 samples in the database, 3,410 had a pH of less than 8.0. Although these samples were not taken in accordance with the proposed sampling protocol (i.e., at the kitchen tap of a worst-case residence), they do indicate that the District would likely be in noncompliance with this "no-action" level if the proposed sampling protocol were followed.

Next, lead concentrations at the 10 distribution system sampling points were compared to lead concentrations at the 2 treatment plants. This was done to determine the amount of lead contributed by the distribution system and sampling point plumbing system. The database was first sorted by sample location and date. Then, the average value of lead concentration for a given date for the 10 sampling points was compared to the average for the same date for the 2 treatment plants. The comparison shows that lead levels in the distribution system are almost always greater than or equal to lead levels in water leaving the treatment plant.

Next, an attempt was made to relate water temperature to lead levels in the distribution system. Lead solubility increases with temperature, and seasonal variations in lead levels in drinking water have been reported in other cities. Monthly average water temperatures were calculated using data from October 1984 to April 1989. Finally, monthly average lead concentrations were calculated using the data from the 10 distribution sampling points.

The resulting averages were plotted as shown in Figure 1-5. This graph shows that there is apparently no increase in lead levels in the distribution system associated with increasing water temperatures.

The final water quality parameter examined was alkalinity. Although the most recently proposed lead regulations do not include a "no-action" level for alkalinity, EPA did consider using alkalinity as a "no-action" trigger, and the final rule may include such a provision. The "no-action" alkalinity level considered by EPA called for the water system to reduce the corrosiveness of its water if total alkalinity in 95 percent or more samples was not 30 mg/L or higher. The sampling procedure would be identical to that for the pH "no-action" level.

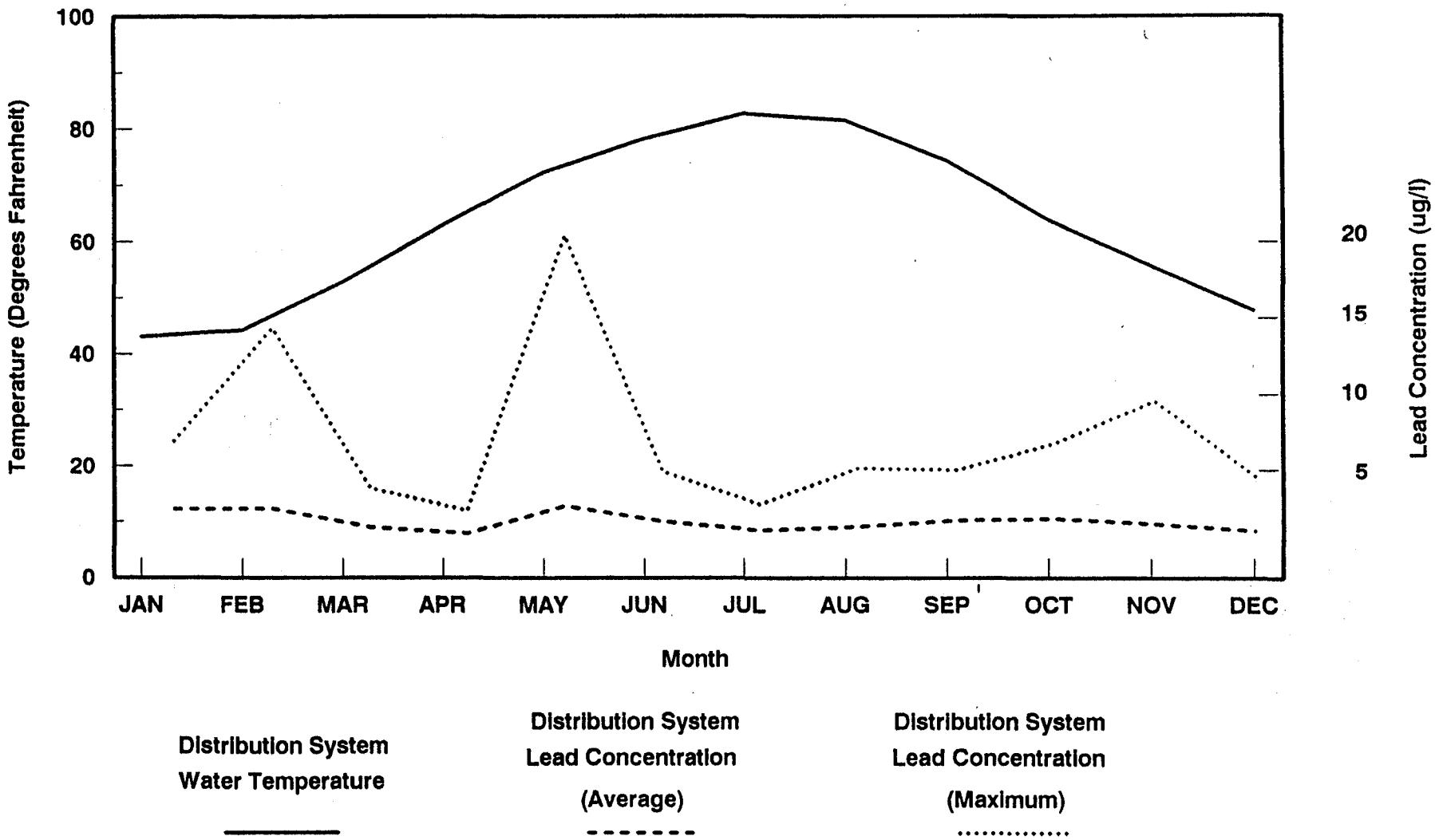


FIGURE 1-5 RELATIONSHIP BETWEEN WATER TEMPERATURE AND LEAD CONCENTRATIONS

only 9 had an alkalinity less than 30 mg/L. Although these samples were not taken in accordance with the proposed sampling protocol (i.e, at the kitchen tap of worst-case residences), it is apparent that the District would be in compliance with a "no-action" level for alkalinity, since the alkalinity in the distribution system is almost always greater than 30 mg/L.

1.6 SERVICE LINE DATA

This subsection contains a summary of data extracted from the Tap Data File and input into the database. As described in Subsection 1.2.1, a total number of 126,099 records was input into the database.

The lead service line data summarized in Table 1-9 comprise a list of the number of records per ward with positive indication of lead service lines based on information in the Tap File, the Meter Replacement Program, the Street Replacement Program, the Lead Service Replacement Program, or the Project Locator File.

Analysis of these data from the point of view of the date that service was installed revealed a few very important facts:

Alkalinity data were examined for the 10 distribution system sampling points. Out of a total of 5,214 samples in the database,

- Before the year 1950, the total existing number of records is 95,583. Of these 95,583 records, 8,844 records have a positive indication of lead service line material. Of the remaining 86,739 records, 49,420 are not lead, 37,319 are unknown.

- After the year 1950, 140 records were found to have positive indication of lead service line material.

- The most recent indication of an installation of a lead service line was 1977.

As described in Subsection 1.2.9 and given the impact that new construction might have in potentially exposing the population to actively leaching lead solder, new construction data were collected from the Planning Commission Files on construction permits starting in 1984. Table 1-10 is a summary of new construction data per ward, including the number of buildings by age group between 0 to 5 years old.

1.7 WATER QUALITY SAMPLING DATA

The data from the three sampling efforts was input into dBASE IV as described in Subsection 1.5.1. Because Data Set 1 and Data Set 2 were included in a single report, they were combined into a

Table 1-9

Summary of Service Line Data

Ward		Number of Records with Recorded Lead Service Lines	Total Number of Records
1		644	11,088
2		545	14,657
3		1,997	17,997
4		1,990	19,518
5		1,174	18,370
6		1,186	17,854
7		854	15,004
8		430	5,549
	Subtotal	8,820	120,037
	Ward Unknown	167	6,062
	Total	8,987	126,099

Table 1-10

Summary of New Construction Since 1984

	Number of Buildings		
Ward	0 to 2 Years of Age	2 to 5 Years of Age	Total
1	30	38	68
2	132	279	411
3	319	301	620
4	122	69	191
5	85	156	241
6	117	34	151
7	38	73	111
8	13	39	52
*	9	26	35
Total	865	1,015	1,880

*35 records did not include a ward designation.

single database and analyzed together. Data Set 3 was analyzed separately. All analyses were performed after the changes were made to the database as described in Subsection 1.5.1.

The first step in the analysis was to sort the data into wards. Neither database, however, originally contained a value for ward. A two-step process was necessary to assign a ward to each record. First, each record was updated to include its appropriate square by linking the database, by address, to a second database containing addresses and squares. Second, each record was then updated to include its appropriate ward by linking the database, now by square, to a second database containing squares and wards.

Unfortunately, it was not possible to assign a ward to each record. This was mainly because the database containing address and square did not contain every address, and certain records did not match. In addition there were other minor inconsistencies in the addresses (spelling errors, abbreviations, unusual addresses, etc.) that could not be corrected easily.

A breakdown of the water quality sampling data by ward is shown in Figure 1-6. By far the largest number of samples was taken in Ward 3 (66.3 percent of Data Sets 1 and 2, and 44.9 percent of Data Set 3). Ward 8 had a total of only 20 samples out of both databases, compared to the total of 1,652 samples for Ward 3.

Finally, the minimum, maximum, and average lead concentrations were calculated for each sample type (midday and first flush) by ward. These results are summarized in Table 1-11 (Data Sets 1 and 2) and in Table 1-12 (Data Set 3).

1.8 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn from the investigation of the District's records:

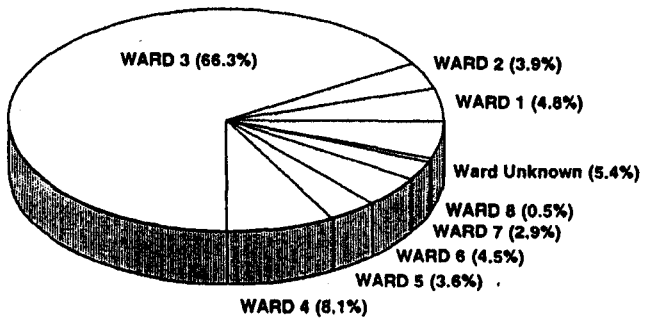
- A large amount of data is available to the District from a variety of sources. However, the data sources are scattered among a number of agencies and/or departments. Individual agencies/departments often are not aware of the information available from other sources.

- The District's Tap File, which contains information about service line installations, is incomplete and/or outdated in some cases.

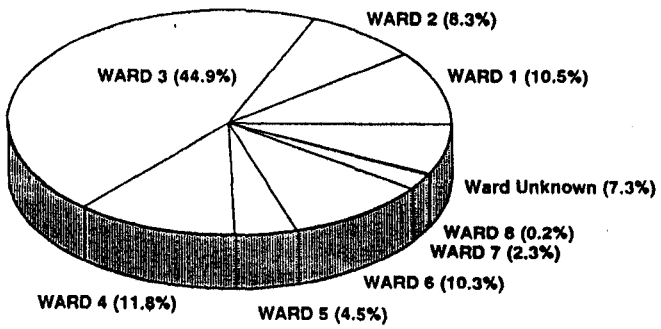
The following recommendations are made:

- The Tap File Database should be installed on a computer(s) and used by District personnel to assist in the Lead Service Replacement Program. The Tap File Database User's Guide presented in Appendix H can be used to familiarize personnel with the database.

- Data from the Meter Relocation Program, Street Replacement Program, and Lead Service Replacement Program should be used to keep the Tap File Database current.



DATA SETS 1 and 2



DATA SET 3

FIGURE 1-6 GEOGRAPHIC DISTRIBUTION OF SAMPLING DATA

Table 1-11

Summary of Lead Concentrations for Data Sets 1 and 2

WARD	NUMBER OF SAMPLES		MIDDAY SAMPLE			SAMPLE A			SAMPLE B			SAMPLE C		
	MIDDAY	FIRST FLUSH	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX
1	45	0	1	6.09	115	--	--	--	--	--	--	--	--	--
2	34	6	1	3.26	9	2	14	39	1	6	21	2	8	27
3	555	132	1	6.66	131	1	16	91	1	18	141	9	1	78
4	76	0	1	6.09	84	--	--	--	--	--	--	--	--	--
5	33	1	1	14.94	309	1	1	1	1	1	1	4	4	4
6	42	0	1	3.88	23	--	--	--	--	--	--	--	--	--
7	27	0	1	6.52	45	--	--	--	--	--	--	--	--	--
8	5	0	1	1	1	--	--	--	--	--	--	--	--	--
Not designated	50	2	1	8.16	217	1	3.50	6	1	2	3	1	11.50	22
District Total	867	141	1	6.68	309	1	15.96	91	1	17.5	141	1	9.28	78

Notes: 1) All values given in ug/L.

2) Values less than the detection limit of 2 ug/L are listed as 1 ug/L.

Table 1-12

Summary of Lead Concentrations for Data Set 3

WARD	NUMBER OF SAMPLES		MIDDAY SAMPLE			SAMPLE A			SAMPLE B			SAMPLE C		
	MIDDAY	FIRST FLUSH	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX
1	0	140	--	--	--	1	10.86	124	1	7.88	116	1	1	1
2	0	110	--	--	--	1	18.61	389	1	10.83	324	1	1	1
3	0	597	--	--	--	1	13.08	399	1	11.70	308	1	1.08	47
4	0	157	--	--	--	1	15.36	278	1	14.57	292	1	1	1
5	0	60	--	--	--	1	23.92	558	1	13.42	152	1	1	1
6	0	137	--	--	--	1	10.09	106	1	9.07	117	1	1	1
7	0	30	--	--	--	1	6.53	28	1	5.53	25	1	1	1
8	0	2	--	--	--	3	4.50	6	2	3.50	5	1	1	1
Not Designated	0	97	--	--	--	1	12.76	210	1	13.56	357	1	1	1
District Total	0	1,330	--	--	--	1	13.57	558	1	11.35	357	1	1.04	47

Notes: 1) All values given in ug/L.

2) Values less than the detection limit of 2 ug/L are listed as 1 ug/L.

3) No Midday samples were collected as part of Data Set 3.

SECTION 2

METHODS OF REDUCING THE LEAD CONTENT IN DRINKING WATER

2.1 GENERAL DESCRIPTION OF EXISTING SYSTEM

The Washington Aqueduct Division (WAD) of the U.S. Army Engineer District, Baltimore, provides the water supply for more than 1 million residents of the District of Columbia (District) and northern Virginia, and to the Federal government. The mission of WAD is the collection, purification, and pumping of an adequate supply of potable water for the District of Columbia, Arlington County, and parts of Fairfax County. Water distribution in these areas is the responsibility of the local governments.

The water treatment system of WAD consists of two intakes from the Potomac River, two conventional treatment plants, and associated raw and finished water transmission lines and water storage facilities. A diagram of the intake and transmission system is shown in Figure 2-1.

Water from the Potomac River at the Great Falls dam and intake and the Little Falls dam and intake is pumped to the Dalecarlia Reservoir. Raw water from the Dalecarlia Reservoir is treated at the Dalecarlia treatment plant. The nominal capacity of the Dalecarlia treatment plant is 164 million gallons per day (mgd) average flow rate and 246 mgd peak flow rate. The average annual flow through the plant for Fiscal Year 1989 was 121 mgd.

Treatment consists of activated carbon addition, aluminum sulfate addition, coagulation, flocculation, settling, prechlorination, filtration (rapid sand and mixed media), hydrofluosilicic acid addition, post-chlorination, and lime addition for corrosion control. The capability for powdered activated carbon addition prior to filtration exists. Treated water is pumped from the Dalecarlia treatment plant to five service area pressure zones.

The McMillan treatment plant receives water from Dalecarlia Reservoir. Fluoride and alum are added to the raw water at Dalecarlia Reservoir before it flows by gravity to Georgetown Reservoir. The provision for addition of chlorine and activated carbon also exists. Georgetown Reservoir acts as a sedimentation basin for the water before it arrives at McMillan Reservoir. The McMillan plant was completely replaced and brought on-line in 1985. The treatment train at the McMillan plant is similar to the Dalecarlia treatment plant. A flow diagram of the McMillan treatment plant is shown in Figure 2-2. The capacity of the McMillan treatment plant is 100 mgd average and 150 mgd peak flow rate. The average annual flow rate for Fiscal Year 1989 was 60 mgd.

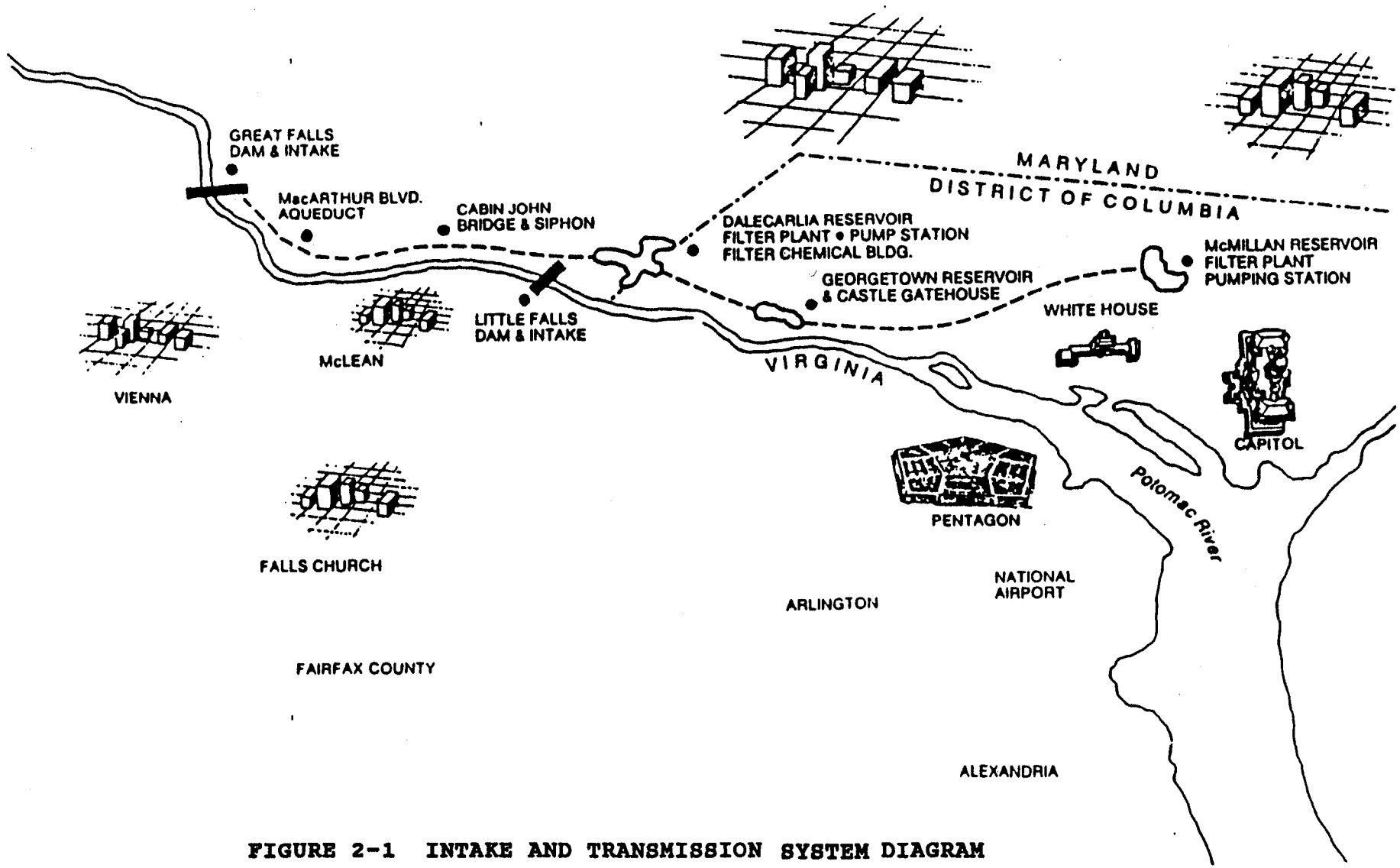


FIGURE 2-1 INTAKE AND TRANSMISSION SYSTEM DIAGRAM

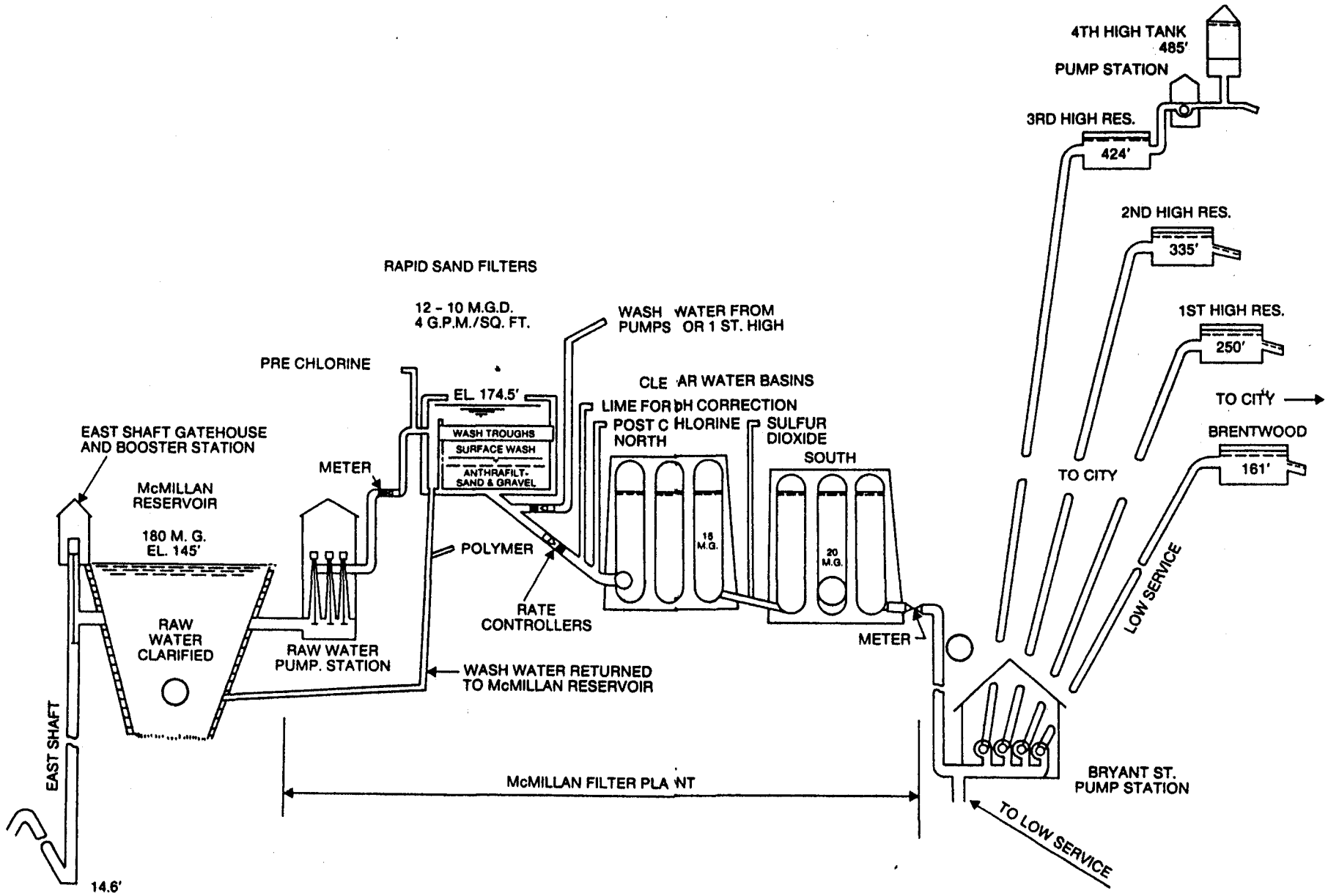


FIGURE 2-2 FLOW DIAGRAM OF THE MCMILLAN TREATMENT PLANT

2.1.1 Description of Current Corrosion Control Practices

Corrosion control is practiced at both treatment plants in the form of lime addition (calcium hydroxide). Lime addition has been used for many years at both treatment plants. Lime addition reduces corrosivity of plant-treated water by raising the pH and increasing the alkalinity. The dosage of lime applied to the filtered water is determined by the pH and turbidity of the water. The target pH level of between 8.0 and 8.5 is used as a guide. The amount of lime added to the filtered water is sometimes limited by the turbidity limit of 1 NTU since addition of lime also increases the turbidity of the finished water. Lime dosage is limited by turbidity mainly in the summer months. The monthly average lime dosage ranges from 39 to 109 pounds per million gallons at the Dalecarlia treatment plant and 32 to 62 pounds per million gallons at the McMillan treatment plant.

2.1.2 Database of Water Quality Data

A large quantity of water quality data is available for the District's water supply system. The Corps of Engineers collects raw water quality data, treated water quality data, and water quality data from sampling points located throughout the distribution system. These data provide the foundation on which the analysis of lead in the drinking water system is based.

Raw water samples collected and analyzed on a monthly basis for a variety of parameters were examined. The raw water data were examined to investigate lead levels in the water prior to treatment. Raw water quality data for the period 1984 through 1988 are presented in Appendix C.

Monthly water quality data after treatment at the two water treatment plants also were examined. The water quality parameters that were of particular interest were pH, alkalinity, calcium, temperature, total solids, hardness, and lead. These parameters were used in all water quality analyses presented in subsequent subsections of this report. Monthly average values of pH and alkalinity since 1985 for the Dalecarlia plant are shown in Figures 2-3 and 2-4. Treated water quality data for each of the treatment plants for the period 1984 through 1988 are presented in Appendix C.

The Corps of Engineers also collects water samples from 75 to 80 sampling points located throughout the distribution system. Of these, nine are used to sample for metals, including lead. The sites are sampled in pairs, with one pair being sampled once per month for a period of 3 months before samplers move to the next pair. These data represent water quality typical of that reaching a customer's service line. Monthly average values of pH and alkalinity of distribution system water since 1985 are shown in Figures 2-5 and 2-6.

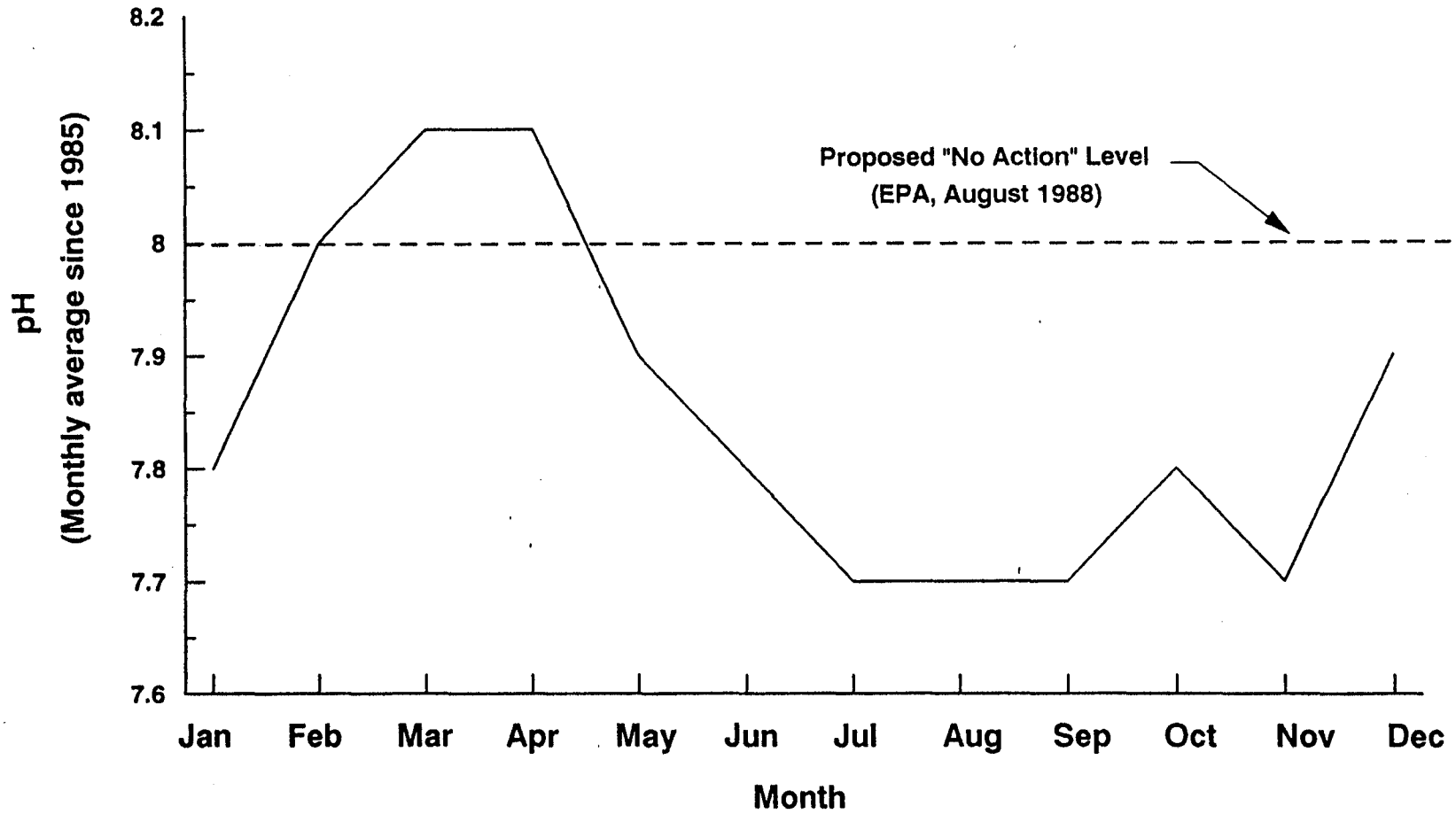


FIGURE 2-3 MONTHLY AVERAGE pH VALUES FOR THE DALECARLIA TREATMENT PLANT

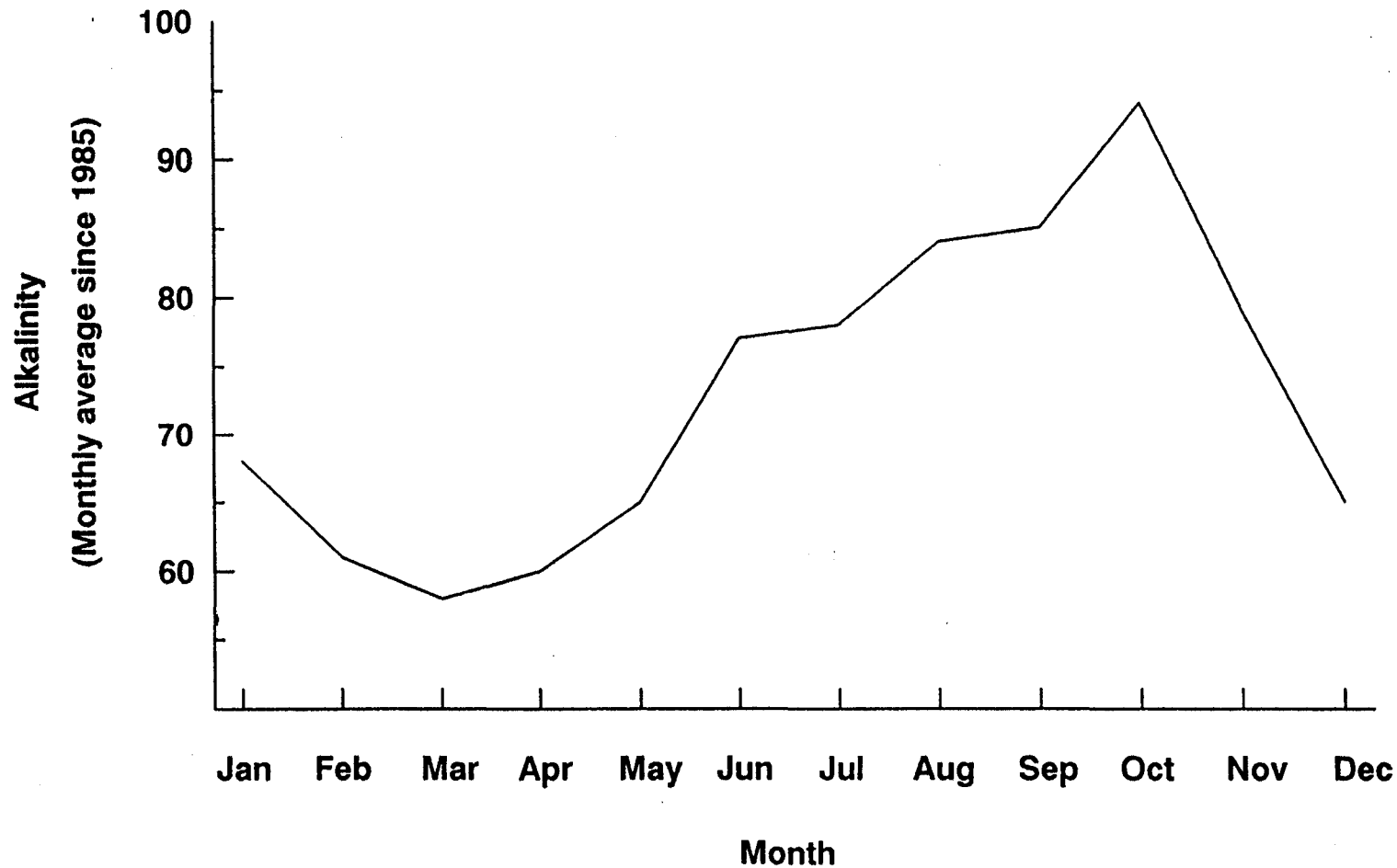


FIGURE 2-4 MONTHLY AVERAGE ALKALINITY VALUES FOR THE DALECARLIA TREATMENT PLANT

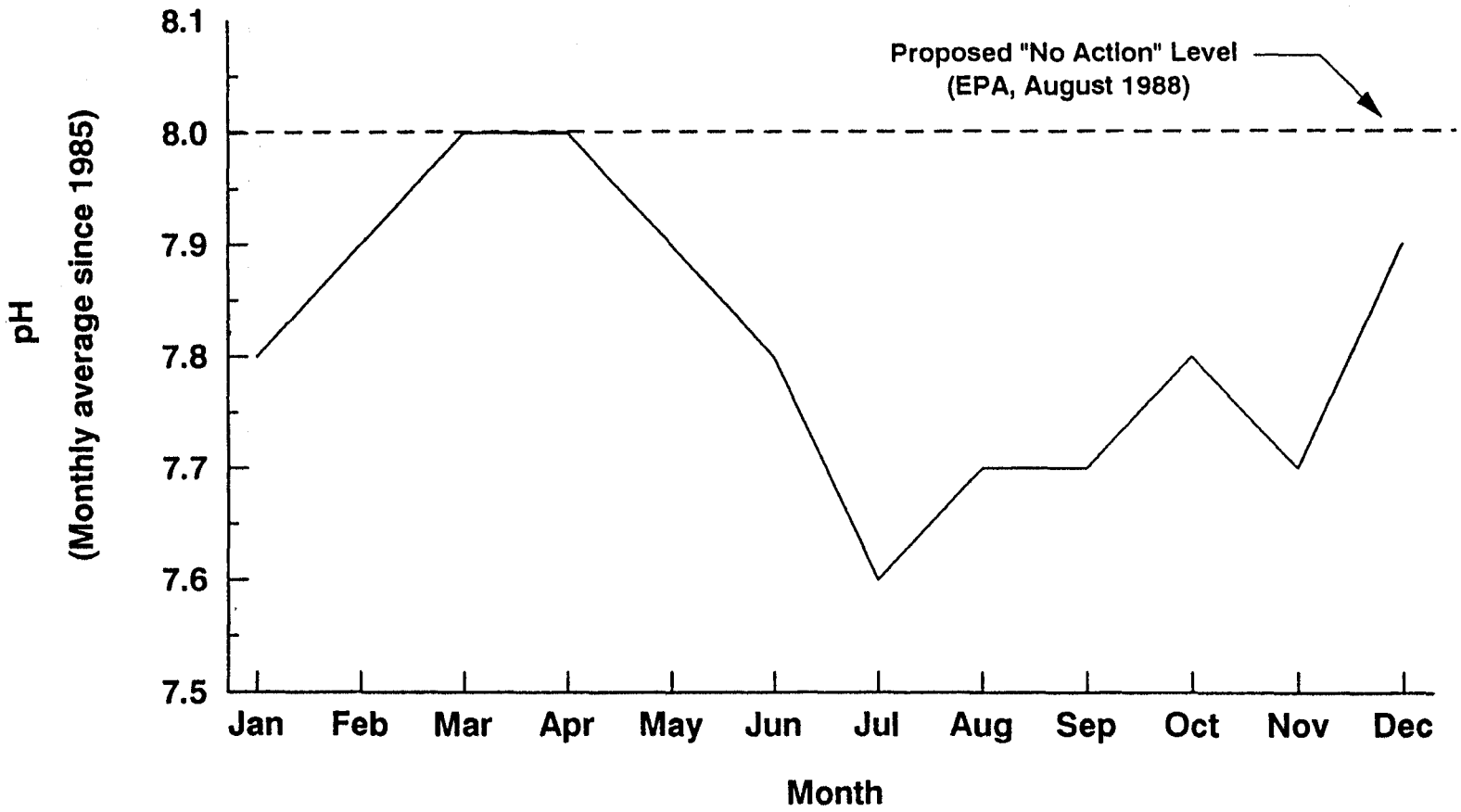


FIGURE 2-5 MONTHLY AVERAGE pH VALUES FOR DISTRIBUTION SYSTEM SAMPLING POINTS

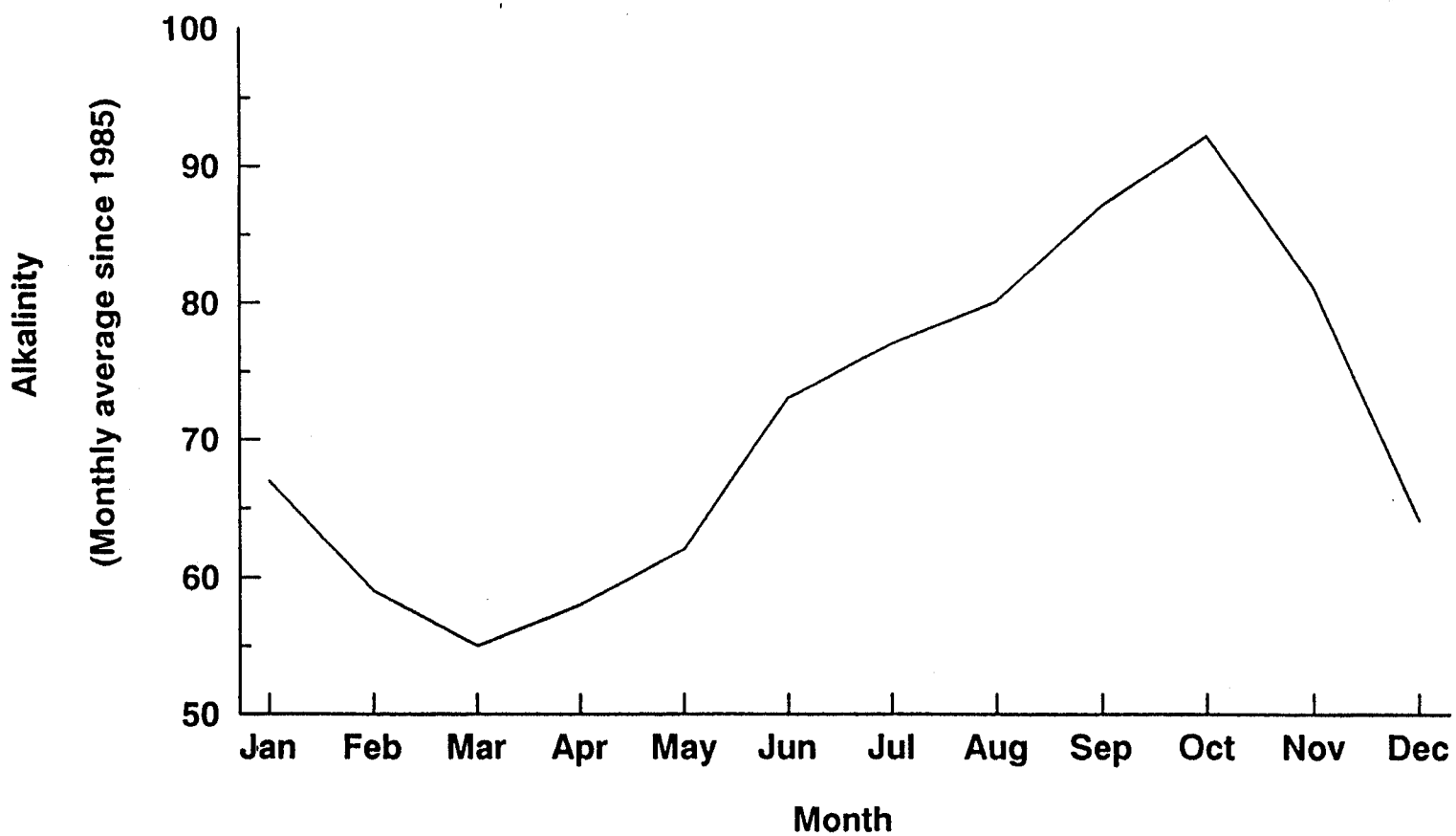


FIGURE 2-6 MONTHLY AVERAGE ALKALINITY VALUES FOR DISTRIBUTION SYSTEM SAMPLING POINTS

2.1.3 Langlier Index of Treated Water

One of the major sources of lead in drinking water is the corrosion of lead service lines and other lead-bearing materials in both the water distribution system and individual home plumbing systems. The Langlier Saturation Index (LSI) is an important indicator of whether such corrosion is taking place. This subsection briefly describes the LSI and how it is calculated and then presents the LSI calculated from water quality data for both the Dalecarlia and McMillan water treatment plants.

The LSI is a measure of the tendency of water to "lay down" or precipitate a protective coating of calcium carbonate ($CaCO_3$) in the interior service line wall. It is important to note that the LSI is not a measurement of the corrosiveness of water. It is simply an indication of the tendency of water to deposit a $CaCO_3$ layer. A thin layer of $CaCO_3$ is desirable as it keeps the water from contacting the service line and reduces the chance for corrosion. However, excessive deposits of $CaCO_3$ can reduce the carrying capacity of the service line.

EPA requires water system managers to calculate and report the LSI of their treated water. The basic procedure for calculating LSI has been in use since the early 1940s (Schock, 1984). The LSI is based on the effect of pH on the solubility of $CaCO_3$. The pH at which water is saturated with $CaCO_3$ is known as the pH of saturation or pH_s. At pH_s water will neither deposit nor dissolve a protective layer of $CaCO_3$. The LSI is defined as (EPA, 1984):

$$LSI = pH - pH_s$$

To calculate the LSI, the following information is needed:

- Total alkalinity as $CaCO_3$ (mg/L).
- Calcium as $CaCO_3$ (mg/L).
- Total dissolved solids (mg/L).
- pH.
- Temperature.

The pH_s can be calculated from these data using the following equation:

$$pH_s = A + B - \log(\text{calcium}) - \log(\text{total alkalinity})$$

Where: A = A constant based on temperature.
B = A constant based on total dissolved solids.

The calculated LSI can then be interpreted as follows:

- LSI > 0: Water is supersaturated and tends to precipitate a layer of $CaCO_3$.

- LSI = 0: Water is saturated (in equilibrium) with $CaCO_3$; a scale layer of $CaCO_3$ is neither precipitated nor dissolved.

- LSI < 0: Water is undersaturated and tends to dissolve $CaCO_3$.

Attempts have been made in the last several years to refine the calculation of LSI based on advances in the solubility chemistry of calcium carbonate and in solution chemistry. Schock (1984) described adjustments made to constants A and B that produce LSI figures more consistent with current aqueous chemical theory. He cautions, however, that it remains to be seen whether even these updated LSI calculations will provide any tangible improvements in the reliability of predicting calcium carbonate deposition.

Monthly water quality records from the Dalecarlia and McMillan water treatment plants were examined for the period 1984 through 1988. A LSI was calculated for each month using two different methods. The first method used the classic equations followed by EPA. These equations follow the typical water industry technique for calculating LSI. The second method used the corrections presented by Schock and produced slightly different values for LSI. The calculated LSI values are presented in Figure 2-7 for both methods.

2.2 LEAD IN THE DISTRICT'S DRINKING WATER

Lead is found in drinking water as a result of either naturally occurring lead in raw water sources or as a by-product of corrosion of plumbing materials. Source water lead levels are typically low, and the techniques for removal are well established. Controlling the corrosion of plumbing materials is more complicated, as there are many factors that affect the corrosion rate. This subsection describes the various ways in which lead enters the drinking water system and presents lead levels currently found in the District.

2.2.1 Sources of Lead

There are two potential sources of the lead found in any drinking water system. Lead may be present in the water source (i.e., the raw water), or may enter the water as a result of corrosion of plumbing materials containing lead. Raw water sources typically have low levels of lead. Of greater concern is lead entering the water as a result of corrosion within the water distribution system and of household plumbing materials. The following subsections describe the sources from which lead may enter the drinking water. Subsection 2.2.2 describes lead corrosion chemistry in more detail.

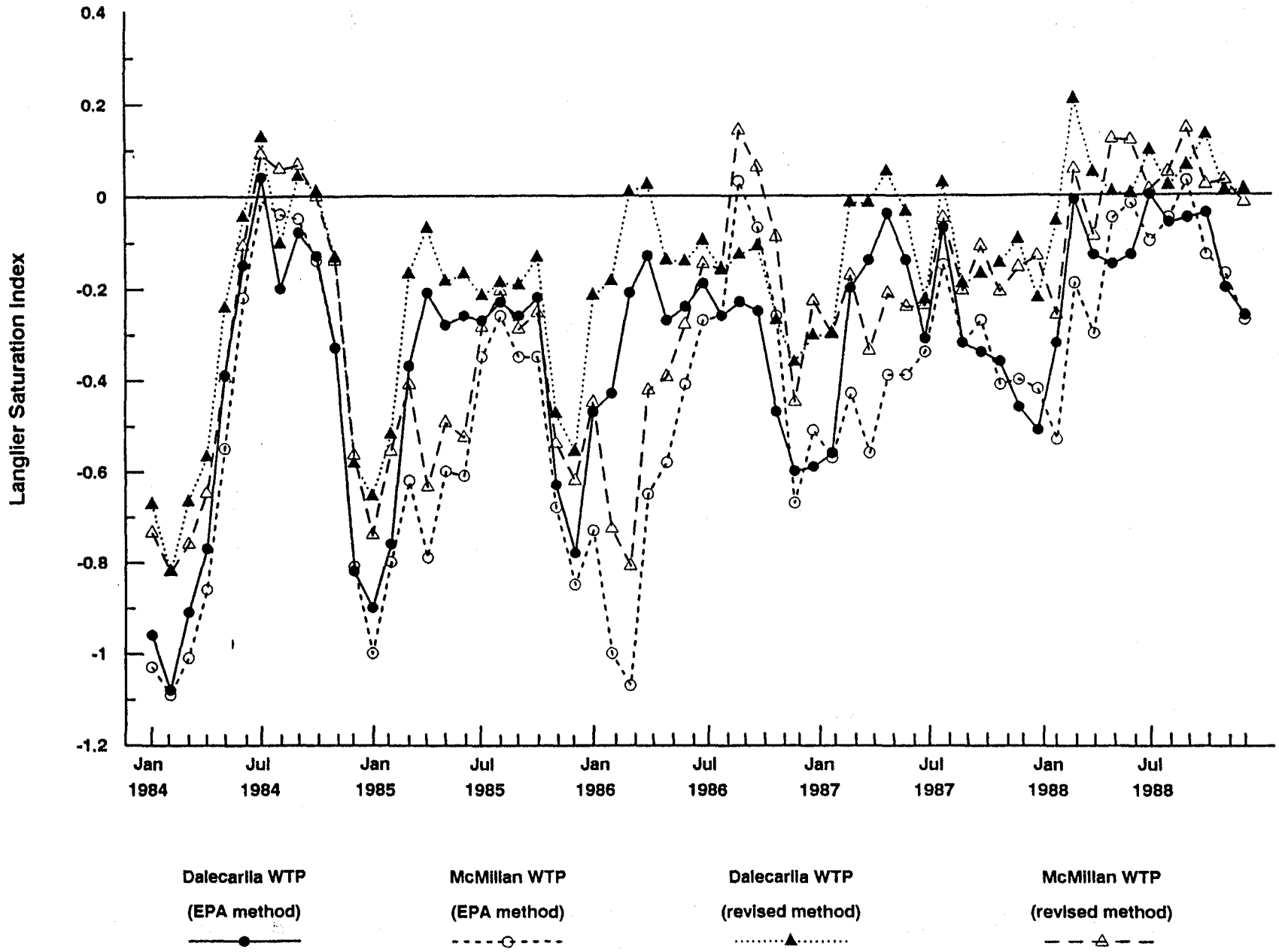


FIGURE 2-7 VARIATIONS IN THE FINISHED WATER LANGLIER INDEX

2.2.1.1 Lead in Source Water

Groundwater used as a drinking water source generally has very low lead concentrations (EPA, 1988). A 1967 study of 1,000 randomly chosen groundwater supplies (The National Inorganics and Radionuclides Survey or NIRS) found that approximately 5 percent of the samples taken exceeded 0.005 mg/L of lead. Due to the sampling procedure used, however, it was believed that lead may also have been present in the samples as the result of corrosion.

Therefore, EPA resampled the sources in the NIRS that showed positive results for lead, and found very few sources in which the lead level was above 0.005 mg/L. Based on these data, EPA has estimated that approximately 900 groundwater suppliers may have water leaving the treatment plant with lead levels greater than 0.005 mg/L (EPA, 1988). This represents approximately 1 percent of the community and nontransient, noncommunity water systems in the country.

Surface water typically contains higher levels of lead than do groundwaters. A significant portion of this lead exists in the form of suspended solids. The lead comes from naturally acquired lead in soils, atmospheric deposition, and industrial and municipal discharges to surface waters. However, water entering the distribution system from these sources generally has a much lower lead level than the raw water because of the effects of treatment, particularly coagulation and sedimentation.

EPA currently estimates that approximately 99 percent of the 219 million people in the country served by public water supplies (both surface and groundwater) are exposed to distribution water lead levels between 0 and 0.005 mg/L, and that the remainder are exposed to distribution water lead levels greater than 0.005 mg/L (EPA, 1988).

2.2.1.2 Lead as a Corrosion By-Product

Lead and lead-bearing materials are used in a variety of locations within both the water distribution system and in individual home plumbing systems. The word plumbing, in fact, derives from plumbum, the Latin word for lead. Although lead service lines within the distribution system are rare, EPA estimates that there are approximately 4.4 million lead service lines in use in the United States (EPA, 1988). In addition to lead service lines, lead is present in a variety of materials used within both distribution systems and home plumbing systems.

Lead materials have been used in plumbing applications for centuries because of the low cost, ease of use, durability, and availability of lead. Most water systems, including the District's, stopped using lead service lines in the late 1940s, although some cities were still installing lead service lines into the 1980s. The review of water distribution system records identified 1977 as the last year in which a lead service line was

installed in the District. Recent Federal legislation has banned the use of lead and lead-bearing material for all plumbing use.

In general, lead and lead-bearing materials have been used for a variety of purposes within both distribution systems and individual home plumbing systems. However, in the District there are no significant sources of lead in the distribution system, excluding service connections to water mains. This is supported by the low lead concentrations measured in distribution system water. A list of typical locations where lead or lead-bearing materials may be found is given in Table 2-1. Lead may leach or dissolve into the drinking water from any of these locations, regardless of the age of the material. However, older materials will contribute lead at a slower rate. Descriptions of each of these potential sources, along with a method of alleviating the lead leaching problem, follow.

Jute/Lead Joint Packing -- A combination of jute and lead was commonly used at the junction of two or more cast iron water mains. Jute was tightly packed into the joint between the two pipes. Molten lead was then poured over the joint to mechanically join the pipe segments. However, since the lead theoretically never comes in contact with the water there should be no leaching of lead.

Galvanized Iron Service Line Connection -- It was a common practice in the District to use a short (2- to 4-foot) section of lead pipe to connect a galvanized iron service line to the distribution main. Galvanized iron pipe has a relatively short service life, and many galvanized iron service lines have been replaced. Galvanized iron pipe is no longer approved for use in new service line installations.

Lead Service Lines -- Lead pipe was commonly used to connect the water main in the street with the customer's home. The District stopped allowing the installation of lead service lines during the 1940s. Lead leaching from lead service lines may or may not affect the levels of lead at the consumer's tap. In many instances an insoluble lead carbonate film will have developed on the inside of the service line, thus preventing lead from entering the drinking water. Under other water quality conditions this film may not form, and water standing in the service line for extended periods, e.g., overnight, may have relatively high lead levels. The options for eliminating lead exposure from this source include removal of the lead service line, flushing of water from pipes before use, and/or treating the water to reduce its corrosive qualities.

Lead Pipes -- Some older homes may have lead pipes as part of the interior plumbing system. These pipes would have to be replaced to reduce the amount of lead in the drinking water. Lead pipes are easily identified; however, the cost of such rehabilitation can be expensive.

Table 2-1

Locations of Lead in Plumbing and Distribution Systems

Location	Source
Distribution system	Jute/lead joint packing Galvanized iron service line connection
Household plumbing	Lead service lines Lead pipes Lead solder Brass fixtures Brass service lines

Lead Solder -- The most common household plumbing systems consist of copper pipe joined by a lead-based solder. Numerous studies have shown that lead will leach from this solder into the drinking water, especially when the soldering was done poorly and an excess of solder is present on the pipe interior. A good plumber may actually put more solder into the joints (rather than simply on the outer surface), thereby increasing exposure to lead. After a period of time (typically considered as approximately 5 years), the lead leaching rate from soldered joints is reduced to a relatively low level. Methods of avoiding lead due to solder joints include reconnecting all pipes with lead-free solder (defined as containing less than 0.2 percent lead) and the flushing of pipes prior to use for drinking or cooking. Lead-free solder is required for all new and remodeling projects.

Brass Fixtures -- The use of brass plumbing fixtures is almost universal. Brass generally contains 3 to 8 percent lead and is still allowed to contain this amount of lead under the 1986 Safe Drinking Water Act lead ban. A study by the American Water Works Service Company (Lee, Becker, and Collins, 1989) found that as much as one-third of the lead in a 1-liter, first-draw sample of water standing overnight in a kitchen tap is contributed from the brass faucet. Flushing the water from the tap prior to use or replacing the brass fixture with a lead-free substitute are options for reducing exposure to lead from this route.

Brass Service Lines -- There are a small number of brass service lines in use in the District. As with brass fixtures, a brass service line contains a small percentage of lead that may leach into the drinking water. The installation of brass pipe for a service line is uncommon, but brass pipe is still an approved material for service line installations.

2.2.2 Lead Corrosion Chemistry

The corrosion of lead plumbing materials is a complex phenomenon. Many of the chemical factors contributing to plumbosolvency have only recently been identified. There is a current need for data relating changes in lead concentration in the distribution system to specific measures for reducing corrosion for various types of water. Prediction of lead levels is hindered further by the fact that data from actual distribution systems seldom agree with those predicted by theory and controlled experiments. Despite these limitations, a sound chemical framework is essential in understanding lead corrosion and in evaluating potential remediation measures. Recent studies of corrosion of plumbing materials suggest that the chemical characteristics necessary to reduce corrosion from solder are different than those needed to reduce corrosion from brass faucets (Schock and Neff, 1988).

Solubility Control

Equilibrium thermodynamics predicts that lead carbonate (cerussite, $PbCO_3$) and basic lead carbonate (hydrocerussite, $Pb_3(OH)_2(CO_3)_2$) will be the predominant solid phases of lead at pH, Eh, and dissolved inorganic carbon (DIC) levels encountered in typical drinking waters. Generally, $PbCO_3$ is predominant in the 6 to 8 pH range, with $Pb_3(OH)_2(CO_3)_2$ the controlling phase at higher pHs. However, x-ray diffraction analysis of distribution pipe coatings seems to indicate that $Pb_3(OH)_2(CO_3)_2$ is the controlling phase regardless of pH (Schock and Gardels, 1983).

Factors Influencing Lead Solubility

Since $Pb_3(OH)_2(CO_3)_2$ appears to be the controlling solid phase in the distribution system, pH and DIC levels of the finished water will affect the leaching of lead from plumbing materials. DIC and pH also may affect solubility through complexation. The precipitation and complexation reactions controlling lead solubility, along with their stability constants, are given in Table 2-2.

EPA experiments (Schock and Gardels, 1983) have determined that a minimum lead solubility of 0.05 mg/L can be obtained at a pH of 9.5 to 10 and a DIC of 30 mg/L as $CaCO_3$. Thus, waters of high pH and low akalinity are nonaggressive to lead plumbing, and control of these variables provides a possible method of reducing lead corrosion. This work also demonstrates that calculations based on the stability constants listed in Table 2-2 provide an effective model for predicting equilibrium lead solubility as a function of DIC and pH.

Orthophosphate can combine with lead to form precipitates less soluble than those formed by carbonate. Thus, adding orthophosphate to finished waters prior to distribution may provide another method of reducing plumbosolvency. Calculations based on the formation of hydroxypyromorphite ($Pb_5(PO_4)_3OH$) indicate that lead solubilities as low as 0.003 mg/L can be achieved using 5 mg/L of orthophosphate to treat water containing 5 mg/L DIC as $CaCO_3$ at a pH of 7.5 to 8 (Schock, 1989). In a survey conducted by the American Water Works Service Company (Lee, Becker, and Collins, 1989) of 96 water companies and districts, the average lead concentration at 11 utilities that employed orthophosphate addition was 0.004 mg/L, the lowest of any of the survey groups. Thus, orthophosphate addition appears to be a promising technology for controlling lead in distribution systems. One drawback to orthophosphate addition, however, is that it may elevate the phosphate levels in the wastewater.

Limitations of Solubility Calculations

Solubility calculations usually agree well with measured lead concentrations in experimental pipe loop systems. However, lead

Table 2-2

Complexation and Precipitation Reactions

	Reaction	Log K	Reference
	<u>Complexation</u>		
1.	$Pb^{2+} + H_2O = PbOH^+ + H^+$	-7.23	(Schock and Gardels, 1983)
2.	$Pb^{2+} + 2H_2O = Pb(OH)_2 + 2H^+$	-16.9	(Schock and Gardels, 1983)
3.	$Pb^{2+} + 3H_2O = Pb(OH)_3^- + 3H^+$	-28.1	(Schock and Gardels, 1983)
4.	$Pb^{2+} + 4H_2O = Pb(OH)_4^{2-} + 4H^+$	-39.7	(Schock and Gardels, 1983)
5.	$Pb^{2+} + CO_3^{2-} = PbCO_2$	7.1	(Schock and Gardels, 1983)
6.	$Pb^{2+} + 2CO_3^{2-} = Pb(CO_3)_2^{2-}$	10.3	(Schock and Gardels, 1983)
	<u>Precipitation</u>		
7.	$3Pb^{2+} + 2CO_3^{2-} + 2H_2O = Pb_3(CO_3)_2(OH)_2 + 2H^+$	18.0	(Schock and Gardels, 1983)
8.	$5Pb^{2} + H_2O + 3PO_4^{2-} = Pb_5(PO_4)_3OH + H^+$	62.8	(Hogfeldt, 1982)

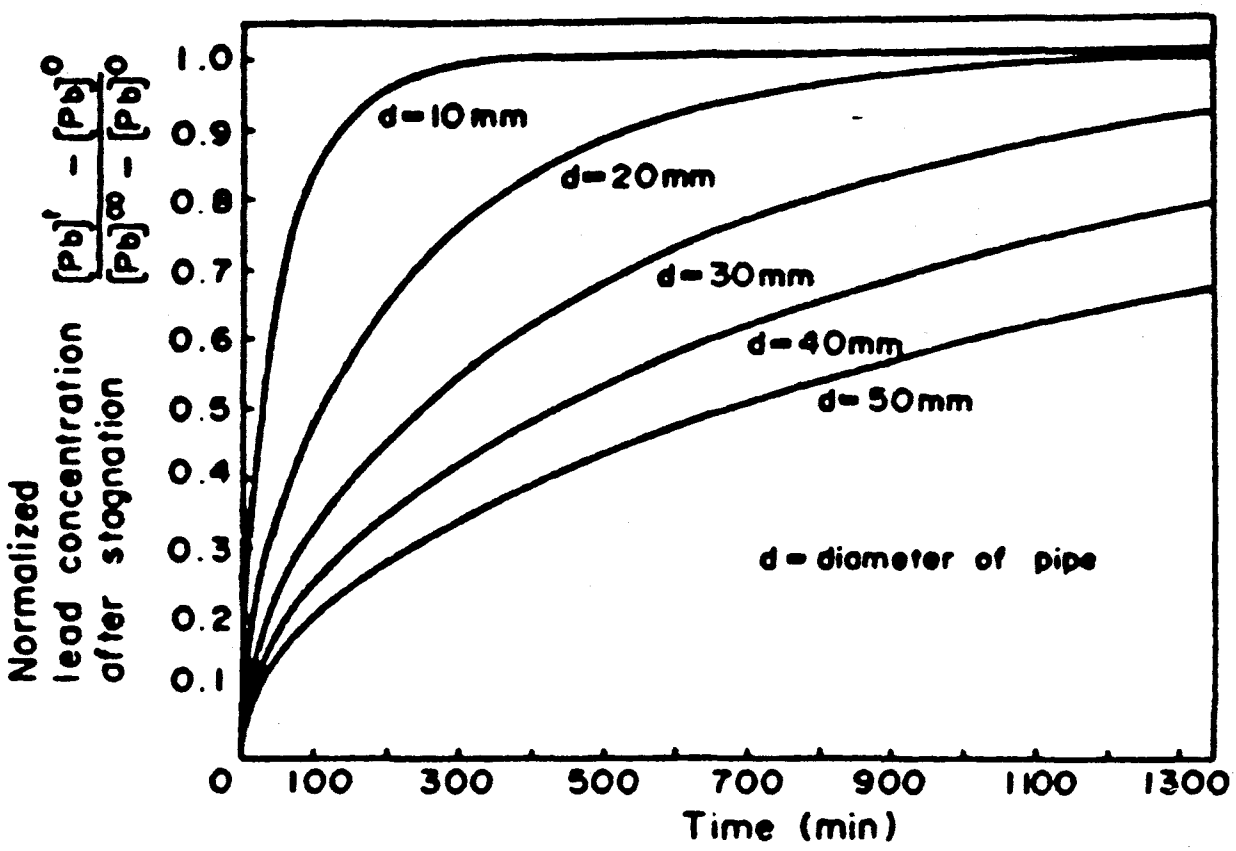
levels measured in actual distribution systems are generally much lower than those predicted by solubility models. For instance, in the aforementioned survey (Lee, Becker, and Collins, 1989), the most corrosive waters (pH < 7.0) had an average lead concentration of only 0.019 mg/L, with only 16 percent of all samples having concentrations higher than 0.020 mg/L. Solubility calculations for these waters would predict lead levels up to 1 mg/L. Factors that may contribute to the discrepancy between model calculations and field data include dilution, inhibition by diffusion, occurrence of unidentified lead compounds of low solubility, protective coatings on interior pipe surfaces, and nonequilibrium sampling conditions (slow kinetics of dissolution) (Schock, 1989). Therefore, although lead solubility calculations provide a basis for determining the tendency of a water type to leach lead, these calculations predict lead levels that are typically much greater than observed lead concentrations in actual distribution systems.

Diffusion Effects

As mentioned previously, diffusion limitation is one factor that may cause the observed lead concentration to be less than that predicted by equilibrium calculations. Since the water will often remain stagnant in service lines and in home plumbing between periods of use, the effect of this factor is of particular interest. Kuch and Wagner (1983) developed a radial diffusion model to predict the approach to equilibrium lead concentration as a function of stagnation time. The results predicted by the model for various diameters are presented in Figure 2-8. For a typical 3/4-in.-diameter (20-mm) service line, the model predicts that the lead concentration will approach 80 to 90 percent of the equilibrium lead concentration for a typical overnight stagnation time of 6 to 10 hours. Thus, lead concentrations in first-draw samples can approach equilibrium concentrations after standing overnight in home plumbing. Diffusion from the interior surface of the pipe does not appear to limit the rate of lead leaching for small diameter pipes.

Deposition of Protective Coatings

Many solid phases that limit lead solubility also act as a physical barrier between the water and plumbing materials. For example, $Pb_3(OH)_2(CO_3)_2$ and $Pb_5(PO_4)_3OH$ meet this description. Waters that are supersaturated with $CaCO_3$ may precipitate protective coatings in the distribution system and provide an effective barrier against corrosion. However, as will be described, conditions promoting $CaCO_3$ precipitation also increase lead solubility. Care must be taken to ensure that the water is properly conditioned to provide an effective coating and to avoid excess scaling.



Source: Kuch and Wagner, 1983.

FIGURE 2-8 PLOT OF NORMALIZED LEAD CONCENTRATION AS A FUNCTION OF STAGNATION TIME FOR LEAD PIPES OF DIFFERENT DIAMETERS

Silicate and polyphosphate addition also are believed to provide protective coatings under certain circumstances. However, the solid phases resulting from such precipitants have not been identified. Thus, the conditions favorable to the production of protective coatings can be predicted only after extensive experimentation with the water and distribution system of interest.

2.2.3 Existing Lead Levels

The District has access to lead in water data for all parts of its water system. The Army Corps of Engineers has data on raw water from the Potomac River, on treated water leaving the Dalecarlia and McMillan treatment plants, and from several sampling points located throughout the distribution system. In addition, the Department of Consumer and Regulatory Affairs (DCRA) has collected data on lead levels at the customers' taps from more than 2,200 homes throughout the District. This subsection describes the data available from these sources and presents the lead levels typically found in the District's drinking water.

EPA first promulgated a Maximum Contaminant Level (MCL) for lead in 1975 as part of the interim drinking water regulations. The MCL was set at 50 ug/L (50 parts per billion) and is still in effect today. In November 1985, EPA began the process of revising the standards for both lead and copper by proposing Maximum Contaminant Level Goals (MCLGs) for each of them. The MCLG for lead was set at 20 ug/L at that time.

In August 1988, EPA proposed new standards for both lead and copper. These standards set the MCLG for lead at 0.0 mg/L. [The MCLG is a nonenforceable level at which "no known or anticipated adverse effects on the health of persons occur and which allows an adequate margin of safety" (EPA, 1988)]. The proposed MCL for lead, measured at the entry points to the distribution system, was set at 5 ug/L.

In addition, EPA also proposed a set of no-action levels for lead and copper. Compliance with these no-action levels was to be measured at the customer's faucet. The four no-action levels were defined as follows:

- 1 -- Average lead level ≤ 0.010 mg/L (10 ug/L).
- 2 -- No more than 5 percent of samples > 1.3 mg/L (copper).
- 3 -- No more than 5 percent of samples have pH < 8.
- 4 -- Lead level ≤ 0.020 mg/L (20 ug/L) in 95 percent of samples.

The sampling program required to monitor for compliance with these no-action levels varies according to the size of the system. In all cases, however, the samples were to be collected in homes

considered to be "worst case." If any one of the first three no-action levels is exceeded, the water system must install or improve its corrosion control capabilities. If no-action level 1 or 4 is exceeded, the water system must conduct a public education program.

The lead and copper rules proposed in August 1988 generated a great deal of comment, both from environmental groups and the water industry. EPA is not expected to produce the final regulations for lead and copper until the end of 1990.

2.2.3.1 Source Water

The Corps of Engineers reports raw water lead levels on a monthly basis. Examination of these data for the years 1984 through 1988 shows a maximum lead level of 0.0095 mg/L occurred in November 1986, while levels of 0.0 (i.e., nondetectable) were found on two occasions. The average lead content in the raw water over this time period was 0.0015 mg/L. This compares favorably with the current lead MCL of 0.05 mg/L and with the anticipated proposed MCL for water entering the distribution system of 0.005 mg/L. A complete breakdown of lead levels in raw water for these years is shown in Figure 2-9.

2.2.3.2 Treatment Plant

The Corps of Engineers reports treated water lead levels on a monthly basis for each water treatment plant (WTP). Examination of these data for the years 1984 through 1988 shows a maximum lead concentration of 0.0019 mg/L at the Dalecarlia WTP, and a maximum of 0.0134 mg/L at the McMillan WTP. The average lead concentrations were 0.0005 mg/L and 0.0009 mg/L at the Dalecarlia WTP and McMillan WTP, respectively.

Lead concentrations at the Dalecarlia WTP were consistently below both the current and proposed MCLs for lead in treated water. However, in May and June 1985 the lead levels in the treated water at the McMillan WTP exceeded the anticipated proposed MCL for lead in treated water of 0.005 mg/L. A summary of lead levels in the water from both treatment plants from 1984 through 1988 is presented in Figure 2-10.

2.2.3.3 Distribution System

The Corps of Engineers reports lead concentrations in water from sampling points located throughout the District. These data, available for the years 1984 through 1988, are presented in Table 2-3.

Examination of the data shows that the current MCL for lead of 0.05 mg/L (50 ug/L) (which is for water leaving the treatment plant) has not been exceeded at any of the sites. However, the anticipated lead rules are expected to set much lower allowable lead levels.

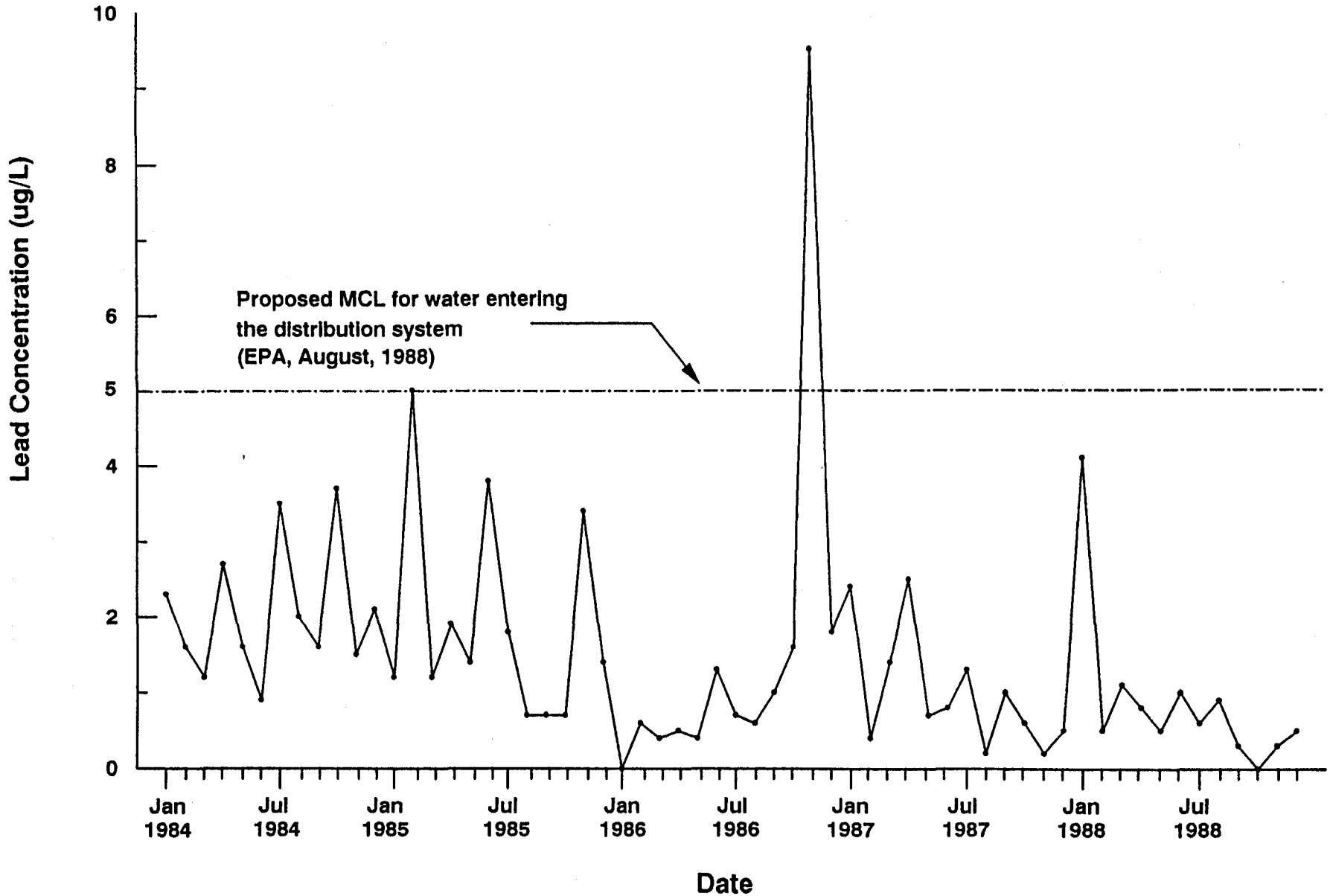


FIGURE 2-9 RAW WATER LEAD CONCENTRATIONS

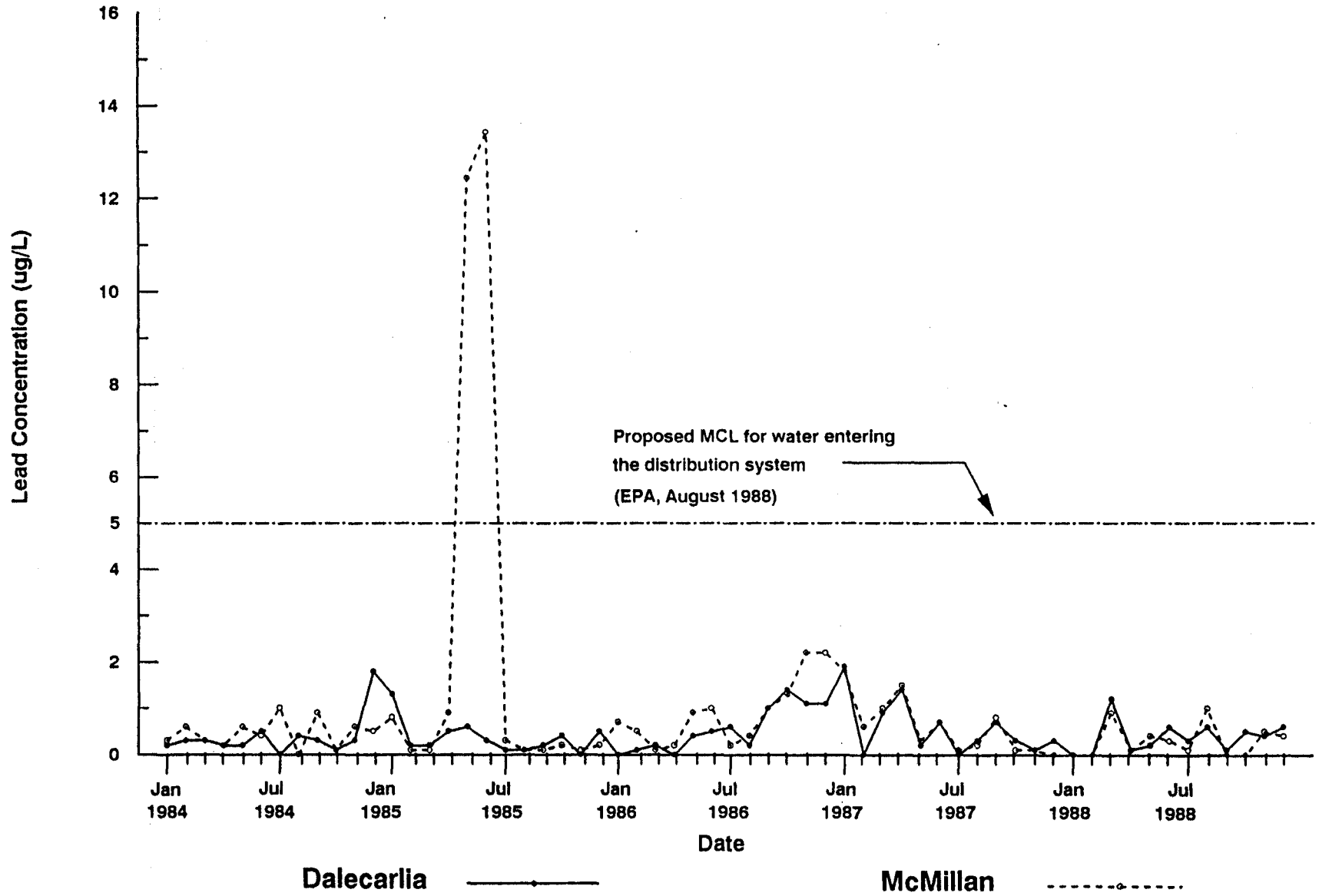


FIGURE 2-10 TREATED WATER LEAD CONCENTRATIONS

Table 2-3

Distribution System Lead Concentrations

LOCATION c-10		LOCATION c-14		LOCATION c-22		LOCATION c-29		LOCATION c-42		LOCATION c-49		LOCATION c-54		LOCATION c-7		LOCATION c-9	
DATE	LEAD VALUE	DATE	LEAD VALUE	DATE	LEAD VALUE	DATE	LEAD VALUE	DATE	LEAD VALUE	DATE	LEAD VALUE	DATE	LEAD VALUE	DATE	LEAD VALUE	DATE	LEAD VALUE
08/05/85	2.3	10/03/84	6.8	04/09/85	0.5	01/03/85	4.8	08/02/85	0.1	04/10/85	1.0	04/09/86	0.2	01/04/85	0.7	10/04/84	0.2
09/09/85	3.2	11/09/84	0.5	07/02/85	2.3	02/14/85	5.9	09/06/85	2.3	05/01/85	2.3	05/02/86	0.3	02/08/85	1.5	11/06/84	2.3
07/03/86	0.2	12/12/84	0.6	04/08/86	0.2	03/07/85	3.9	07/07/86	0.2	06/06/85	1.0	06/03/86	0.6	01/13/86	0.8	12/10/84	0.9
08/04/86	0.6	11/08/85	0.7	05/01/86	1.3	05/02/85	2.7	08/04/86	3.3	07/08/85	2.3	04/07/87	2.3	02/05/86	0.9	10/03/85	0.8
09/09/86	2.0	12/04/85	0.4	04/07/87	1.8	06/04/85	5.0	09/10/86	3.0	04/12/88	0.7	05/20/87	1.9	03/05/86	0.5	11/07/85	0.8
07/06/87	1.5	10/08/86	5.7	06/02/87	2.6	01/16/86	1.8	07/06/87	0.8	05/17/88	20.0	06/02/87	1.1	01/07/87	1.8	12/04/85	0.5
08/04/87	1.8	11/10/86	1.4	04/12/88	0.5	02/04/86	1.7	08/05/87	0.9	06/01/88	1.4	04/04/89	0.9	02/04/87	14.1	10/07/86	3.0
09/10/87	5.1	10/16/87	0.5	05/17/88	0.5	03/04/86	1.3	09/09/87	2.1					03/06/87	1.0	11/10/86	1.7
07/01/88	2.9	11/25/87	1.4	06/01/88	1.4	01/07/87	3.7	07/01/88	0.4					01/22/88	6.9	12/01/86	1.8
08/01/88	5.2	12/14/87	0.5	04/04/89	0.8	02/05/87	0.8	08/01/88	1.3					02/08/88	0.6	10/13/87	1.5
09/01/88	1.3	10/03/88	0.4			03/03/87	0.3	09/02/88	0.4					03/07/88	1.0	11/24/87	0.2
		11/02/88	0.2			01/19/88	4.8							01/04/89	0.6	12/14/87	0.8
		12/05/88	0.5			02/09/88	0.8							02/01/89	1.3	10/03/88	0.4
						03/08/88	1.7							03/01/89	3.5	11/01/88	0.3
						01/10/89	2.3									12/05/88	4.7
						02/02/89	2.5										
						03/02/89	2.0										
AVG =	2.37	AVG =	1.51	AVG =	1.19	AVG =	2.71	AVG =	1.35	AVG =	4.10	AVG =	1.04	AVG =	2.51	AVG =	1.33
MIN =	0.2	MIN =	0.2	MIN =	0.2	MIN =	0.3	MIN =	0.1	MIN =	0.7	MIN =	0.2	MIN =	0.5	MIN =	0.2
MAX =	5.2	MAX =	6.8	MAX =	2.6	MAX =	5.9	MAX =	3.3	MAX =	20.0	MAX =	2.3	MAX =	14.1	MAX =	4.7

All lead values given in ug/L.

Location Index

c-10 Connecticut Ave. and Fessenden St., NW

c-14 13th and K Sts, NW

c-22 18th St and Rhode Island Ave., NE

c-29 Minnesota Ave. and Hayes St, NE

c-42 4th and E Sts, SW

c-49 1500 Pennsylvania Ave, SE

c-54 8th and E STs, SE

c-7 1227 Monroe St, NW

c-9 1301 East Capitol St, NE

2.2.3.4 Customer's Faucet

The District has conducted three water sampling studies to collect data on lead levels in water at the customer's faucet. Data Sets 1 and 2 consisted of information on midday and first flush samples from 941 homes, while Data Set 3 contained information on first flush sample results from 1,330 homes. These sampling efforts were described in detail in Section 1. The results of these sampling efforts are described in the following subsections.

Four basic types of samples were collected during the sampling efforts, although not all homes had all four samples collected. The midday sample was taken during the day with the water in contact with home plumbing for a short duration. The A, B, and C samples were first flush samples taken after allowing the water to stand overnight for a minimum of 8 hours. Sample A was the first 1 liter of water drawn from the kitchen faucet. Sample B was meant to be a sample of water standing in the service line overnight. Finally, Sample C was meant to be a sample of water from the distribution system.

2.2.4 Data Evaluation

The monthly data for finished water quality and lead concentrations in the distribution system for the Dalecarlia and McMillan WTPs, for the period 1984 through 1988, are analyzed in this subsection. Prior to analysis, the quality of the treatment plant data was assessed by performing an ion charge balance for each monthly water analysis. A charge balance error of <10 percent was considered acceptable. All monthly data sets met this criterion, with the majority being within 5 percent. Likewise, a hardness balance also was within acceptable limits.

Lead Solubility

The solubility of lead, assuming equilibrium with $Pb_3(OH)_2(CO_3)_2$, was calculated for each month based on the average water quality measured in each month. All calculations were made at 25°C and at an ionic strength effect of 0.01 M. To calculate the total soluble lead, the concentration of Pb^{2+} was first calculated from the pH and alkalinity assuming equilibrium with $Pb_3(OH)_2(CO_3)_2$ alone (Equation 7 in Table 2-2). Next, the concentrations of soluble lead complexes were computed from pH, alkalinity, and Pb^{2+} concentration based on the reactions and stability constants listed in Table 2-2. Finally, concentrations of all soluble lead complexes and Pb^{2+} were added to obtain the total lead solubility.

The calculated solubilities of treated waters from each of the two treatment plants are shown in Figure 2-11. Calculated lead solubilities range from 0.14 to 0.34 mg/L. The calculated lead

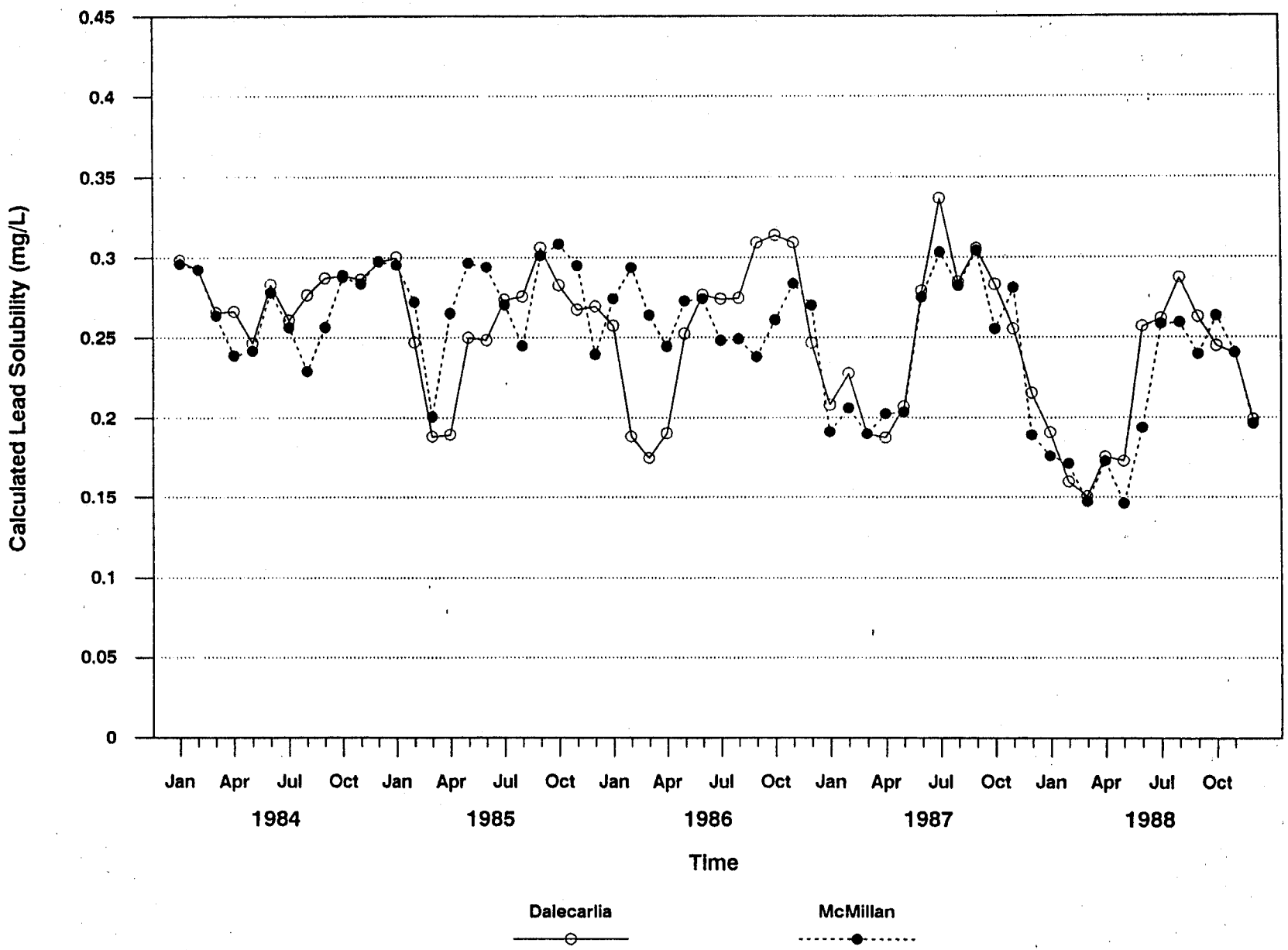


FIGURE 2-11 VARIATION IN CALCULATED LEAD SOLUBILITY

solubilities of the finished waters from the two plants are quite similar. There also is an apparent seasonal trend to the solubility calculations; lead solubility is high from August to December relative to that from January to July. It appears these variations are related to seasonal changes in the raw water quality.

As shown in Figure 2-11, the calculated lead solubility invariably exceeded the current 0.050 mg/L for lead. However, when the predicted solubilities are compared with observed lead concentrations in the District's distribution mains (Figure 2-12), first-draw samples in homes served by lead service lines (Figure 2-13), and first-draw samples in homes served by nonlead service lines (Figure 2-14), relatively few violations of the current MCL are observed. The new no-action limit proposed by EPA is 0.010 mg/L measured at the customer's tap. Comparisons between predicted and observed lead concentrations in the District's water mains and in first-draw samples collected from customers' taps can aid in evaluating various strategies for meeting the new no-action limit.

In Figure 2-12, the measured lead concentrations in the District's distribution mains are plotted against predicted lead solubilities for the period 1984 through 1988. Measured lead concentrations are very low during this period. There were no violations of the current 0.050 mg/L MCL measured during this period; and only 2 of the 105 samples would have been in violation of the proposed no-action limit. It can be concluded that there is little potential for leaching of lead from the District's mains.

It was desired to obtain a relationship between the calculated equilibrium lead solubility and observed lead concentration in homes served by lead service lines. Preliminary analysis of the Data Set 3 database indicated that the distribution of observed lead concentrations is lognormal. Thus, the natural logarithms of the observed lead concentrations were plotted against the equilibrium values as shown in Figure 2-13. The relationship between predicted and observed lead concentrations is as follows:

$$\ln Pb_{obs} = 0.00663\ Pb_{eq} + 0.9442 \qquad (1)$$

This relationship was found to be statistically significant ($r = 0.273$, $p < 0.001$). However, it is unsuitable for predicting actual lead concentrations because of the variation in observed concentration for a given equilibrium value. The 95-percent prediction limit also was plotted as shown in Figure 2-13. The point at which the 95-percent prediction limit crosses the no-action limit could serve as a target value for equilibrium lead solubility. If the chemistry of the water could be adjusted so that the equilibrium lead solubility was below this target value, 95 percent of all observed lead concentrations should be below the no-action limit. Unfortunately, the statistical 95-percent prediction limit (labeled "A" in Figure 2-13) did not cross the

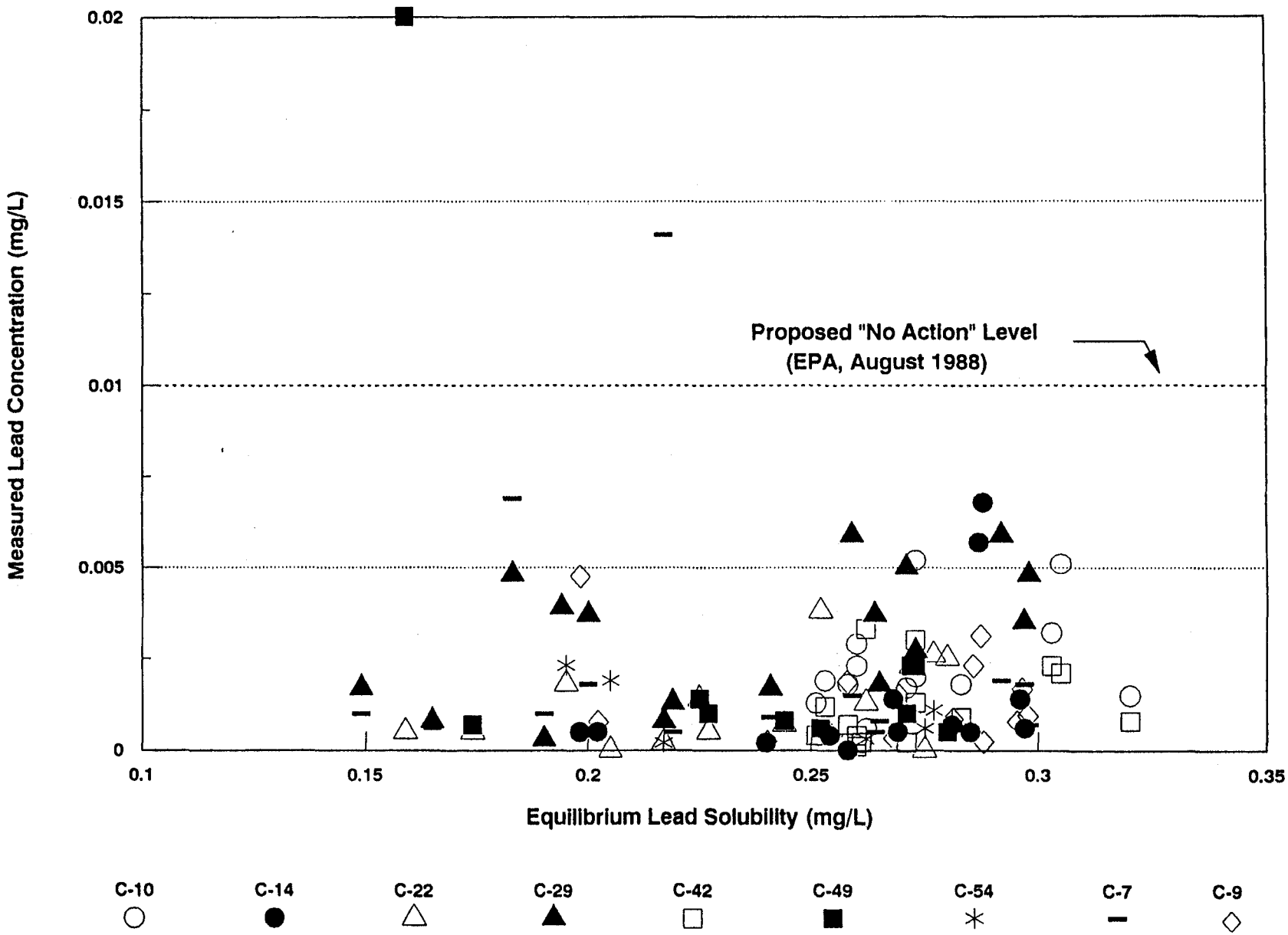
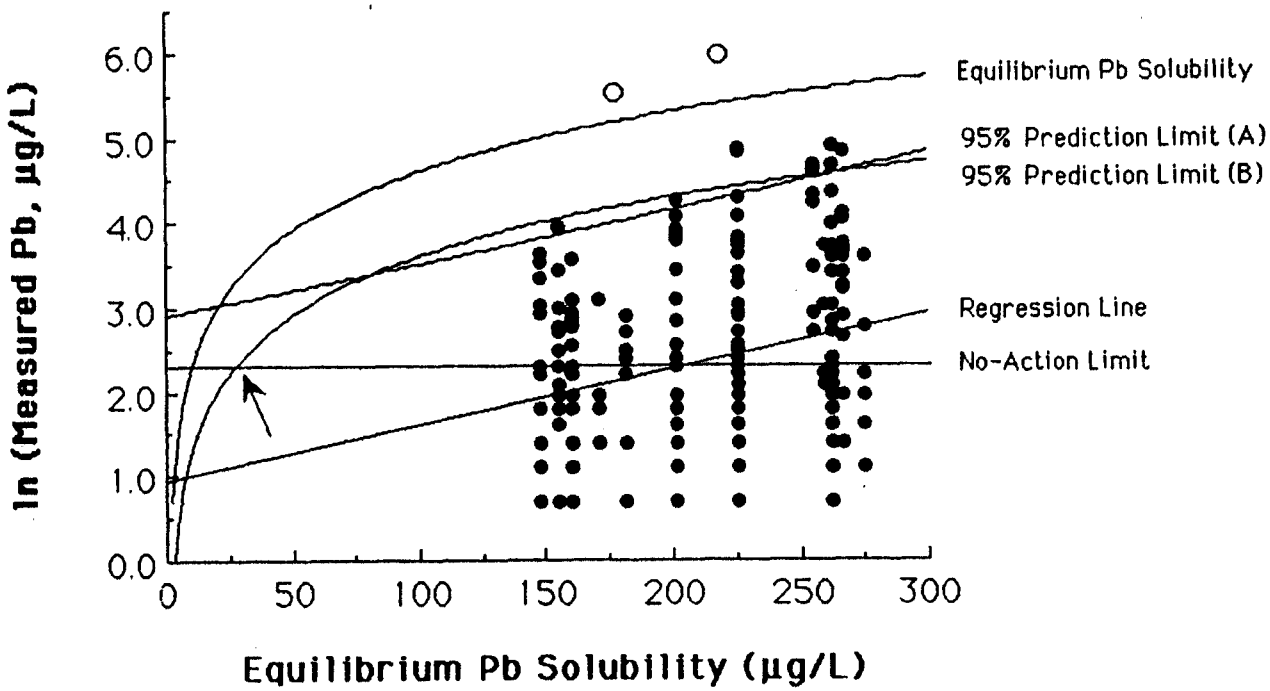
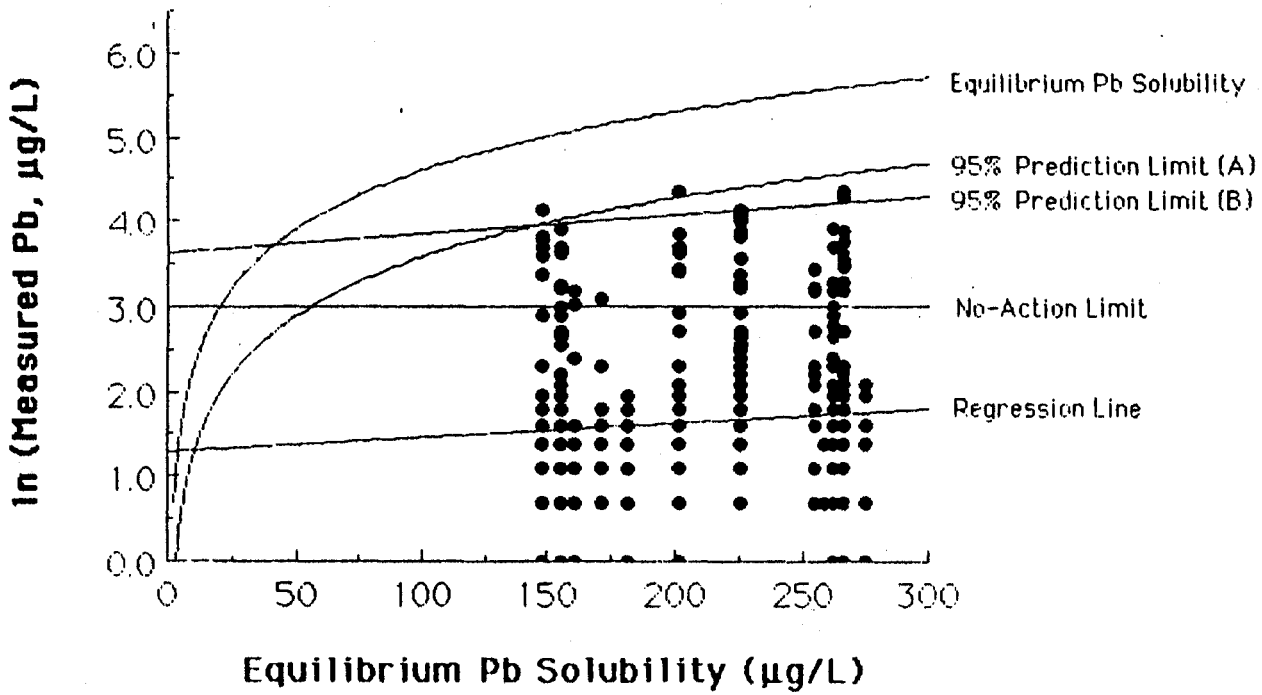


FIGURE 2-12 MEASURED LEAD CONCENTRATION IN DISTRICT WATER MAINS AS A FUNCTION OF EQUILIBRIUM LEAD SOLUBILITY OF FINISHED WATERS



95% Prediction Limits: A) Statistically Derived, B) Equation (2) Text. Data from Data Set 3 Database.

FIGURE 2-13 MEASURED LEAD CONCENTRATIONS IN FIRST-DRAW SAMPLES COLLECTED FROM HOMES SERVED BY LEAD SERVICE LINES AS A FUNCTION OF EQUILIBRIUM LEAD SOLUBILITY



Data from Data Set 3 Database

FIGURE 2-14 MEASURED LEAD CONCENTRATIONS IN FIRST-DRAW SAMPLES COLLECTED FROM HOMES SERVED BY NONLEAD SERVICE LINES AS A FUNCTION OF EQUILIBRIUM LEAD SOLUBILITY

no-action concentration limit, probably because of a lack of data for low values of equilibrium lead concentrations. It can be seen in Figure 2-13 that the statistical 95-percent prediction limit parallels the equilibrium lead solubility curve over the range of equilibrium lead solubility for which data are available. Since there is a relationship between the equilibrium and observed lead concentrations, we have assumed that the observed lead concentrations will parallel the equilibrium lead solubility over the entire concentration range. With this assumption we have derived an expression for the 95-percent prediction line that we believe will reflect more accurately the observed lead concentration over the entire range of equilibrium lead solubilities:

$$Pb_{obs95\%} = 0.36\ Pb_{eq} \qquad (2)$$

This line is plotted in Figure 2-13 (labeled "B") and agrees with the statistically derived 95-percent prediction limit over the range of equilibrium lead solubility for which data are available. Thus, in order for 95 percent of all observed lead concentrations to be below the no-action limit of 0.01 mg/L, we can project from Equation 2 that the equilibrium lead solubility must be near 0.03 mg/L. Since data are not available at low equilibrium lead solubilities, it is impossible to determine precisely the maximum value of equilibrium lead solubility resulting in lead concentrations below 0.01 mg/L. A reasonable range for this value of equilibrium lead solubility is 0.01 to 0.05 mg/L. It may be possible to achieve equilibrium lead solubilities as low as 0.01 mg/L; in practice, however, a more reasonable goal is 0.03 to 0.05 mg/L. The aforementioned analysis indicates that this equilibrium lead solubility may be sufficient to meet the no-action limit; however, without data for low values of solubility, it is impossible to say for certain.

The two data points in Figure 2-13 that are indicated by open circles are above the equilibrium lead solubility calculated for these waters. These high lead concentrations could be related to particulate lead-containing corrosion products sloughing from the interior surface of the pipe (Schock, 1989). These data points were not included in the regression analysis.

A similar analysis was performed for nonlead service lines. The natural logarithms of lead concentrations reported in the Data Set 3 database file for homes served by nonlead service lines are plotted against equilibrium lead solubility in Figure 2-14. Several data points with lead concentrations greater than 0.10 mg/L were not included in this plot because they were believed to be related to particulate corrosion products. In general, the lead concentrations in homes served by nonlead service lines are lower than those in homes served by lead service lines. Nevertheless, it can be seen that the measured lead concentration is higher than the no-action limit for several of the samples collected. The lead observed in these samples may have leached from lead solder joints, brass plumbing fixtures, or lead plumbing in the home. Figure 2-14 illustrates that measured lead concentrations in first-draw samples

are likely to exceed the no-action limit even if lead service lines are replaced. The relationship between predicted and observed lead concentrations is as follows:

$$\ln Pb_{obs} = 0.001729\ Pb_{eq} + 1.279 \qquad (3)$$

A regression line was fit through the data in Figure 2-14 and was found to be statistically significant. However, the lower value of the slope of this regression line (compared to the slope of the regression line for lead service lines shown in Figure 2-13) suggests that the effect of changes in equilibrium lead solubility of the water is less for nonlead service lines than for lead service lines. We have assumed that since the lead levels are lower in homes served by nonlead service lines, satisfactory lead levels in these homes will be achieved by reduction of lead below the no-action limit in homes that are served by lead lines.

Data Sets 1 and 2 were used to verify Equations 1 and 2. Of the 941 records in this database, 72 were identified as being served by lead service lines. Of these 72 files, midday samples were collected for 68 of them and first-flush A, B, and C samples were collected for 13. The data were collected during November 1986. The average equilibrium lead solubility for this month was 0.293 mg/L. Thus, a mean lead level of 0.018 mg/L would be predicted by Equation 1, while Equation 2 would predict that 95 percent of all samples will be less than 0.105 mg/L. The measured lead levels in Data Sets 1 and 2 for homes served by lead service lines are summarized in Table 2-4. In general, the predictions given by Equations 1 and 2 agree fairly well with the data, with the exception of Sample B, which represents water in contact with the service line.

2.3 INVESTIGATION OF ALTERNATIVES

There is a variety of alternatives available for reducing customers' exposure to lead in drinking water. This subsection briefly summarizes the approach involved in each of these alternatives.

2.3.1 Centralized Treatment Alternatives

One category of alternatives for reducing lead in drinking water is to add or modify the water treatment plants. Centralized treatment for lead removal is based on the principles of corrosion control rather than removal of lead at the treatment plant since the levels of lead in the source water are very low. Corrosion control techniques can be categorized as barrier methods. Barrier methods involve placement of a protective coating on the interior surface of the pipe to prevent or reduce dissolution of lead from plumbing materials. Protective coatings can be calcium carbonate, silicates, or lead orthophosphates. Solubility-based methods involve

Table 2-4

Lead Levels* in Homes Served by Lead Service Lines

Sample Type	N (number of (samples)	Measured Mean	Predicted Mean	Measured 95% Level	Predicted 95% Level	Range
Midday	68	0.013	.018	0.046	0.105	0.001 - 0.108
A	13	0.021	.018	0.064	0.105	0.001 - 0.065
B	13	0.032	.018	0.121	0.105	0.001 - 0.125
C	13	0.013	.018	0.048	0.105	0.001 - 0.058

*All units in mg/L.

modification of the water chemistry to reduce the solubility of lead in the water distribution system. Several recent papers have appeared on the subject of reducing the corrosivity of drinking water (Schock, 1989; Neff et al., 1987; Schock and Neff, 1988; Lee et al., 1989; and Gardels and Sorg, 1988).

Centralized treatment options are attractive because centralized treatment facilities exist that could be modified to reduce corrosivity of water to a greater extent than is currently practiced. Four centralized treatment options are described in detail in Subsection 2.4.1.

2.3.2 Point-of-Use Devices

Point-of-use devices are water treatment units placed in the homes of water users. Point-of-use devices are designed and sized to reliably produce potable quality water for drinking and cooking. All other water uses including bathing, washing, lawn watering, and toilet flushing are not affected by the levels of lead found in the Washington, D.C., drinking water system. Therefore, most point-of-use devices are sized to produce enough water for drinking and cooking uses, approximately 5 to 8 gallons per day.

Point-of-use devices using a variety of treatment processes are available. These include mechanical filtration/granular activated carbon, distillation, and reverse osmosis units. A detailed description of these units is included in Subsection 2.4.2.

2.3.3 Removal of Lead Material

A major source of lead in drinking water is the corrosion of lead from lead-bearing materials within distribution systems and home plumbing systems. By removing these materials and replacing them with lead-free materials, this source of lead would be eliminated.

In the most recently proposed lead regulations, EPA considered requiring the replacement of lead service lines where it was shown that the service line was contributing measurable amounts of lead to water at the tap. This option, however, has uncertainties about the effectiveness of partial service line removal resulting from legal and financial questions over replacement responsibility. EPA's August 1988 proposed lead regulations have no provision for removal of any lead-bearing materials currently found in water systems or home plumbing systems.

The District has an ongoing program to replace the District's portion of a lead service line. At the same time, the homeowner is notified and encouraged to replace the remaining portion of the service line. This program has resulted in the partial replacement of many lead service lines over the last several years.

Replacement of other lead-bearing materials such as solder, flux, and brass fixtures is beyond the control of the water system managers. Newly enacted plumbing codes (see Subsection 2.3.4) should prevent the use of such materials in the future. Also, lead solder and flux is typically considered to no longer contribute significantly to lead in drinking water after a period of approximately 5 years.

2.3.4 Plumbing Code Modifications and Enforcement

As previously described, a major source of lead in drinking water is the corrosion of lead from lead-bearing pipe, fittings, solder, and flux. There are two basic methods for eliminating this source of lead: prevent corrosion by modifying water quality or eliminate corrosion by removing the lead-bearing materials. Modifications to the plumbing code, while they cannot undo what has been done in the past, can reduce future exposures to lead by requiring the use of lead-free pipe, fittings, solder, and flux.

The Safe Drinking Water Act (SDWA) amendments of 1986 require the use of lead-free pipes, fittings, solder, and flux in the installation or repair of public water systems and individual home plumbing systems. Solder and flux are considered lead-free when they contain no more than 0.2 percent lead. Pipes and fittings (including fixtures) are considered lead-free when they contain no more than 8.0 percent lead. The District has enacted its own version of such a lead ban legislation.

The effectiveness of such a lead ban is dependent on the degree to which the ban is enforced. For example, lead solder will still be available under the ban. Its use, however, is meant to be restricted to applications other than in drinking water installations. Lead-free solder is generally more difficult to work with, and homeowners and even plumbers may be tempted to use lead solder in its place.

2.3.5 Public Education

A relatively simple yet effective method of reducing customers' exposure to lead in drinking water is to conduct a public education program. Public education is a requirement under the most recently proposed lead regulations for water systems failing to meet certain no-action levels. In addition, the SDWA amendments of 1986 required all water system managers to notify the public about lead in drinking water, regardless of whether the system was in compliance with existing lead standards.

The most recently proposed lead regulations are quite specific regarding what must be included in a public education program. The basic purpose of such a program is to inform the public on the sources of lead in their drinking water, describe potential health effects of lead exposure, describe what the water system can and is doing to reduce lead concentrations, and to give advice as to

how homeowners could minimize their own exposure to lead in drinking water.

2.3.6 Alternative Distribution Techniques

Lead in water becomes a health issue only when the water is ingested through drinking or food preparation. For this reason it may be possible to eliminate lead intake from drinking water by providing alternate sources of water for drinking and cooking. Two possibilities are an expanded use of bottled water and the implementation of some form of alternative water distribution system.

The use of bottled water has increased in recent years. As consumers have become more concerned with the quality of their drinking water (from a health standpoint, and preferences concerning taste and odor), they have become willing to pay the additional cost for bottled water. The costs associated with bottled water use are high; however, and the socioeconomic impacts must be addressed before bottled water use could be advocated as a means of reducing lead exposure from drinking water.

A major portion of lead in drinking water originates in the customers' plumbing systems. Exposure to this lead could be eliminated by providing customers with direct access to water in the distribution system mains. This could be accomplished by setting up common distribution points where the customer could obtain water for drinking and cooking, or by installing new services that connect directly to a separate fixture in the house to be used only for cooking and drinking.

2.4 IDENTIFICATION AND EVALUATION OF SPECIFIC ALTERNATIVES

2.4.1 Centralized Treatment Options

Adjustment of water chemistry at the treatment plant can potentially reduce the formation of lead-containing corrosion by-products in the distribution system. Four treatment options were considered for lowering distribution system lead concentrations: (1) adjustment of pH and alkalinity to greater than 8.0 and 30 mg/L as $CaCO_3$, respectively; (2) precipitation of a protective $CaCO_3$ film; (3) orthophosphate addition alone; and (4) control of pH and DIC in conjunction with orthophosphate addition. Selection of the appropriate technology depends upon the final format of EPA's lead regulations. Also, pilot studies would be necessary to verify the effectiveness of the chosen technique.

The first option, adjustment of pH and alkalinity, was considered in the August 1988 EPA proposed lead regulations as a corrosion control technology to be implemented in response to a violation of lead standards at the customer's faucet. Precipitation of calcium carbonate films has long been considered an effective method of corrosion control. The third and fourth treatment methods are suggested by the decision tree diagram for lead control strategies

shown in Figure 2-15 (Schock, 1989). Polyphosphate and silica additives were not considered because currently there is no scientific basis for predicting their effectiveness for a given water type. Extensive experimentation would be required to determine the feasibility of these options.

2.4.1.1 Adjustment of pH and Alkalinity

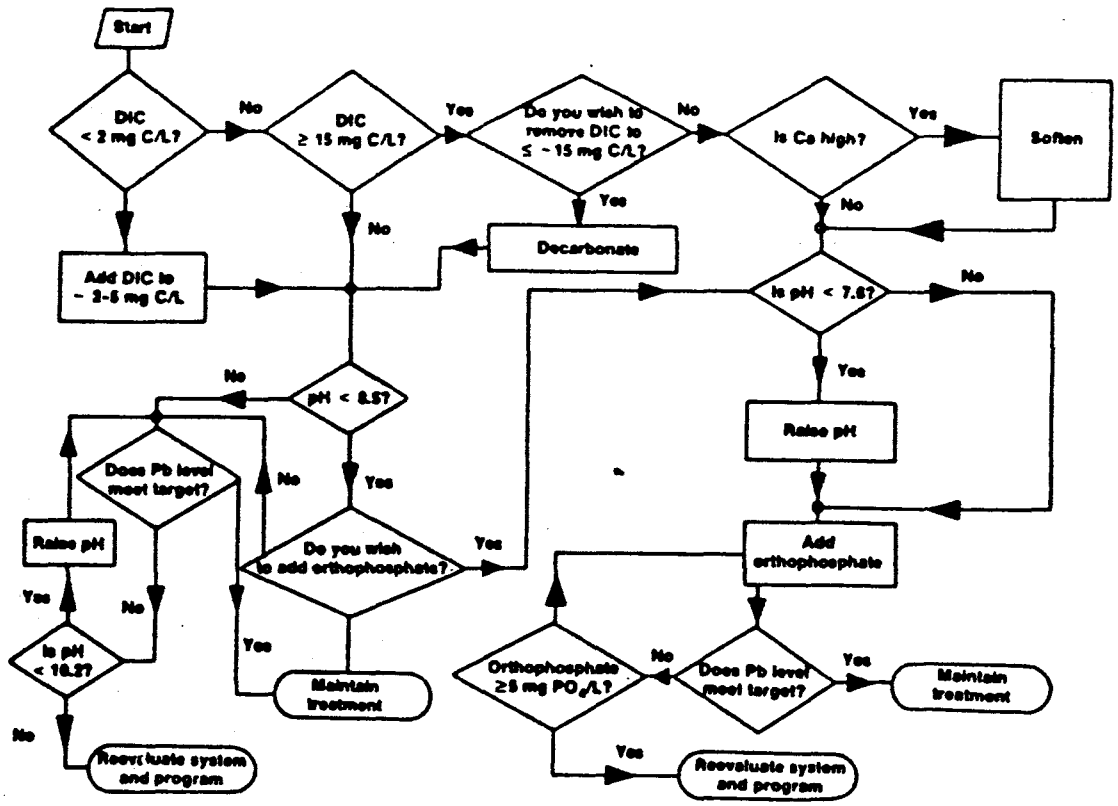
Corrosion control by adjustment of pH and alkalinity was practiced by 42 percent of the utilities responding to the 1987 AWWA Lead Information Survey (Frey, 1989). The average lead concentration was below the 0.01 mg/L no-action limit for 48 percent of the utilities practicing this technology. The City of Boston was successful in reducing mean lead concentrations in the distribution system below the current 0.05 mg/L MCL by addition of NaOH (Karalekas, Ryan, and Taylor, 1983). Water of pH greater than 8.0 had the lowest lead levels among homes with copper plumbing in a survey conducted by the American Water Works Service Company (Lee, Becker, and Collins, 1989). Mean lead levels for samples of pH greater than 8.0 were 0.005 mg/L, with only 4 percent of these samples exceeding 0.020 mg/L. It can be concluded that adjustment of pH and alkalinity is a commonly practiced corrosion control technology. Water of pH greater than 8.0 appears to be less corrosive than water of lower pH.

The performance of this treatment option can best be predicted by considering historical data from the Washington, D.C., distribution system. The technology considered in the 1988 EPA proposed lead regulations consisted of increasing the pH above 8.0 and increasing alkalinity above 30 mg/L as $CaCO_3$. The monthly composite analysis of treated water from the Dalecarlia and McMillan WTPs indicates that alkalinity is greater than 30 mg/L as $CaCO_3$ for all samples, and that pH is greater than 8.0 for some samples. Therefore, the water currently being produced by the Dalecarlia and McMillan WTPs occasionally meets the proposed treatment criteria being considered by EPA. Thus, EPA's recommended treatment may not significantly improve the lead levels measured at the tap. Based on a projected equilibrium lead solubility of 0.150 mg/L and Equations 1 and 2, mean lead levels from homes served by lead service lines can be expected to be between 0.005 and 0.010 mg/L, while 95 percent of all samples will be below 0.055 mg/L.

There should be no need for capital expenditure for this treatment option since lime addition is currently practiced at both treatment plants. The cost for additional lime would be less than $1/MG.

2.4.1.2 Calcium Carbonate Precipitation

Calcium carbonate precipitation on internal pipe surfaces has long been considered an effective means to prevent corrosion. The stabilization of water by adjustment of the LSI has been practiced for more than 60 years. Therefore, it must be considered as a



Source: Schock, 1989.

FIGURE 2-15 CONCEPTUAL DECISION TREE FOR THE SELECTION OF TREATMENT OPTIONS FROM AMONG pH, DIC, AND ORTHOPHOSPHATE

feasible and practical option for reducing the corrosiveness of water.

The performance of this treatment technology is contingent on the ability of the $CaCO_3$ coating to provide a complete, continuous, and stable physical barrier between the internal pipe surface and the water. Despite the long-standing use of this corrosion control strategy, there is little evidence demonstrating the existence of these films in actual distribution systems (Schock, 1989). Lead service lines in the District that have been excavated to date show no evidence of these films. Assuming that formation of these films is possible, solubility of lead could be increased during the period of initial deposition of these coatings because of the higher DIC levels required to precipitate $CaCo_3$. It would also seem to be extremely difficult to achieve a uniform coating throughout the distribution system. Controlling the dosage of conditioning chemicals to keep pace with changing water quality also could prove challenging. For these reasons, this treatment option is not expected to provide significant reduction in lead levels in the distribution system, other than what would be achieved by reducing the solubility through increasing pH. Thus, the performance and cost of this treatment option are comparable to the first treatment option.

2.4.1.3 Orthophosphate Addition

Of the utilities responding to the aforementioned AWWA lead survey, 26 percent used some type of corrosion inhibitor (Schock and Gardels, 1983), such as orthophosphate. The American Water Works Service Company survey indicated that samples from homes served by utilities that add orthophosphate as a corrosion inhibitor had mean lead levels of 0.004 mg/L, with only 1 percent of all samples exceeding 0.02 mg/L (Schock, 1989). Thus, it can be surmised that orthophosphate addition is a well-established and effective method of reducing lead levels in distribution systems. One drawback to orthophosphate addition, however, is that the addition of phosphates to drinking water may cause other environmental problems in the Potomac River. This is because the water sent through the distribution system as drinking water eventually returns (after treatment) to the Potomac River as wastewater. Higher phosphate levels in this wastewater would result in increased nutrient loads in the river.

The effect of orthophosphate addition on calculated lead solubility was determined by use of the water quality model MINEQL (Westall, Zachary, and Morel, 1976). MINEQL is a chemical equilibrium model that solves a set of mass action equations describing a chemical system under the constraint of mass balance for each chemical component. The values of stability constants listed in Table 2-2 were used in lieu of the default values supplied by MINEQL.

The effect of orthophosphate addition on lead solubility for typical finished waters is shown in Figure 2-16. The calculation of DIC = 2.0 mM is representative of orthophosphate addition to

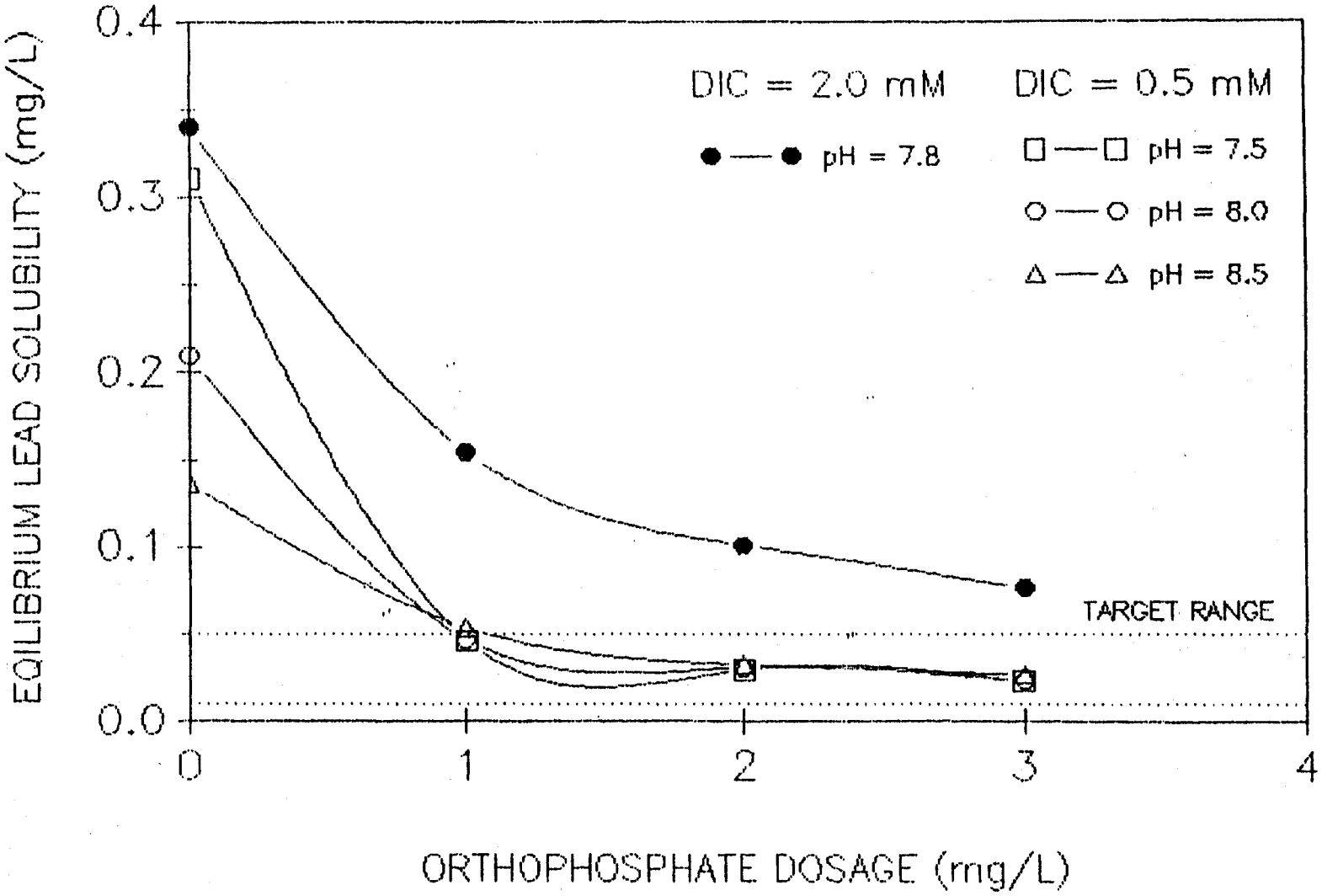


FIGURE 2-16 EFFECT OF PHOSPHATE CONCENTRATION ON EQUILIBRIUM LEAD SOLUBILITY

finished water produced at the present time. A significant decrease in lead solubility can be achieved through addition of orthophosphate, without otherwise altering the water chemistry. Figure 2-16 indicates that addition of 2 mg/L orthophosphate is capable of reducing equilibrium lead solubility to approximately 0.08 mg/L. This corresponds to a predicted mean level of 0.004 mg/L, and a prediction that 95 percent of all samples will be below 0.029 mg/L.

A phosphate feed system and possibly some mixing equipment and instrumentation would have to be added to each treatment plant to implement this technology. It is estimated that these improvements will cost less than $1 million per plant. Orthophosphate addition will cost approximately $6.30/MG, assuming addition of phosphoric acid.

2.4.1.4 pH and DIC Control with Orthophosphate Addition

MINEQL calculations indicate that lead complexation by carbonate prevents phosphate from lowering the lead solubility to levels below the expected EPA no-action levels. Thus, to make phosphate addition more effective it is necessary to remove DIC from the water. Lime softening, air stripping, and ion exchange are treatment processes applicable to DIC removal. For evaluating the feasibility and cost of lead solubility control by DIC removal, lime softening was chosen as the treatment process. Lime softening has the additional advantage of removing Ca^{2+} and Mg^{2+} from the water, which can potentially bind with the phosphate, thus leaving it unavailable for control of lead solubility. Both softening and orthophosphate addition are well-established treatment processes. It should be noted, however, that soft waters have been statistically linked to increased rates of heart disease and should be considered in more detail if serious consideration is given to this option.

Analysis of this treatment option is based on raw water quality data for the Potomac River in August 1988. The potential for lead solubility is relatively high for this water. Water quality goals of 30 mg/L Ca, 10 mg/L Mg, 0.5 mM DIC, and pH of 7.5 to 8.5 were selected. Since the primary objective of the softening process is to lower the DIC, it may not be necessary to remove Ca and Mg to such low levels. Thus, the softening scheme presented below may not be the most cost-effective scheme possible; however, it does allow preliminary investigation into the feasibility and cost of lead solubility reduction by pH and DIC control with orthophosphate addition.

The first step in the treatment process is addition of lime and soda ash and the resulting precipitation process. This is represented schematically in the Caldwell-Lawrence diagram (Loewenthal and Marias, 1976) shown in Figure 2-17. Point 1 in Figure 2-17 represents the raw Potomac River water from August 1988 equilibrated with $CaCO_3$.

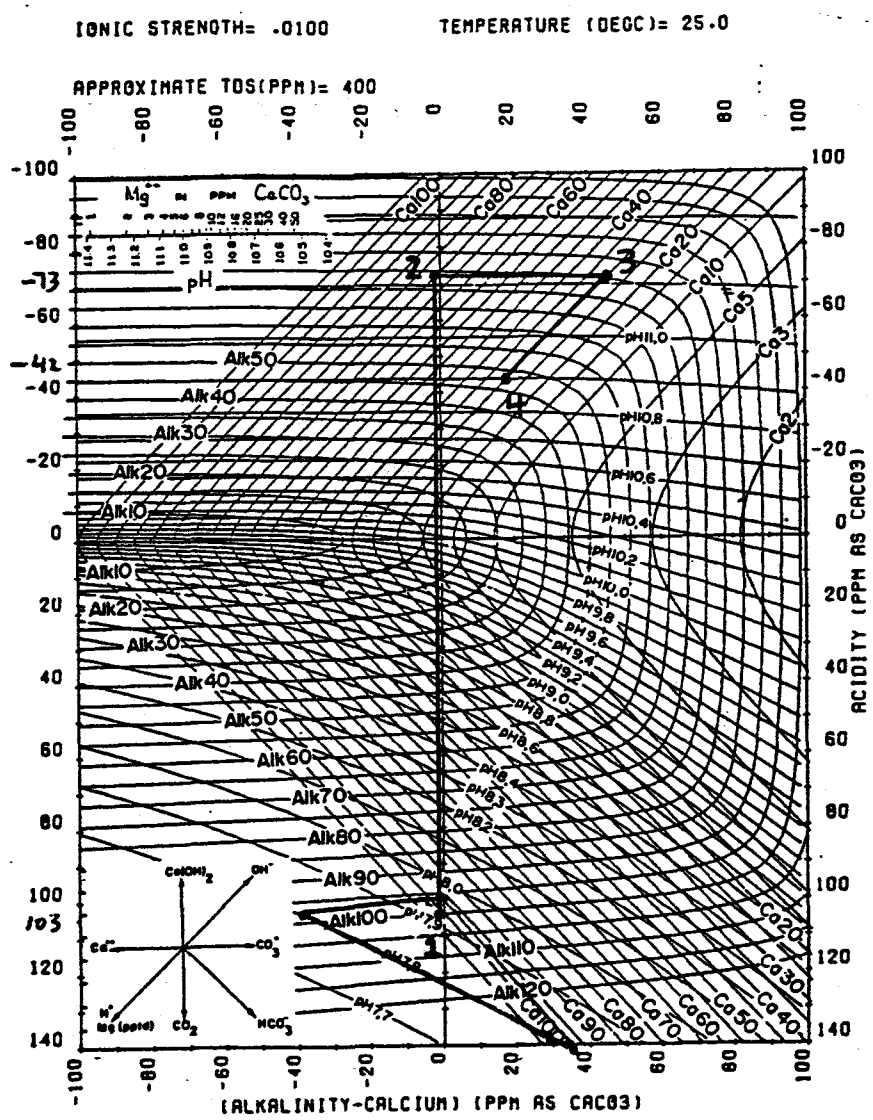


FIGURE 2-17 CALDWELL-LAWRENCE DIAGRAM DEPICTING THE PROPOSED DIC REMOVAL SOFTENING TREATMENT PROCESS

The path from points 1 to 2 represents addition of lime, while the path from points 2 to 3 represents soda ash addition. Point 4 represents the water after precipitation.

Prior to filtration, the water must be neutralized and recarbonated. Point A on the Deffeyes diagram (Deffeyes, 1965) (see Figure 2-18) represents the softened water prior to recarbonation. While the low DIC (0.1 mM) of this water is desirable for reduction of lead solubility, the DIC is too low to provide buffering capacity. The pH of a water of such low buffering capacity could easily drop below 7.0, resulting in high lead solubilities. Thus, it is necessary to raise the DIC level of the water to 0.3 to 0.5 mM to provide buffering capacity at the pipe surface. Recarbonation by CO_2 addition is represented by the path from A to B in Figure 2-18. H_2SO_4 is then added (path B to C) until an approximate pH of 8 is obtained.

Finally, orthophosphate can be added to produce a water of low equilibrium lead solubility. Figure 2-16 indicates that an equilibrium lead solubility of less than 0.030 mg/L can be obtained at an orthophosphate dosage of 2 mg/L in the pH range of 7.5 to 8.5 for waters containing 0.5 mM DIC. The final DIC, pH, and orthophosphate levels must be optimized to minimize lead concentrations measured in first-draw samples collected at customer taps.

By reducing the equilibrium lead solubility to the range of 0.03 to 0.05 mg/L, the average lead concentrations measured in first-draw samples should be well below the no-action limit. In addition, the number of samples that exceed the no-action limit should be reduced to a few percent. However, it must be stressed that it is impossible to predict accurately the response of measured lead concentration for low values of equilibrium lead solubility without data taken in the low solubility range.

Furthermore, water with an equilibrium lead solubility below 0.01 mg/L could still contain greater than 0.01 mg/L lead because of sloughing of particulate, lead-containing corrosion products from interior plumbing surfaces. Therefore, it would be difficult, if not impossible, to produce water for which 100 percent of all first-draw samples contain less than the no-action limit of 0.01 mg/L.

Since water softening sludges are more dense and are produced in higher volumes than turbidity removal sludges, this treatment scheme would require extensive upgrading of the existing water treatment plants. Several additional unit processes would have to be added to each plant, in addition to facilities for handling and disposing of sludges.

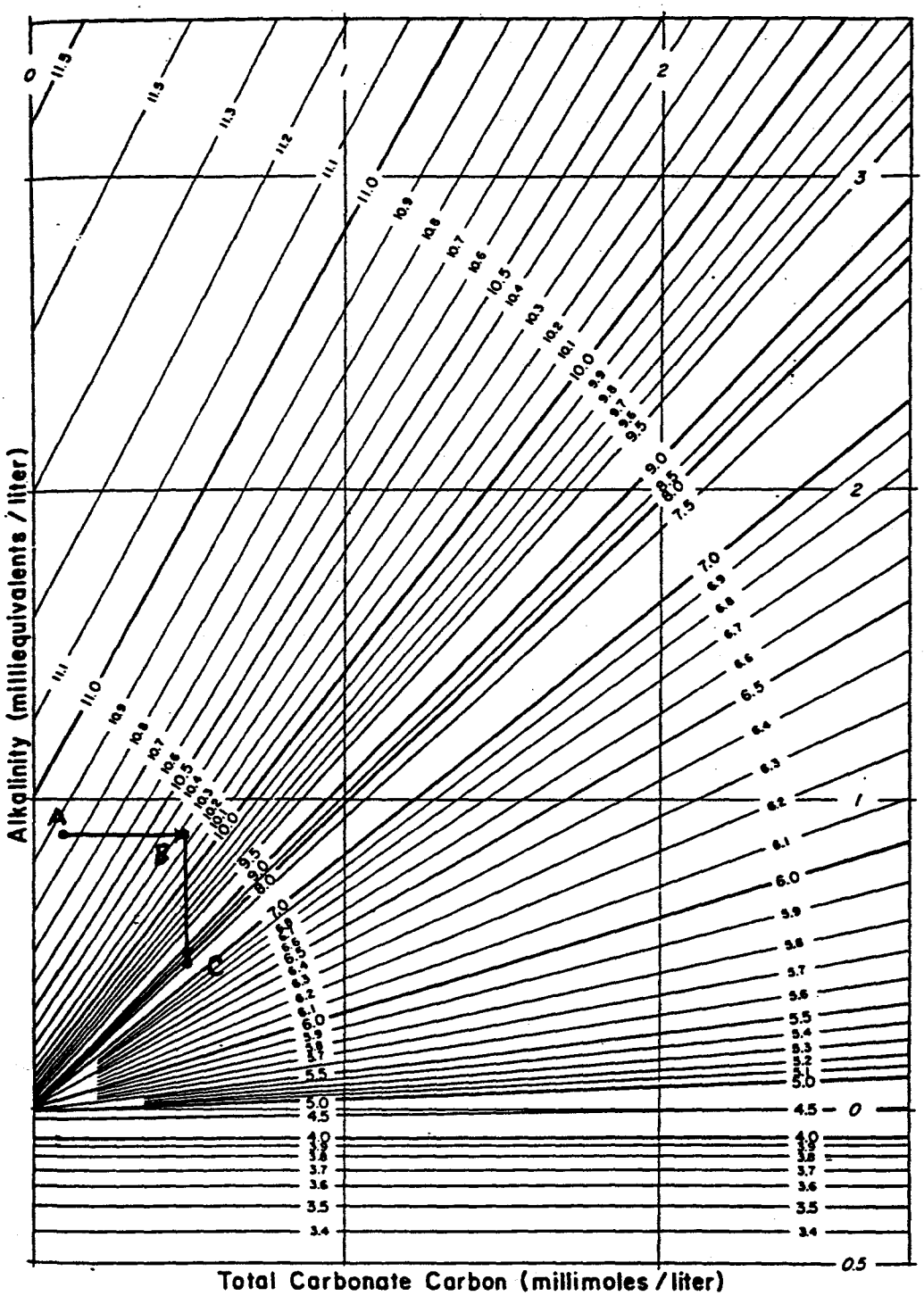


FIGURE 2-18 DEFFEYES DIAGRAM DEPICTING RECARBONATION OF SOFTENED WATERS

It should be noted that sludge handling and disposal costs would be particularly high. Cost notwithstanding, sludge disposal is a particularly severe problem for both the Corps of Engineers and the District of Columbia, Department of Public Works. The additional sludge generated by this option limits the feasibility and practicality of this treatment option.

The chemical dosages and approximate costs for treating the water, assuming the August 1988 raw water quality and the proposed treatment scheme, are summarized in Table 2-5. Labor, energy, and sludge disposal costs will be more expensive than present costs because of the added complexity of the treatment process and the greater mass of sludge. Table 2-6 summarizes effectiveness and costs of various treatment options. The cost of sludge disposal may be very high and depends on various available options. The capital cost for the last treatment option has not been estimated because of uncertainties concerning the sludge disposal options available.

2.4.2 Point-of-Use Devices

As described in Subsection 2.3.2, point-of-use devices represent an alternative method of removing lead from drinking water. The capability of certain point-of-use devices to remove lead from drinking water has been established by independent testing agencies. As with any water treatment unit, point-of-use devices must be maintained. Responsibility for maintenance must rest with the homeowner or user. In some cases, lack of maintenance can cause the quality of drinking water to become worse than the water entering the treatment unit. The issue of maintenance is a serious one that affects all point-of-use devices.

2.4.2.1 Reverse Osmosis

Reverse osmosis is a well-established and reliable method for removing dissolved materials from water. Reverse osmosis (RO) treatment units are available for installation and use in domestic residences. Typical units have a capacity to treat between 2 and 8 gallons of water per day. This is sufficient for the cooking and drinking water needs of an average household.

The cost of an RO unit is approximately $800 installed, with maintenance costs of $50 per year for replacement of pre- and post-filters and RO modules. In addition, there are energy costs associated with the operation of the unit. - RO is a technically feasible, reliable alternative for removing lead from drinking water. The cost is relatively high, however; and the need for continuous maintenance has both water quality and legal implications that the District should explore before more serious consideration can be given to this alternative.

Table 2-5

Chemical Dosages and Costs for Lead Solubility Control

Chemical	Dosage (lb/1,000 G)	Unit Cost ($/ton) (Ref. 14)	Treatment Cost ($/MG)
CaO (90%)	0.913	45.00	20.54
Na_2CO_3 (58%)	0.737	93.00	34.25
CO_2	0.183	120.00	10.98
H_2SO_4 (98%)	0.125	96.00	6.00
H_3PO_4	0.020	630.00	6.30
		Total	$78.07

The effectiveness and cost of the various treatment options are summarized in Table 2-6.

Table 2-6

Effectiveness and Cost of Various Treatment Options

Treatment Option	Mean Lead Level (mg/L)	95% Lead Level (mg/L)	Capital Cost (millions of dollars)	Chemical Cost ($/MG)
pH and alk. control	0.01	0.055	---	1.00
L.I. adjustment	0.01	0.055	---	1.00
Phosphate addn.	0.004	0.029	2	6.30
pH & DIC control with phosphate addn.	0.003	0.010	*	78.07

*Not available.

2.4.2.2 Granular Activated Carbon

Water treatment units using granular activated carbon (GAC) to remove impurities from drinking water are available for home use. GAC is widely used for the removal of organic compounds from water but has not generally been thought to be capable of removing lead from water. Recent evidence suggests that some removal of lead by GAC is possible under certain pH ranges (National Sanitation Foundation, 1989). Some point-of-use devices have been rated as being capable of removing lead from water while the majority are not. The factors allowing one unit to remove lead while other units cannot are not known. The use of GAC to remove lead is not well-accepted or well-established among sanitary engineers. Therefore, the performance of GAC in removing lead from water is uncertain. The cost of GAC point-of-use devices ranges from $105 to $325 without installation. Maintenance costs range from $25 to $70 per year for replacement of filter cartridges. Maintenance of GAC units is particularly important since organics adsorbed to the carbon particles provide an ideal nutrient source for bacteria. Bacteria levels will increase over time in water treated by GAC filters as more nutrients and bacteria accumulate on the carbon. Although bacteria alone may not cause health problems, the possibility of pathogenic microorganisms increases as the number of bacteria increases. As with all point-of-use devices, maintenance requirements have significant water quality and legal implications that must explored by the District before further consideration can be given to this option.

2.4.2.3 Distillation

Distillation is capable of treating water to a very high degree of purity. However, the resulting water is highly corrosive and has a flat taste compared to natural water. Distillation units are available for home use that range in cost from $500 for nonpressurized units to $1,200 for pressurized units capable of pumping distilled water to different floors of a house. Operation costs are high for distillation units.

2.4.3 Removal of Lead Material

Water is exposed to lead-bearing materials in several locations once it leaves the distribution main and enters the customer's service line. As described in previous subsections, the corrosion of these materials may result in increased lead levels in drinking water. Removal of these materials would effectively eliminate this source of lead.

2.4.3.1 Lead Service Line Replacement (Partial)

In the District's water system, as in most water systems throughout the country, ownership/control of the service line is shared between the water system and the homeowner. The District is currently replacing its portion of the service line when it is found to be lead. At the same time the District notifies the

homeowner that a lead service line is present and suggests that the homeowner replace the remaining portion.

As part of the most recently proposed lead regulations (August 1987), EPA considered making service line replacement mandatory where it was shown to contribute to high lead levels at the tap.

Partial replacement of a lead service line does not necessarily result in lower lead levels at the tap. At this time no data are available that relate partial lead service line replacement to lead levels at the tap. EPA is likely to make lead service line replacement a part of the final lead rule.

The current cost of replacing the District's portion of a lead service line has been estimated at $2,890 per service. This cost includes all labor charges (direct labor and administrative labor, plus employee benefits); equipment costs (using the purchase cost of equipment and the expected life); and the cost of supplies. A detailed calculation of this replacement cost is given in Table 2-7. This represents actual cost incurred by the District in replacing lead service lines in the District during 1989.

2.4.3.2 Lead Service Line Replacement (Total)

In cases where the lead service line has been shown to contribute to high lead levels at the tap, consideration should be given to the complete removal of the service line. Since it is impractical to test each location for the contribution of the lead service line to total lead concentrations, it is likely that a replacement program would have to include all lead service lines in the District.

While the District's portion of a service line is fairly standard, the homeowner's portion can vary greatly in length and depth. This makes estimating the cost of a total service line replacement difficult. Replacement of the District's portion of a lead service line has been estimated at $2,890, including $600 for street replacement. Based on the actual cost incurred by the District, a rough approximation of total service line replacement cost can be made assuming that replacing the homeowner's portion is about equal to the cost of replacing the District's portion, excluding the cost of street replacement. Thus, the cost of a total service line replacement for each house is estimated at $5,180 [$2,890 + ($2,890 - $600)].

2.4.3.3 Replacement of Lead Soldered Joints

The most common household plumbing system consists of copper pipes joined by solder. Until recently, this solder consisted of an alloy containing up to 50 percent lead. Recent studies (Lee, Becker, and Collins, 1989) have shown that a large portion of the lead at the tap is contributed by corrosion of lead solder joints. Removal of such joints from the plumbing system would reduce overall lead levels in the water.

WESTON.

Table 2-7

Cost Estimate for the Existing District of Columbia Lead Service Replacement Program

Total Annual Program Costs (375 replacements)

ITEM	COST
Labor	$696,344
Equipment	$109,680
Supplies	$277,875
TOTAL	$1,083,899

Cost per service line = $2,890

WESTON.

Table 2-7
(continued)

DIRECT LABOR COSTS

Labor Category	Quantity	Salary Grade	Salary ($/hr)	% of Time on Program	Cost
General Foreman	1	SW15	$23.18	20%	$9,272
Foreman	3	SW10	$18.92	100%	$113,520
Crew Chief	3	RW10	$15.22	100%	$91,320
Crew 1	3	8	$13.76	100%	$82,560
Crew 2	7	6	$10.93	100%	$153,020
Backhoe Operator	1.5	RW10	$15.22	100%	$45,660
Truck Driver	1.5	RW7	$13.05	100%	$39,150
TOTAL					$534,502

ADMINISTRATIVE LABOR COSTS

Labor Category	Quantity	Salary Grade	Salary ($/hr)	% of Time on Program	Cost
Data Management	1		$12.50	20%	$5,000
Deputy Chief	1		$19.00	10%	$3,800
Chief	1		$25.00	10%	$5,000
TOTAL					$13,800

TOTAL LABOR COSTS

Item	Cost
Direct	$534,502
Administrative	$13,800
Subtotal	$548,302
Fringe Benefits (27%)	$148,042
TOTAL	$696,344

Table 2-7
(continued)

EQUIPMENT COST

Equipment	Quantity	% Used	Purchase Cost	Life (yrs)	Total Cost ($/yr)
Crew Cab	3	100%	$14,000	6	$7,000
Compressor	3	100%	$11,000	6	$5,500
Backhoe	1.5	100%	$38,000	6	$9,500
Dump Truck	1.5	100%	$45,000	6	$11,250
Pickup Truck	3	100%	$11,000	6	$5,500
(foreman)				6	
Pickup Truck	1	20%	$11,000	6	$367
(general foreman)				6	
Pickup Truck	1	10%	$11,000	6	$183
(deputy chief)				6	
Pickup Truck	1	10%	$11,000	6	$183
(chief)				6	
Power Mole Machine	1	10%	$5,000	6	$83
Portable Pumps	4	100%	$600	6	$400
Pavement Breakers	6	100%	$600	6	$600
Tampers	4	100%	$840	6	$560
Pneumatic Tools	3	100%	$1,400	6	$700
Generators	4	100%	$800	6	$533
Radio	3	100%	$1,000	10	$300
Tap Machine	3	100%	$1,400	10	$420
SUBTOTAL					$43,080
Uniforms					$2,850
Maintenance Cost ($/yr)					$63,750
TOTAL					$109,680

WESTON.

Table 2-7
(continued)

SUPPLY COST

ITEM	COST PER SERVICE	TOTAL * ANNUAL COST
One length of copper pipe	$100	$37,500
1" corporation cock	$16	$6,000
1" curbcock	$13	$4,875
1" bend	$12	$4,500
Street Replacement	$600	$225,000
		$0
TOTAL	$741	$277,875

* Based on the total number of services replaced in a given year.

Soldered joints will not contribute lead at the same rate. Studies have shown that typically after 5 years a soldered joint will no longer contribute significant levels of lead. Also, a neatly soldered joint should, theoretically, contribute less lead than a sloppy joint using excessive amounts of solder. Finally, joints soldered within the last 2 years should be lead-free because of the enactment of the lead ban in 1988.

Regardless of the number of joints that would need replacement, replacing all lead soldered joints within the District would be a monumental task and beyond the control of the District. Encouraging homeowners to undertake such a rehabilitation of their plumbing systems could be done as part of a public education program (see Subsection 2.4.5). The danger inherent in this is that homeowners may mistakenly use leaded solders to make the repairs, thus aggravating the situation they were trying to remedy. Therefore, although technically feasible, this option appears to be impractical.

2.4.3.4 Replacement of Brass Faucets and Fixtures

Fixtures containing brass are almost universal in interior home plumbing applications. Recent studies (Lee, Becker, and Collins, 1989) have shown that the lead contained in these brass fixtures can contribute up to one-third of the lead found in a 1-liter, first-flush sample.

The District has no control over the types of fixtures individuals choose to install. They can, however, through a public education program, encourage homeowners with brass fixtures to replace them with newer fixtures having a lower lead content.

2.4.4 Plumbing Code Modifications and Enforcement

While replacement of all existing lead pipe and solder in the District is impractical, it is possible to ensure that all new installations (and repairs of existing systems) use only lead-free materials. The first step in such a plan has already been taken with the passage of the District's lead ban in 1988. Simply having such a lead ban is insufficient. Active enforcement is needed to make the program effective in reducing exposures to lead.

Enforcement must be directed at professional plumbers, as there can be little direct control over a homeowner making his/her own repairs. It must be remembered that lead solder is still on the market; only its use in drinking water supply systems has been banned. Building inspectors must be aware of the difference between lead and lead-free solder.

The cost of enforcement is negligible. There should be little extra effort required to ensure that a building's plumbing system has been installed using lead-free materials, assuming that the work is inspected at all. For homeowners doing their own repairs (i.e., without a permit), the only "enforcement" possible is to

stress to the public the importance of working with lead-free material.

2.4.5 Public Education

The implementation of a public education program to teach consumers about the sources of lead in drinking water and methods of reducing their exposure to the lead can be an effective method of reducing exposure. Over the last several years the Federal government has passed legislation requiring water system personnel to conduct public information campaigns and, under certain circumstances, public education programs. Such programs cannot be considered as complete solutions to the problem of lead in drinking water. Rather, they should be combined with other measures as part of an overall lead reduction program.

The effectiveness of a public education program to reduce customers' exposure to lead in drinking water is difficult to measure. The methods of reducing lead exposure outlined in such programs are simply suggestions. Homeowner initiative is needed to carry out the suggestions and make them successful.

The cost of developing and implementing a successful public education program would vary depending on the scope of the program and the target audience.

2.4.6 Alternative Distribution Techniques

As described in Subsection 2.3.6, lead exposure from drinking water could be reduced by altering the way in which customers receive their water for cooking and drinking. The following subsections detail two ways in which this could be accomplished: bottled water and dual water distribution.

2.4.6.1 Bottled Water

The major source of lead in the District's water is from the corrosion of lead-bearing materials. Providing water to customers that has never been in contact with these lead-bearing materials would eliminate the exposure to lead in water. One way to accomplish this is through the use of bottled water for cooking and drinking.

Many customers already use bottled water for reasons of taste. However, bottled water is not inexpensive, and many customers would balk at suggestions that they must purchase it. In addition, there also would be many customers who could not afford the bottled water even if they did wish to purchase it.

Bottled water currently has a retail cost of approximately $0.70 per gallon. Assuming a per capita consumption of 2 gallons per day for cooking and drinking, a typical family of four could expect to pay an additional $2,044 per year for its water, if the water were purchased retail. The District could choose to have the consumer

bear the entire cost of the water, or could enact programs to help pay all of part of the cost. One option would be for the District to subsidize the use of bottled water through a reduction in water rates. A second option would be for the District to bottle its own water and provide it free of charge to customers. In either case, a careful analysis would be required to determine the cost effectiveness of such a plan.

In summary, although the use of bottled water is attractive in that it basically eliminates a major source of lead in drinking water, it would appear that this solution is impractical from an economic perspective.

2.4.6.2 Dual Water Distribution System

Another option to provide customers with water that has been isolated from any possible contact with lead-bearing materials is the concept of a dual water distribution system. This concept is based on the fact that lead levels in the water distribution system are quite low. By providing water for cooking and drinking that never comes in contact with lead in service lines, solder joints, brass faucets, etc., exposure to lead in water will be minimized.

This could be accomplished in one of two ways. The first is to simply install a new tap for each affected customer, and install a new service line. Once inside the house, a new pipe would be installed directly to a separate fixture at the kitchen sink. This new plumbing work would, of course, be lead-free. The customer would then be instructed to use only this new installation for all cooking and drinking purposes.

The second method would be to install a common distribution point in each neighborhood or block. This faucet would tap directly into a distribution main. Customers who are found to have high lead levels at the tap could collect a supply of water for cooking and drinking from this tap, while continuing to use their regular supply for all other purposes.

While each of these methods would effectively eliminate exposure to lead in drinking water from corrosion, each has significant problems. Installing new service lines and fixtures in all houses with high lead levels would be costly and impractical. The common distribution point concept has serious potential to create public health problems, as well as requiring customers to undergo dramatic changes in water use habits.

2.5 CONCLUSIONS

The following conclusions can be made about lead in drinking water in the District:

- The raw water supply of the District contains low concentrations of lead, typically <5 ug/L.

- Lead concentrations in water in the distribution system are typically <5 ug/L.
- High concentrations of lead in tap water, more than 500 ug/L in one case, can be found in some homes in the District.
- High concentrations of lead in tap water may result from corrosion of lead in brass faucets, lead-bearing solder, or lead service lines.
- The presence of a lead service line does not necessarily result in elevated lead levels in water at the tap.
- The current cost to replace the District's portion of a single lead service line is approximately $2,900.

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SECTION 3

INVESTIGATION OF GEOPHYSICAL AND REMOTE SENSING TECHNIQUES TO DETECT BURIED LEAD PIPES

3.1 INTRODUCTION

3.1.1 Background

One of the objectives of this study is to determine the extent of lead service lines in the District. When possible, the type of service line can be determined from existing data files. However, in many cases the information in the data files will not be sufficient, and physical methods will be required to ascertain the presence of buried lead pipes. Because the service lines are buried and on private property, these lines cannot be directly examined without direct access to the customers' premises, or by excavation. Therefore, the use of remote sensing techniques would be of substantial benefit to acquire this information.

To fulfill one of the requirements of this study, an investigation of available techniques that could be used to locate and identify buried lead pipes was conducted.

3.1.2 Objectives

The major objectives of this task are to research available geophysical methods and remote sensing techniques to determine whether any of them would be effective in locating and identifying buried lead pipes, and to issue a report summarizing the results and recommendations including the expected accuracy of the methods.

The following geophysical methods were researched: ground penetrating radar, electrical conductivity, metal detectors, resistivity, and magnetometer. The use of fiber-optic instruments as remote sensing equipment was also analyzed. Subsection 3.2 presents discussions of each of the techniques covering the theory of operation, general applications of the technique in other fields, and the possible limitations of the method for this project. Subsection 3.3 is a summary of the findings of the literature review and the interviews, followed by the conclusions and recommendations.

3.1.3 Literature Search and Interviews

In order to accomplish the objectives of this task, a computer literature search was conducted using electronic information search facilities. The search listed the available published sources of similar field applications as well as state-of-the-art research on the subject.

Many telephone consultations were also conducted with different experts in the field such as geophysical instrument manufacturers, university laboratories, and independent research facilities. Our own field staff also were interviewed to inquire about currently used techniques for locating buried materials. These conversations were especially valuable in that they provided a great deal of information from hands-on experience necessary to complement the literature sources.

The thorough review of the existing literature substantiates the summary of conclusions and recommendations in Subsection 3.3.

3.2 TECHNIQUES INVESTIGATED

3.2.1 Ground Penetrating Radar

3.2.1.1 Theory

Ground penetrating radar is a surface interface radar that transmits an electromagnetic pulse into the subsurface. The electromagnetic pulse travels through the subsurface until it encounters a soil interface or an object with a different dielectric constant (Telford, 1984). The dielectric constant is a measure of the ability of a material to polarize an electric field.

This contrast in dielectric constant causes part of the transmitted pulse to be reflected back to the surface. Variations in dielectric constants occur at soil/rock interfaces, rock/air interfaces, voids, buried pipelines, manmade objects, etc. For example, digging a trench and filling it again can create a difference between the dielectric properties of the disturbed earth and those of the undisturbed material, and it will be sensed by the radar. Figure 3-1 is a schematic diagram showing the various components of a ground penetrating radar system.

The time the pulse takes to travel from the antenna to the buried object and back to the antenna is dependent on the depth of the object and the dielectric properties of the media through which the pulse travels. The reflected energy is received by the antenna and is then transmitted to a microprocessor in the control unit. There the reflected electromagnetic pulse is processed and transmitted to an oscilloscope and a graphic recorder. The graphic recorder produces a hard copy of the electromagnetic energy's response to the subsurface profile that can be subsequently analyzed. As an example, Figure 3-2 shows the cross section resulting from a radar measurement across a traverse that produces the images of three buried 55-gallon drums.

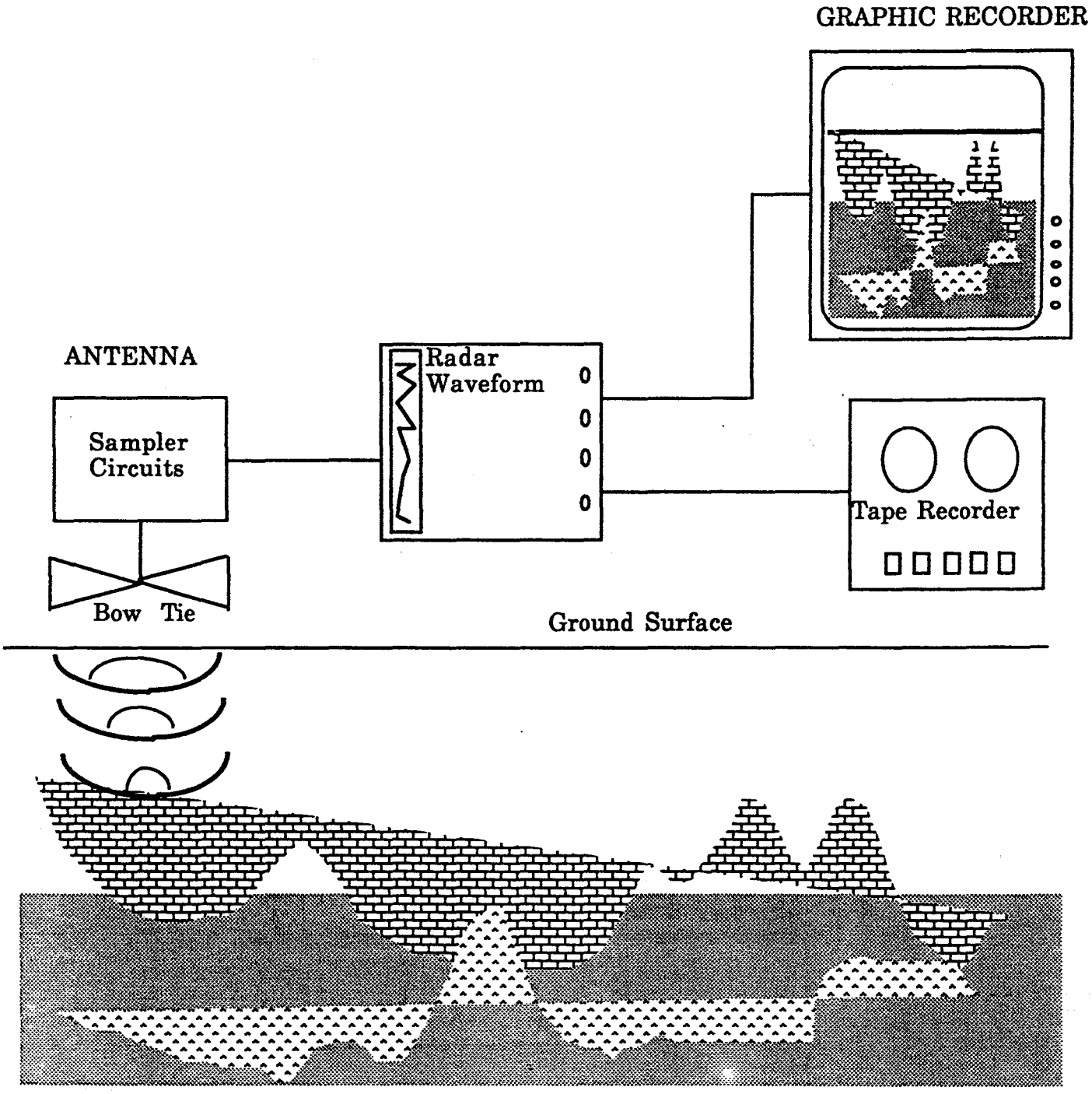

FIGURE 3-1 SCHEMATIC DIAGRAM OF GROUND PENETRATING RADAR METHOD

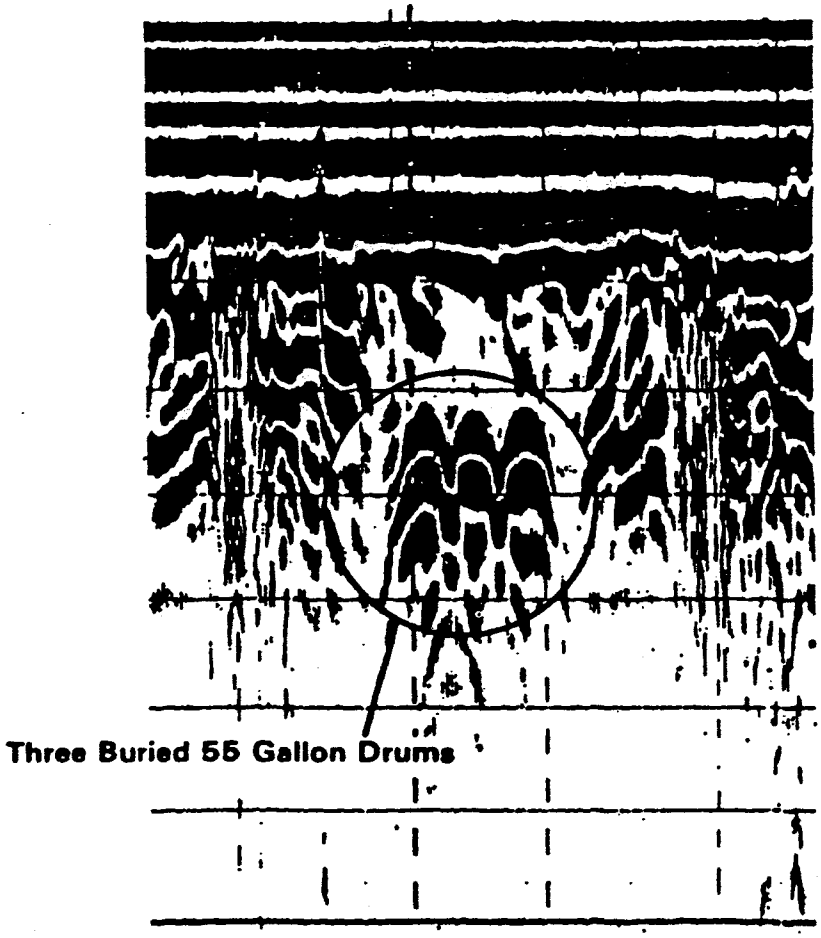

FIGURE 3-2 GROUND PENETRATING RADAR DATA OVER TRENCH WITH BURIED METAL

3.2.1.2 General Applications

Ground penetrating radar is typically used to map geohydrologic features, to locate boundaries of buried trenches, and to locate buried metallic objects.

3.2.1.3 Limitations

This method can be used to determine the location of a metal object buried in a dielectric (insulating) medium by the change in dielectric properties, i.e., transition from a dielectric (soil) to a conductor (lead pipe), but the radar cannot be used to obtain information about the conductor because by definition it has no dielectric constant (the charges are free to move) (Evans, 1982). Therefore, if this method were used to locate a lead service line, analysis of the hard copy of the profile would display a continuous profile of the pipe, which would confirm its location, but the same experiment performed with a copper pipe would exhibit no significant difference in the profile because the radar does not penetrate conductors.

The depth of radar penetration is very site-specific. This depth is reduced if water encountered in the profile has high electrical conductivity, or if there are sufficiently high concentrations of fine-grained materials (e.g., silts or clays) present. For example, high concentrations of salts tend to defeat the radar pulse, and penetration may not exceed 3 feet (WESTON, 1987).

Electromagnetic measurements in general are affected by "cultural features" such as fences, buildings, vehicles, storage tanks, power lines, railroad tracks, scrap metal, etc., which considerably diminish the reliability of the instruments.

3.2.2 Electrical Conductivity

3.2.2.1 Theory

The principal operation of the electrical conductivity method is shown in Figure 3-3. The instrumentation consists of a transmitter coil that radiates an electromagnetic field, which induces current loops in the earth which act as a conductor. These current loops in turn generate a secondary electromagnetic field that is proportional to the current flowing in the loop. Part of the secondary magnetic field of each loop is intercepted by the receiver and produces an output voltage that is related to subsurface conductivity. Subsurface conductivity varies according to Archie's Law, which states that the conductivity of a material is directly proportional to the conductivity of water and the square of the porosity of the material (e.g., soil/rock type, percent of saturation, etc.) (Keller et al., 1982). Figure 3-4 illustrates a typical electrical conductivity profile over a metal pipe.

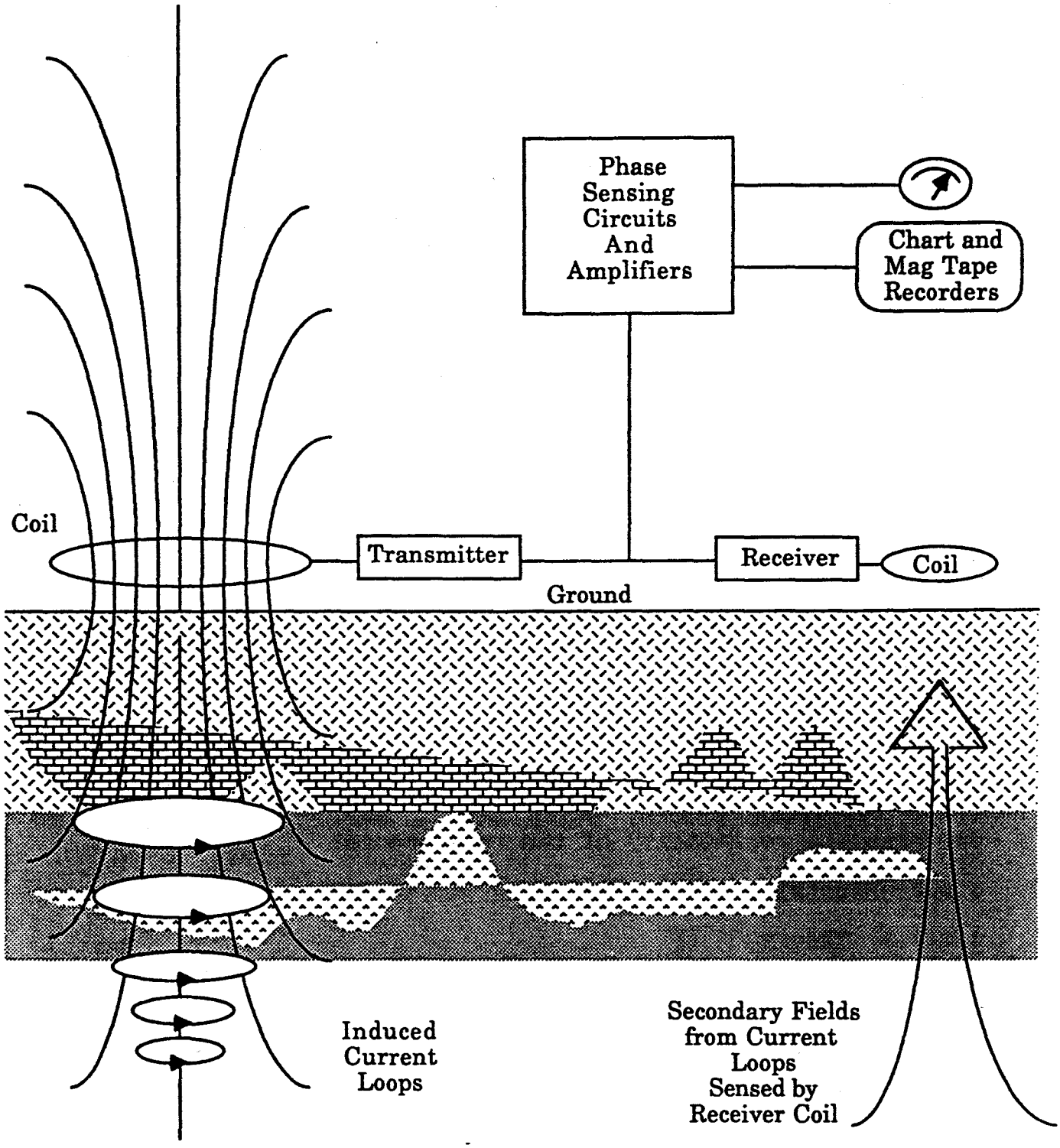

FIGURE 3-3 SCHEMATIC DIAGRAM OF AN ELECTRICAL CONDUCTIVITY INSTRUMENT

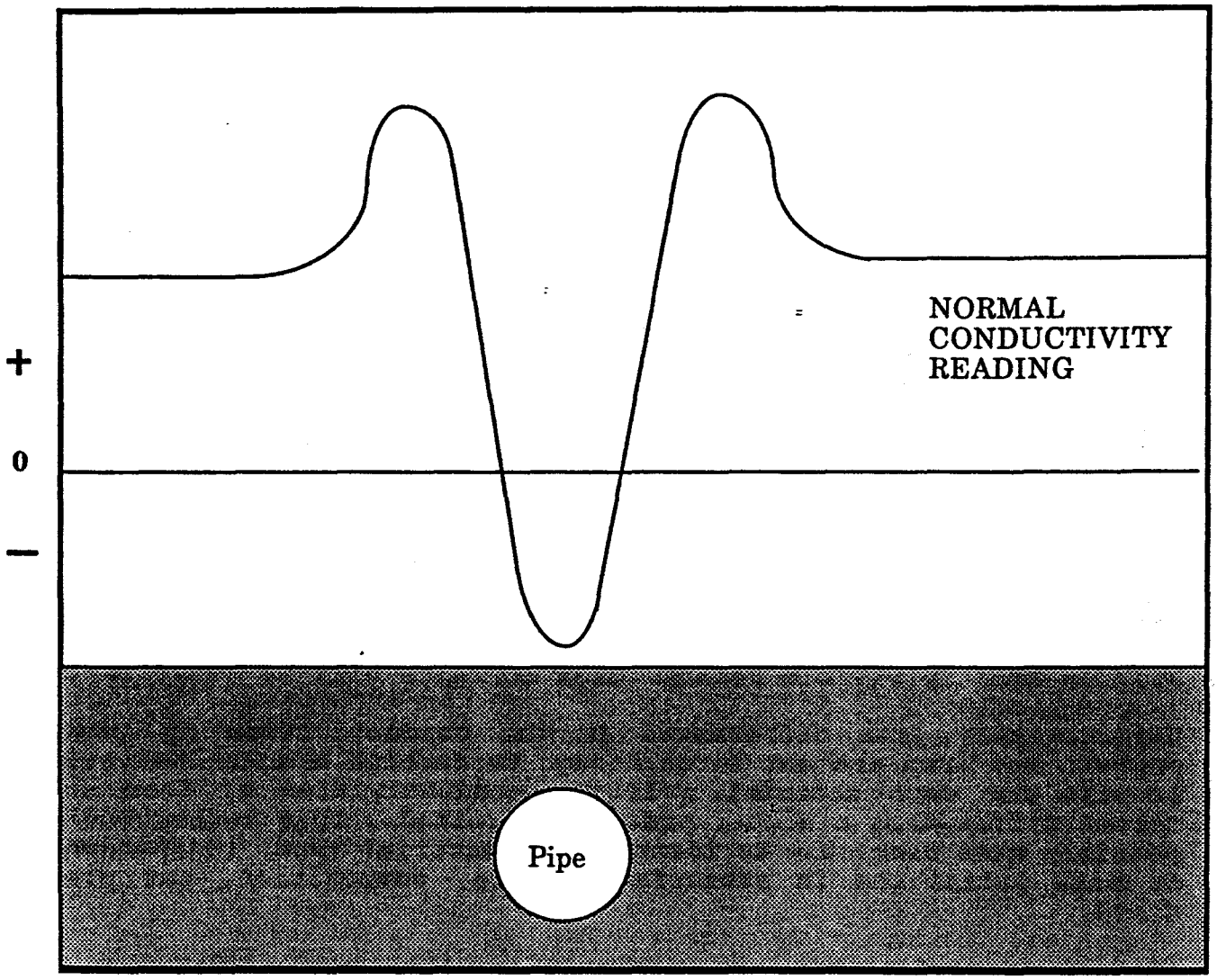

FIGURE 3-4 TYPICAL ELECTRICAL CONDUCTIVITY PROFILE OVER A METAL PIPE

3.2.2.2 General Applications

Electrical conductivity instruments may be calibrated to read the true subsurface conductivity within a uniform earth; however, subsurface conditions are rarely uniform. In a layered earth where each layer has a different conductivity, the reading will depend on the thickness and depth of the layers, and the specific conductivities of each layer. The resulting conductivity measurement is a complex function of all these conditions. An accurate solution requires knowledge of the layer thicknesses, depth, and relative conductivities.

This method is well suited for acquiring information on lateral changes in electrical conductivities in the subsurface (called profiling) and vertical changes in subsurface conditions (called sounding). Electrical conductivity is used primarily to identify areas of anomalous electrical conductivities, to find lateral and vertical variations of electrical conductivity in the subsurface, to locate buried materials, and to determine the presence of plumes and the distribution of contaminants in groundwater (Evans, 1982).

An alternative electrical conductivity method consists of directly measuring the electrical conductance of the pipe. This requires access to two points in the service line, either by excavation or by entry to the residence.

3.2.2.3 Limitations

Since metals are of much higher conductance with respect to air, water, and soils (see Table 3-1), any subsurface metallic object will be readily visible because high currents will be generated.

Unfortunately, the differences in the conductivities of lead, copper, and iron are not large enough to furnish a characteristic profile for each material. If the conductivities of lead and copper differed by a higher order of magnitude, this method would possibly have been able to identify the material type, independent of site variations in subsurface strata, composition, and pipe depth.

Electrical conductivity measurements are negatively affected by cultural features that are typical of residential areas, such as fences, buildings, vehicles, storage tanks, power lines, railroad tracks, scrap metal, antennas, etc. These cultural features mask the small differences in conductivity between copper and lead.

3.2.3 Metal Detectors

3.2.3.1 Theory

The transmitter of a metal detector creates an alternating magnetic field around the transmitter coil. The primary field will induce eddy currents in a metal target within range of the instrument

Table 3-1

Approximate Conductivities of Different Materials*

Material	Conductivity (mmho/m)
Air	0
Fresh water	0.1
Seawater	4,000
Clay	1,000
Marble	<10
Copper	5.8×10^{-10}
Iron	1×10^{9}
Lead	5×10^{9}

*Adapted from Telford et al., 1984.

(Telford, 1984). These eddy currents in turn produce a secondary field that interacts with the primary field to upset the existing balance. The result is an output on a meter and/or an audio signal. Figure 3-5 shows the operation of a simple metal detector.

The metal detector responds to changes in electrical conductivity caused by the presence of metallic objects. The magnitude of response from a metal detector is a function of several variables, including target-to-sensor distance, target size, target orientation, target geometry, and type of metal.

3.2.3.2 General Applications

Figure 3-6 shows profiles taken with a metal detector at a rural site at which drums were suspected of being buried (Tyagi, 1983). Metal detectors respond to the electrical conductivity of metal targets and are commonly used for locating buried drums. They can detect both ferrous metals, such as iron and steel, and nonferrous metals, such as lead, aluminum, and copper.

3.2.3.3 Limitations

Among the various types of metal detectors, the detector used for locating buried drums may also be used for locating utilities; however, in general, they have been found to be insensitive to buried objects of small cross-sectional size. Special effort went into finding the latest available technology in metal detectors. Table 3-2 summarizes WESTON's discussions with leading manufacturers of metal detectors.

Cintex of America has metal detectors that measure the permeability of materials. This allows differentiation of materials, because measurements close to zero are obtained for PVC pipes, medium responses for lead and copper, and high responses for ferrous materials.

The Cintex technical representative, Mr. Daniels, commented that in our specific application, copper should show a slightly higher permeability response than lead; however, variabilities in the surrounding medium (e.g., depth, composition, and additional cultural features) might add to the problem of differentiation. For instance, the electrical response to a copper pipe buried 6 feet deep could be identical to that of a 3-foot-deep lead pipe. Differentiation between lead and copper with some degree of accuracy could be ascertained up to a maximum depth of 12 inches. The representative of Garret Electronics, Inc., Mr. Jack Lowry, also believes that it is possible to discriminate between lead and copper buried less than 12 inches deep with 70 to 75 percent reliability.

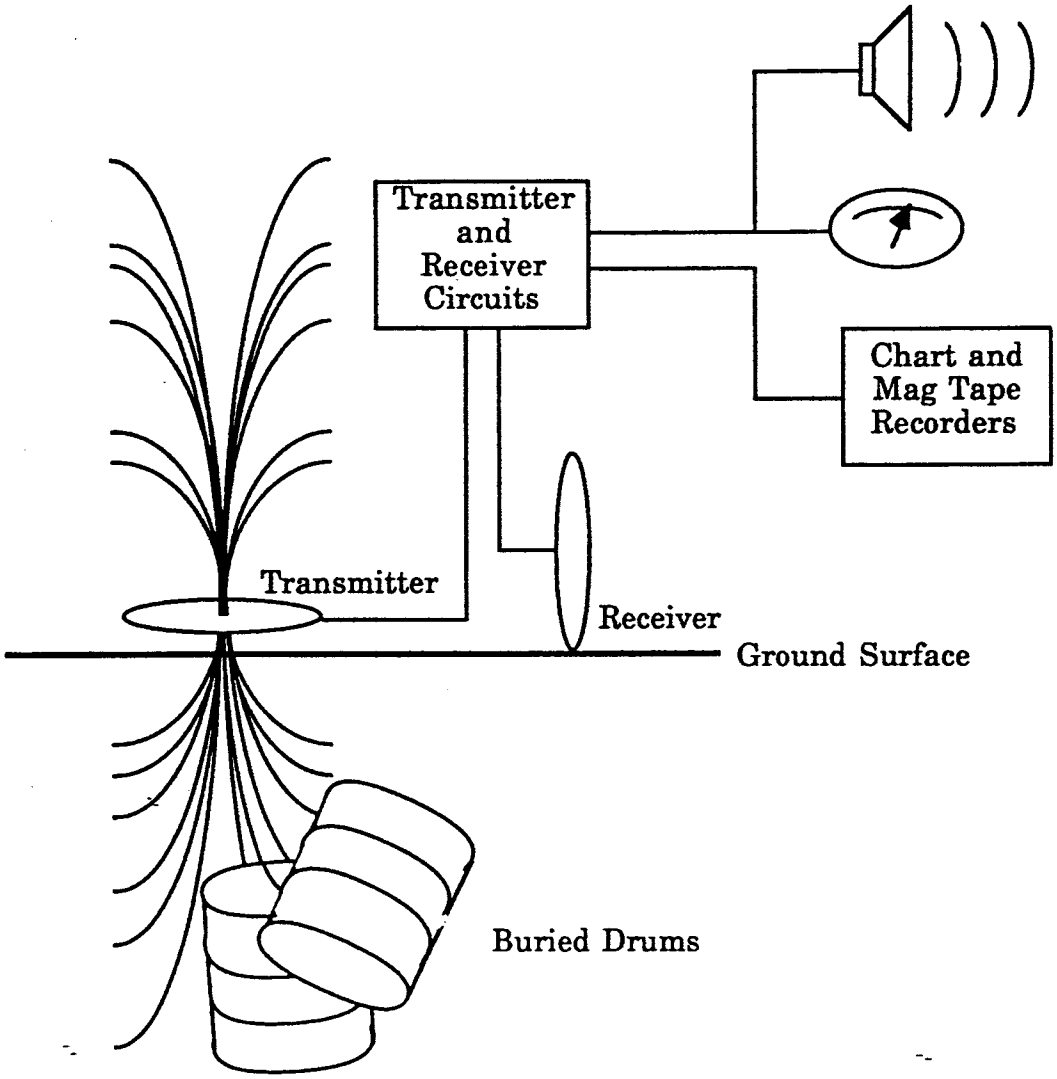

FIGURE 3-5 SCHEMATIC DIAGRAM OF A SIMPLE METAL DETECTOR

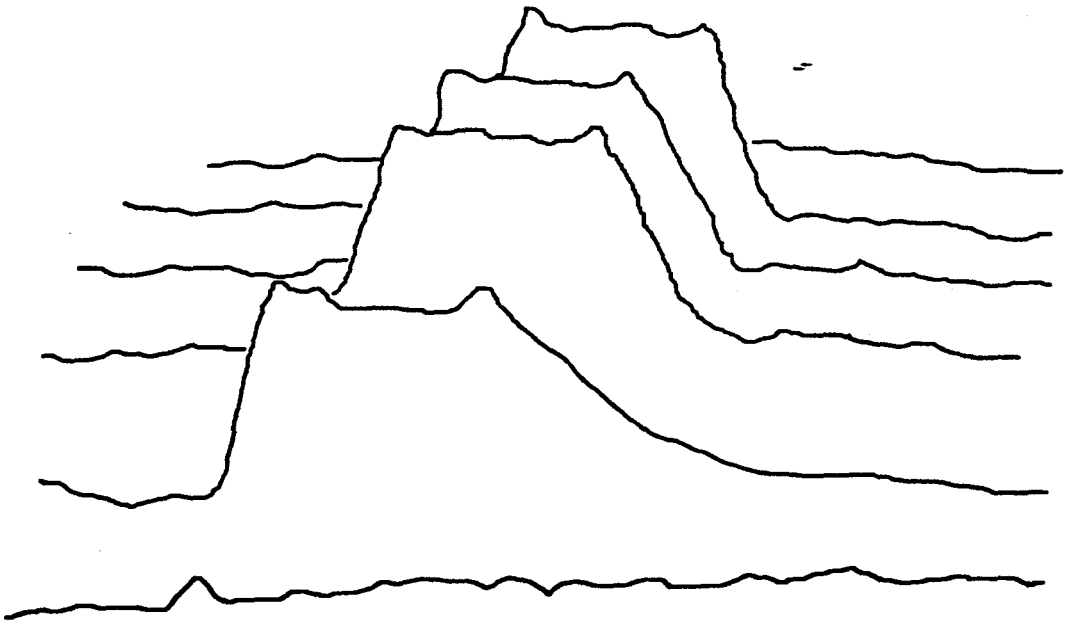

FIGURE 3-6 METAL DETECTOR DATA OVER TRENCH WITH BURIED DRUMS

Table 3-2

Summary of Discussions with Technical Representatives

Manufacturer	Instruments Manufactured and Capabilities
Applied Electronics Corp.	Manufactures heavy-duty industrial equipment, aperture-type only; for food, drug, and lumber industries for detecting ferrous and nonferrous metals only.
Cintex of America	Manufactures hand-held, portable metal detectors for differentiating metals from nonmetals, and within the metals for differentiating ferrous from nonferrous. The metal detectors work on a phase dispersion system compared to the permeability of air. Nonferrous metals have a permeability coefficient less than 1, very small range. In comparison, ferrous metals have permeability coefficients of 1 to 1,000, wide range, i.e., ferrite. Nonmetals have permeability coefficients of 0. The difference in ranges provides the ability to discriminate metals from nonmetals and ferrous from nonferrous. However, the permeability range of nonferrous metals is too small to adequately discriminate between types of nonferrous metals. Permeabilities of lead and copper are too similar to distinguish.
Garret Electronics, Inc.	Manufactures several types of portable metal detectors, and has been in the industry for many years. These metal detectors operate on the same principle as those described for Cintex of America. The representative is not familiar with any metal detection system that in general will discriminate between nonferrous metals with any degree of confidence. However, he did note that it "may be possible to discriminate between lead and copper buried less than 12 in. deep with 70 to 75 percent reliability."
Stearns Magnetics, Inc.	Manufactures primarily industrial aperture-type metal detectors for food, drug, wood, and plastics industries. The representative does not believe metal detection will work for our specific application, he suggested calling White Electronic, Inc.
White Electronic, Inc.	Designs, manufactures, and distributes pipe and cable locator systems and metal detection systems for private and government use. Top of the line systems include: PCL-400 pipe and cable locator, and EAGLE 2 SL metal detector. In our particular case, copper will give a slightly higher response than lead; however, variabilities in the surrounding medium, i.e., depth, composition, and additional cultural features, compound the problem of differentiation. The representative also believes it is possible to discriminate between lead and copper with some degree of accuracy, but only to a depth of 12 in.
Lock International, Inc.	Manufactures industrial metal detectors. The representative believes that this system will not solve our problem of differentiating lead and copper.
Barkley Dexter, Inc.	Manufactures industrial metal detectors. Representative believes we may get some response with the permeability detector, and, depending on depth, we may be able to differentiate lead from copper, but not with much reliability for depths greater than 12 in.

Table 3-2
(continued)

Manufacturer	Instruments Manufactured and Capabilities
Gisco, Inc.	Is not aware of any remote sensing method commercially available that is able to differentiate lead from other types of nonferrous metals.
Sandia National Lab	The Electromagnetic and Optical Testing Group was not aware of any instrumentation or research specifically related to the proposed application of distinguishing between lead and copper in a soil medium.
Los Alamos National Lab	Some independent facilities are doing research, but Los Alamos is not aware of any progress. References recommended: Proceedings IEEE July 1979, special issue on EM Theory to Geophysical Exploration. Ohio State University. Microwave Association, Inc.
University of Arizona	Electrical Engineering Department. Dr. James Wait is involved in research on "Electromagnetic Theory in Dissipated Media," which will eventually lead to metal-specific metal detectors. As of now, he has no knowledge of any metal detectors available on the market able to locate specific metals.

Based on the survey conducted in this study of more than 20 manufacturers of metal detectors, plus many independent contractors that are currently using these instruments, the permeabilities of lead and copper are too similar to distinguish between the metal types with any degree of certainty at the present state of the art. Additional research and more powerful detectors may result in metal detectors in the future that can differentiate lead and copper pipe, if manufacturers believe there is a market for such devices. A few manufacturers have offered to set up a pilot study to test their equipment for our purposes.

3.2.4 Resistivity

3.2.4.1 Theory

Application of the resistivity method requires that an electrical current be injected into the ground by a pair of surface electrodes (Keller et al., 1982). The current flow within the subsurface produces an electric field with lines of equal potential, perpendicular to the lines of current. The potential field is measured by a voltmeter at the surface by a second pair of electrodes. A schematic of such a configuration is shown in Figure 3-7. The subsurface resistivity is calculated from the electrode separation, the applied current, and measured voltage.

The method provides data similar to that obtained using the electrical conductivity method. It measures the electrical resistivity (or inverse conductivity) of the subsurface or geohydrologic section which includes soil, rock, and ground water. Similarly, the electrical resistivity of the subsurface varies according to subsurface composition (e.g., soil/rock type, percent saturation, etc.). Interpretation of these measurements provides information on layering and depths of subsurface horizons as well as lateral changes.

3.2.4.2 General Applications

In general, most soil and rock minerals are electrical insulators (high resistivity), and, as a result, the flow of current is conducted primarily through the moisture-filled pore spaces. Therefore, the resistivity of soils and rocks is predominantly controlled by the amount of pore water, the porosity, and permeability of the system (SOILTEST, Inc., 1982).

In most applications, the presence, quantity, and quality of groundwater are the dominating factors influencing the resistivity value. As such, the method is primarily used to evaluate contaminant plumes at hazardous waste sites, and to assess lateral and vertical changes in natural geohydrologic settings of uniformly layered geological conditions, where the results will indicate the

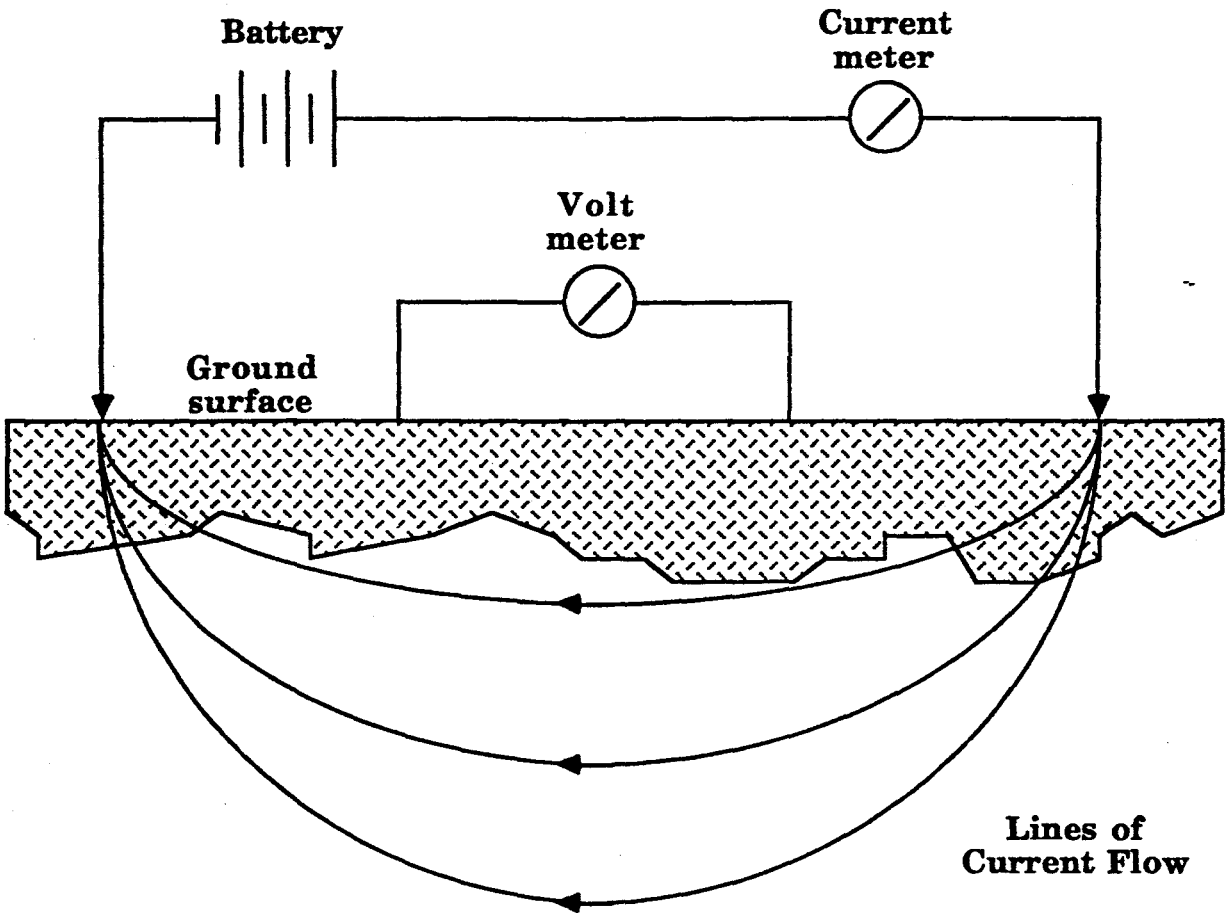

FIGURE 3-7 SCHEMATIC DIAGRAM OF A RESISTIVITY INSTRUMENT

number of geologic layers with contrasting electrical properties. Horizontal variations (profiling) in resistivity are observed by moving the entire array laterally over the surface. This approach can be used to map the horizontal extent of contaminant plumes in groundwater. Vertical variations (sounding) are obtained by observing the resistivities that result from progressively greater electrode spacings which lead to greater depths of penetration.

3.2.4.3 Limitations

The limitations of this method are similar to the limitations of the electrical conductivity method. In this case the differences in electrical resistivity (inverse of electrical conductivity) of lead, copper, and iron are not large enough to furnish a characteristic profile for each material. Similarly, if the resistivities of lead and copper differed by a higher order of magnitude, this method would possibly identify the material type independent of site variations in subsurface strata, composition, and pipe depth.

Another limitation is that the resistivity instruments are negatively affected by cultural features that are common to residential areas. In addition, urban site conditions, such as dry surface materials, and concrete or paved roads, preclude the use of this method because they behave as insulators.

3.2.5 Magnetometer

3.2.5.1 Theory

The magnetic method detects variations in magnetic susceptibility within the subsurface environment, this being a physical property of matter that describes the ease of its magnetization (Telford, 1984). When the earth's magnetic field encounters a material having a high magnetic susceptibility, induced magnetization occurs. The material is magnetized and the resulting induced magnetic field is the product of its volume magnetic susceptibility and the earth's field intensity. A magnetometer measures the vector sum of the earth's magnetic field and the induced magnetic field (GISCO, 1980).

Figure 3-8 is a schematic diagram of a magnetometer system that shows a concentration of ferromagnetic material, in this case a steel drum that acts as a magnetic dipole and distorts the total magnetic field. Figure 3-9 is a sample output of data obtained over a trench with buried steel drums, which shows the anomalies in the earth's magnetic field as a result of disturbances caused by changes in the magnetization of the drums. A magnetic profile over a magnetically homogeneous region does not contain any anomalies (Tuagi, 1982).

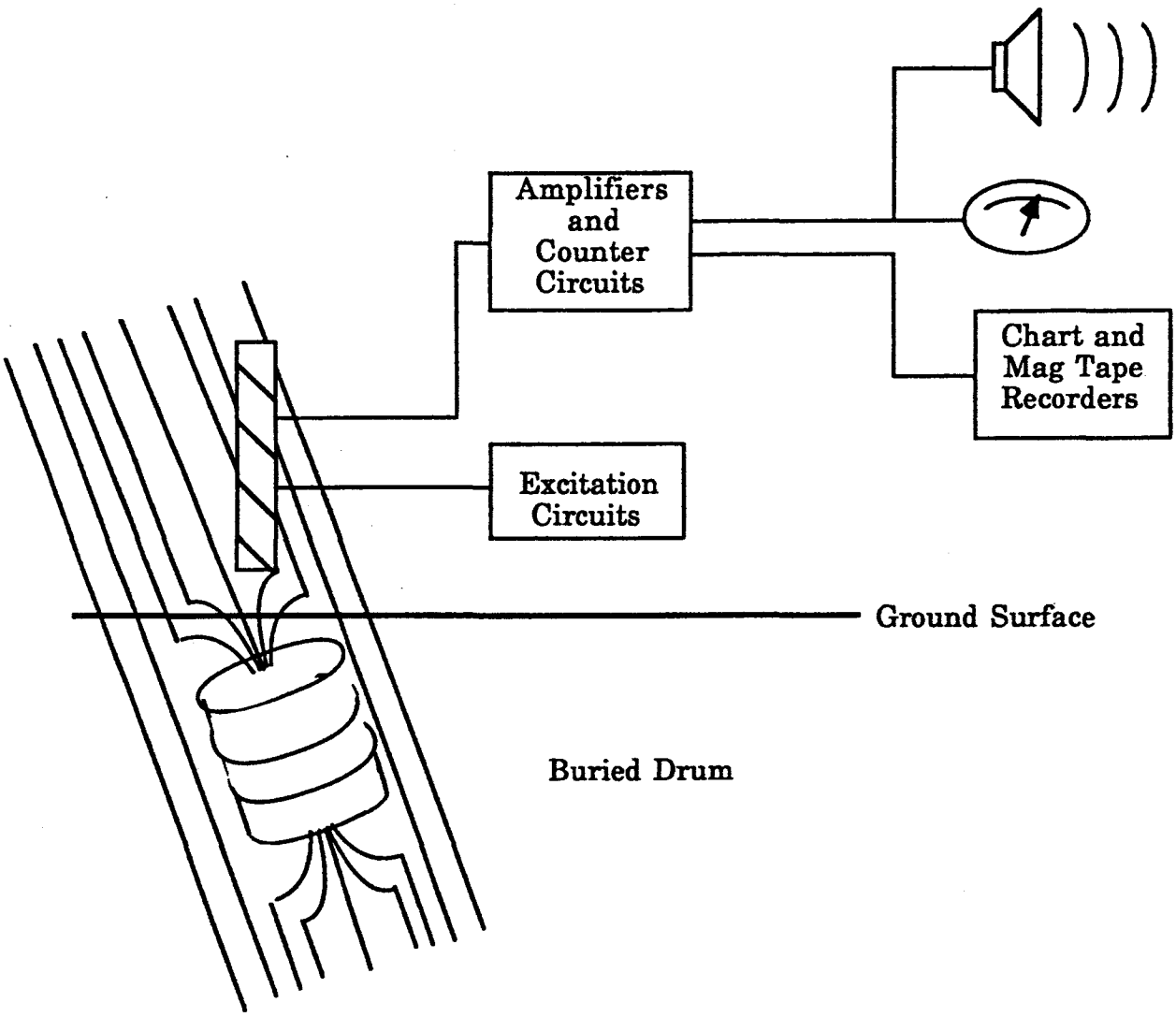

FIGURE 3-8 SCHEMATIC DIAGRAM OF A MAGNETOMETER

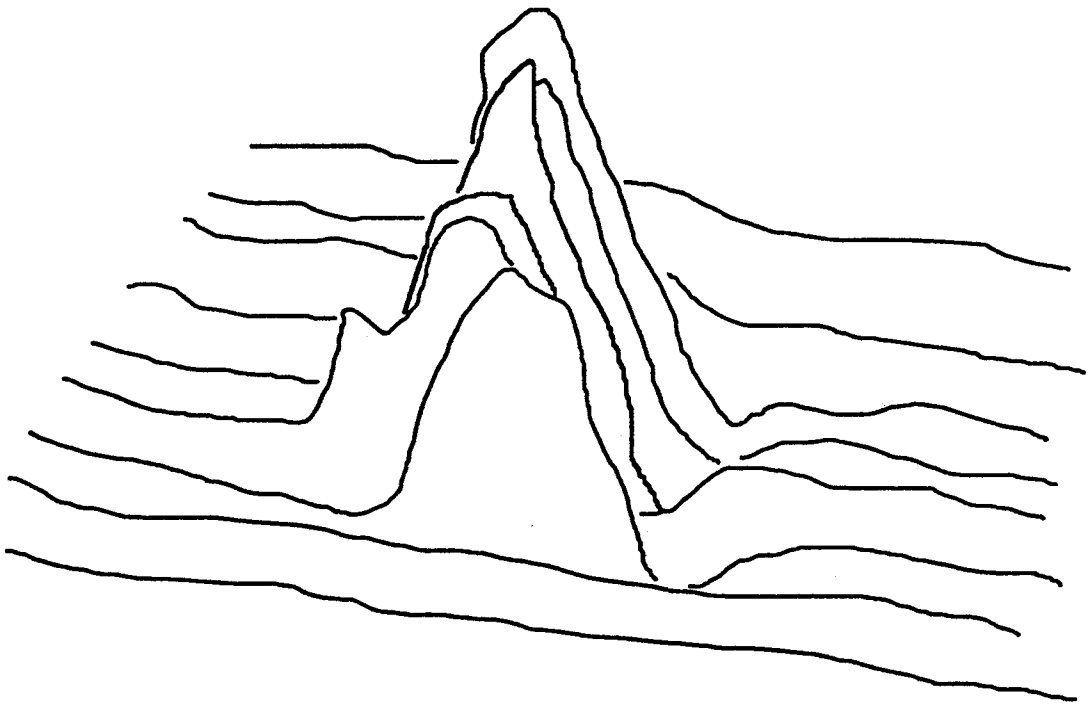

FIGURE 3-9 MAGNETOMETER DATA OVER TRENCH WITH BURIED METAL

3.2.5.2 General Applications

The magnetometer is commonly used to locate ferrous metals because their presence creates variations in the local strength of the magnetic field, permitting their detection. The response is proportional to the mass of the ferrous target (Fowler, 1985).

3.2.5.3 Limitations

Magnetometers detect only ferrous metals such as underground iron pipes or tanks (Geonics, 1980). Since magnetometers do not respond to nonferrous metals such as lead and copper, they are, therefore, unsuitable for locating and identifying buried lead service lines.

3.2.6 Fiber-Optic Instruments

3.2.6.1 Theory

A fiberscope comprises a light source unit, an eyepiece, and a flexible probe containing optical fibers that transmit the image. Additional instruments can include a still-camera or video system for the eyepiece, metal armor and waterproof sheathing for the probe, and steering mechanisms (Carruthers and Evins, 1985).

Figure 3-10 is a schematic diagram of a fiber-optic instrument. Charge-coupled devices (CCDs), developed by Bell Research Laboratories, have replaced the add-on cameras that, in general, are bulky and cumbersome. These new silicon semiconductor components are able to perform image sensing, analog signal processing, and digital or analog memory.

The CCD is a unique method of generating, storing, and conveying images to a viewing monitor by means of electrical signals. The CCD imager is a solid-state silicon chip similar in structure to a photovoltaic cell, but more complex; and it carries the information needed to form an image. Because of the CCD's diminutive size, the silicon chip can be placed within the tip of a small-diameter probe capable of penetrating the smallest apertures, which enables the CCD to function as a miniature TV camera able to record and display images on a video monitor with great clarity.

3.2.6.2 General Applications

Fiberscopes have been used as inspection tools in aircraft engines and boiler tubes and to verify remedial work such as pipe linings. Commonly used to acquire information on the condition of pipelines, fiberscopes provide a practical way of visual inspection of inaccessible pipelines without having to cut a short sample of pipe.

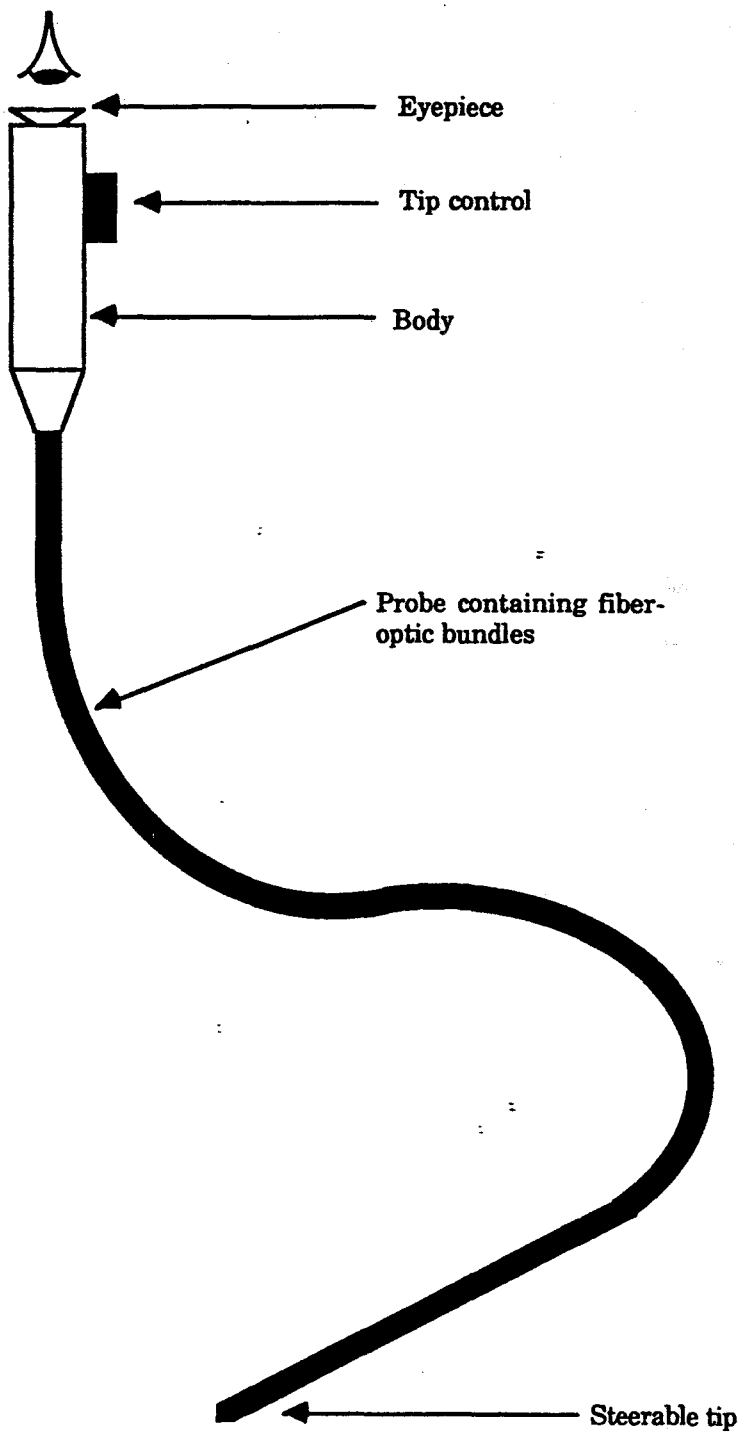

FIGURE 3-10 SCHEMATIC DIAGRAM OF A FIBERSCOPE

Silica-based fiberscopes feature ultra-thin scopes with diameters down to 0.5 mm and remote steering, with cord lengths from 50 to 100 feet.

Common entry points for fiberscopes to water mains are fire hydrants (Carruthers and Evins, 1985). Figure 3-11 shows how to insert a fiberscope into a hydrant. It is preferable to inspect mains when they are depressurized to avoid subjecting the fiberscope to pressure and to facilitate the insertion procedure. Inspection can be performed quickly, usually in 30 minutes or less. Another possible entry point into the water system is the water meter. The water meter is typically connected to two risers that connect with the customer's service line. Meters, when not located in the customer's basement, are usually accessible through meter pits.

3.2.6.3 Limitations

A field test of the ability of a fiberscope to detect lead service lines was conducted on 16 August 1989 at three residences in the District having lead service lines. Attempts were made to: (1) observe the outside of the service line at the curb cock (shut off) and (2) observe the interior of the service line by removing the water meter and inserting the fiberscope through the riser. The first approach was not successful because of the presence of water, mud, and debris around the curb cock. At one residence, the service line was deeper than 10 feet and was beyond the reach of the fiberscope being used for the demonstration. The second approach was not successful because the fiberscope was not flexible enough to negotiate the gooseneck bends in the riser pipes.

Currently available fiberscopes do not appear to be a solution to the problem of locating buried lead service lines.

3.3 CONCLUSIONS AND RECOMMENDATIONS

3.3.1 Conclusions

Currently available geophysical methods evolved in the mining and oil exploration industries, and are also applied today in hazardous waste site investigations to evaluate much deeper and larger targets than buried service lines.

Because ground penetrating radar is unable to penetrate conductors, it cannot be used to distinguish among metal pipes, and thus is unsuitable for our purposes.

The electrical conductivity method provides insufficient data for a small metal object in a large soil mass since the difference in conductivity among various metal pipes would be insignificant with respect to normal conductivity variations of the soil. The electrical conductivity method, with direct connection, is able to distinguish among metal pipes, but requires entry into the residence and/or excavation of the service line.

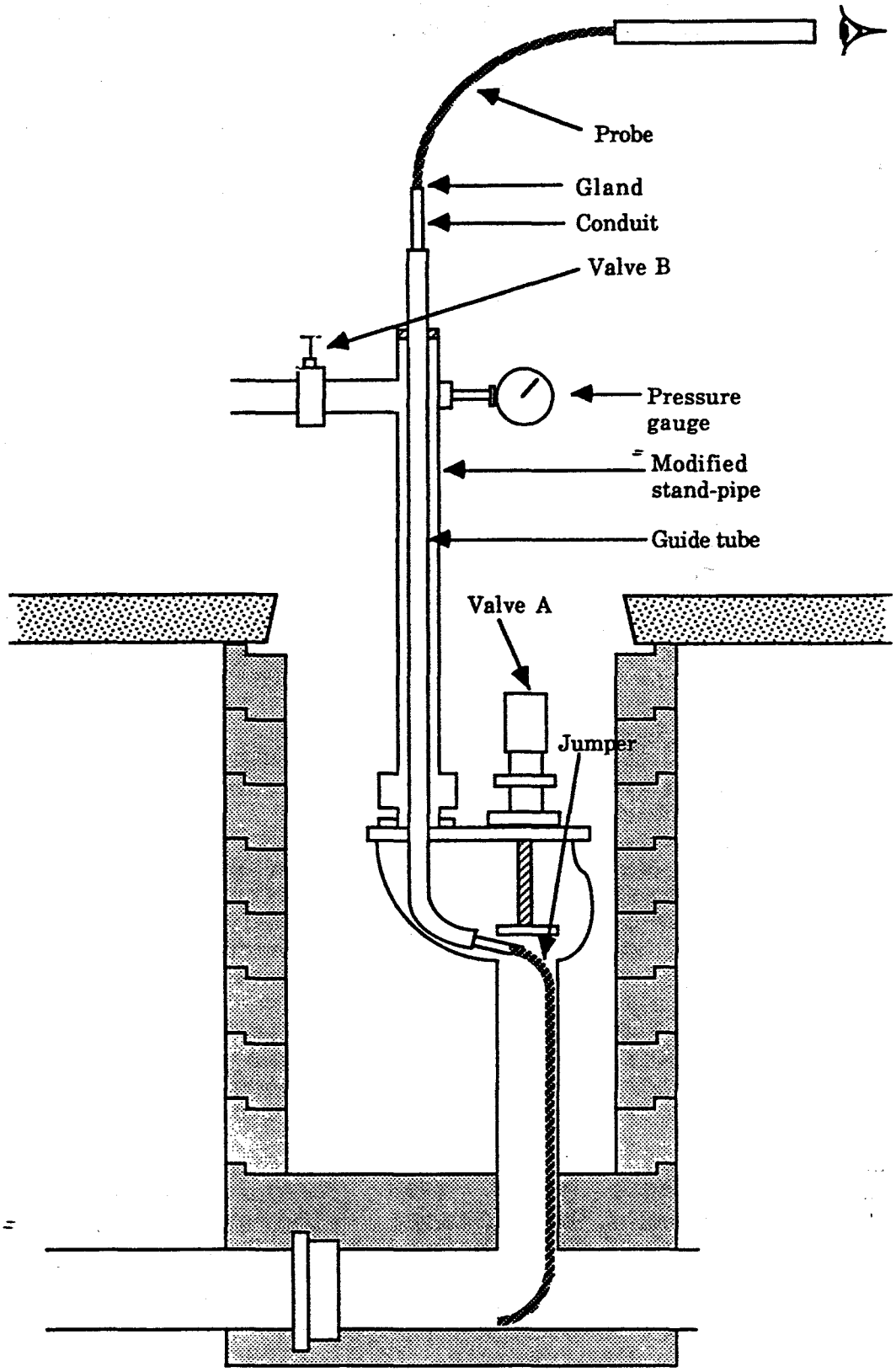

FIGURE 3-11 INSERTING A FIBERSCOPE INTO A HYDRANT

Currently available metal detectors are marginally able to distinguish between buried lead and copper pipes. This may be a possibility in the future, but additional research will have to be conducted before the method can be considered reliable. Currently, only pipe material buried less than 12 inches below the surface can be distinguished. Therefore, and based on a survey of more than 20 manufacturers of metal detectors as well as recommendations from staff members, it is concluded that metal detectors would not currently be able to distinguish copper from lead service lines for typical residential installations.

The resistivity method is unsuitable for reasons similar to those of the electrical conductivity-induced field method.

The magnetometer detects only ferrous metals and is, therefore, unsuitable for our purposes, given that lead is a nonferrous metal.

Fiberscopes do not appear to be a practical tool for identifying lead service lines. A more flexible fiberscope than the one tested might be able to identify lead service lines.

The many technical limitations of the geophysical methods investigated for our particular purposes have been described in this review, and it was found that most geophysical techniques would not provide the reliable location and identification of lead pipes.

3.3.2 Recommendations

As a result of the research conducted in this task, the following recommendations are made:

- A metal detector pilot study should be conducted to determine its practical feasibility of detecting buried lead service lines. Additional research should be followed closely as manufacturers may develop more appropriate detectors in the future.

- A more flexible fiberscope should be identified and tested to see: (1) whether it can negotiate the gooseneck in the riser pipe, and (2) whether the service line material can be reliably identified.

3.4 REFERENCES

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SECTION 4

METHODOLOGY FOR IDENTIFYING LEAD SERVICE LINES

4.1 INTRODUCTION AND OBJECTIVES

One of the objectives of this project was to identify a procedure or procedures for predicting the probability of a lead service line existing at a given address. These probabilities were then to be used to determine the extent of lead service lines throughout the District.

The work relied greatly on the databases developed as part of this study, as described in Section 1. These databases were analyzed to identify trends that could be used to develop predictive techniques. The methods developed by using these techniques were then to be calibrated using the results of service line excavations performed as part of this study.

4.2 DESCRIPTION OF THE DATABASES

The methodology relied on the databases that were developed previously. To clearly understand the analyses that were performed, it is necessary to review the makeup of each database. The following subsections briefly describe each of the two databases and the analyses that were performed on them. Refer to Section 1 for a more detailed description of the databases and the methods by which they were assembled.

4.2.1 Tap File Database

The Tap File Database consists of data on residential service connections throughout the District. The database was developed using data from a variety of sources. The main sources of data were the Tap File maintained at the Bureau of Water Measurement and Billing (BWMB), the Meter File of the Department of Public Works Office of Information Systems (OIS), the Project Locator File, and the Maintenance File, also maintained by BWMB. These sources were used to obtain the basic data included in the Tap File Database. Other sources, such as Meter Relocation Program records and Street Replacement Program records, were used to update the service line material for individual addresses.

The structure of the Tap File Database is presented in Table 4-1.

The completed database consisted of a total of 126,099 records. However, the database was not completely without error. As an example, 30 records were identified that had an installation date

Table 4-1

Structure of the Tap File Database

Field Name	Description	Data Source
SCHEDNUM	Schedule number	Tap File, Meter File
DATE	Service line installation date	Tap File, Meter File
ADDNUM	Street number	Tap File, Meter File
STRADDR	Street name	Tap File, Meter File
QUADRANT	Quadrant	Tap File, Meter File
PIPESIZE	Diameter of service line	Tap File
PIPEMATL	Service line material indicated in Tap File or Meter File	Tap File, Meter File
REPLACED	Logical (i.e., true or false) indicating that the service line has been replaced	Lead Service Replacement Program, Meter Relocation Program, Street Replacement Program
ABAN_REPL	Indicates an abandoned service line with an "X"	Tap File
SQUARE	Square	Tap File
WARD	Political ward	Planning Commission Data File
CUSTSERV	Service line material indicated in Project Locator File	Project Locator File

outside the date range of 1900 to 1989. Because the installation date is an important indicator of a possible lead service line (as explained in Subsection 4.3), these 30 records were not considered in analyzing the database.

4.2.2 Water Quality Database

The Water Quality Database consists of the results of three sampling programs for lead in water conducted by the Department of Consumer and Regulatory Affairs (DCRA). The three sampling programs were described in detail in Section 1. Some common terminology is defined in this subsection, followed by a description of the database developed from the results of the sampling. The definitions of sample types follow:

- First Flush Sample -- A first flush sample is a set of water samples that is taken first thing in the morning, before any water use has occurred in the household. The set of samples consists of up to three water samples taken at the cold water kitchen tap and labeled Sample A, Sample B, and Sample C.
  - Sample A -- The first sample taken from the faucet: Its purpose was to determine the contribution of interior plumbing (i.e., brass fixtures and lead solder) to lead levels at the tap.
  - Sample B -- The second sample taken from the faucet: Its purpose was to determine the contribution of the service line to lead levels at the tap.
  - Sample C -- The third sample taken from the tap: Its purpose was to identify the contribution of the distribution main to lead levels at the tap.
- Midday Sample -- A 1-liter sample collected during the day, generally, though not always, taken from the kitchen tap. It was meant to represent typical exposure levels to lead in drinking water.

The results of the three sampling programs were entered into a common database. The structure of the database is shown in Table 4-2.

The addresses in the Water Quality Database were matched with addresses in the Tap File Database to obtain information about the service line. However, not all addresses in the Water Quality Database had a match in the Tap File Database. For those addresses that did not have a match, the service line material was considered to be unknown.

Table 4-2

Structure of the Water Quality Database

Field Name	Description
ADDNUM	Street number
STRADDR	Street name
QUAD	Quadrant
SQUARE	Square
WARD	Political ward
ZIPCODE	Zipcode
SAMPIDMID	Sample identification for midday sample
MIDRESULT	Midday sample result
SAMPIDFF	Sample identification for first flush sample
ARESULT	Sample A result
BRESULT	Sample B result
CRESULT	Sample C result
PIPEMATL	Service line material (from Tap File or Meter Data File)
CUSTSERV	Service line material (from Project Locator File)
DATE	Service line installation date
REPLACED	Logical (i.e., true or false) indicating that the service line has been replaced

DCRA did an extensive statistical analysis of the data generated by these three sampling programs. One result of this analysis was the development of equations that would predict the probability of a service line being lead based on the lead concentration of a midday sample.

4.3 DATABASE ANALYSIS

The two databases developed were to be analyzed to develop techniques for predicting the occurrence of lead service lines. Each database focused on a different aspect of the problem. The Tap File Database contained data on Known Lead Service Line installations. The Water Quality Database contained results of sampling for lead in drinking water. The analyses performed on the individual databases are described in the following subsections.

4.3.1 Tap File Database

All analyses performed on the Tap File Database were done on a District-wide level and on a ward-by-ward basis. Before discussing the analyses that were performed it is necessary to define several terms relating to the database:

- **Known Lead Service Line** refers to an address for which there is a positive indication that the service line is lead. This indication may come from the BWMB Tap File, the Project Locator File, or both.

- **Unknown Service Line** refers to an address for which there is no indication of material type, either from the BWMB Tap File or the Project Locator File.

- **Nonlead Service Line** refers to an address for which there is positive indication that the service line is not lead. This indication may come from either the BWMB Tap File or the Project Locator File, or both.

- **Known Service Lines** refers to the total number of records for which there is an indication of service line material, either lead or nonlead. It is calculated as the sum of Known Lead Service Lines plus Nonlead Service Lines.

- **Total Number of Service Lines** refers to the total number of addresses in the database (126,069 records, excluding the 30 records outside the date range of 1900 to 1989). It is also the sum of Known Service Lines plus Unknown Service Lines.

- **Ratio of Known Service Lines** refers to the ratio of Known Service Lines to the Total Number of Services Lines.

- **Ratio of Lead Service Lines** refers to the ratio of Known Lead Service Lines to the number of Known Service Lines.

Next, it is important to discuss the priorities given to the BWMB Tap File and Project Locator File when conflicts arose in assigning a material type to each record. The highest priority was given to indications of a lead service line. If either the BWMB Tap File or Project Locator File indicated a lead service line, the address was considered to be a Known Lead Service Line, regardless of any other indication of material type. In cases in which there was no indication of a lead service line, but there was a discrepancy between the material indicated in the BWMB Tap File and Project Locator File, the Project Locator File material type was used since these data were collected more recently. The complete list of priorities used is given in Table 4-3.

Finally, it should be noted that lead service lines that have been replaced in recent years were still treated as Known Lead Service Lines for analysis purposes. This was done because these service lines are part of the overall trend of lead installations. Lead service lines that have been replaced are considered in Subsection 4.4, in which the number of lead service lines still in place in the District is discussed.

The first step was to calculate the number of Known Lead Service Lines, Unknown Service Lines, Nonlead Service Lines, etc., for each year from 1900 to 1988. These data were compiled on District-wide and ward-by-ward bases. The results were entered into a Lotus 1-2-3 spreadsheet for additional data manipulation. A printout of a small portion of this spreadsheet is shown in Figure 4-1, and the entire spreadsheet can be found in Appendix D.

Graphs were developed from this spreadsheet showing trends of service line installations since 1900. These graphs are discussed later in this section. It should be noted that service line installations listed for the year 1911 include installations done up to and including 1911. For this reason, the year 1911 was treated carefully when identifying installation trends.

The first plots (Figure 4-2 through 4-4) show distribution of service line installations on District-wide and ward-by-ward bases. The purpose of these plots was to examine the general growth of the District's water system. Figure 4-2 shows that on a District level, service line installations peaked in the mid-1920s, the late 1930s through the early 1940s, and late 1940s through early 1950s. The rate of service line installation at all other times was approximately 1,000 service lines per year.

Figures 4-3 and 4-4, which show service line installation on a ward-by-ward basis, illustrate how the various District wards grew over time. Wards 1,2,5, and 6 are older wards, with most service lines installed in or prior to 1911. Wards 3,4,7, and 8 were developed later, with most service lines installed in the period of 1920 through the mid-1950s.

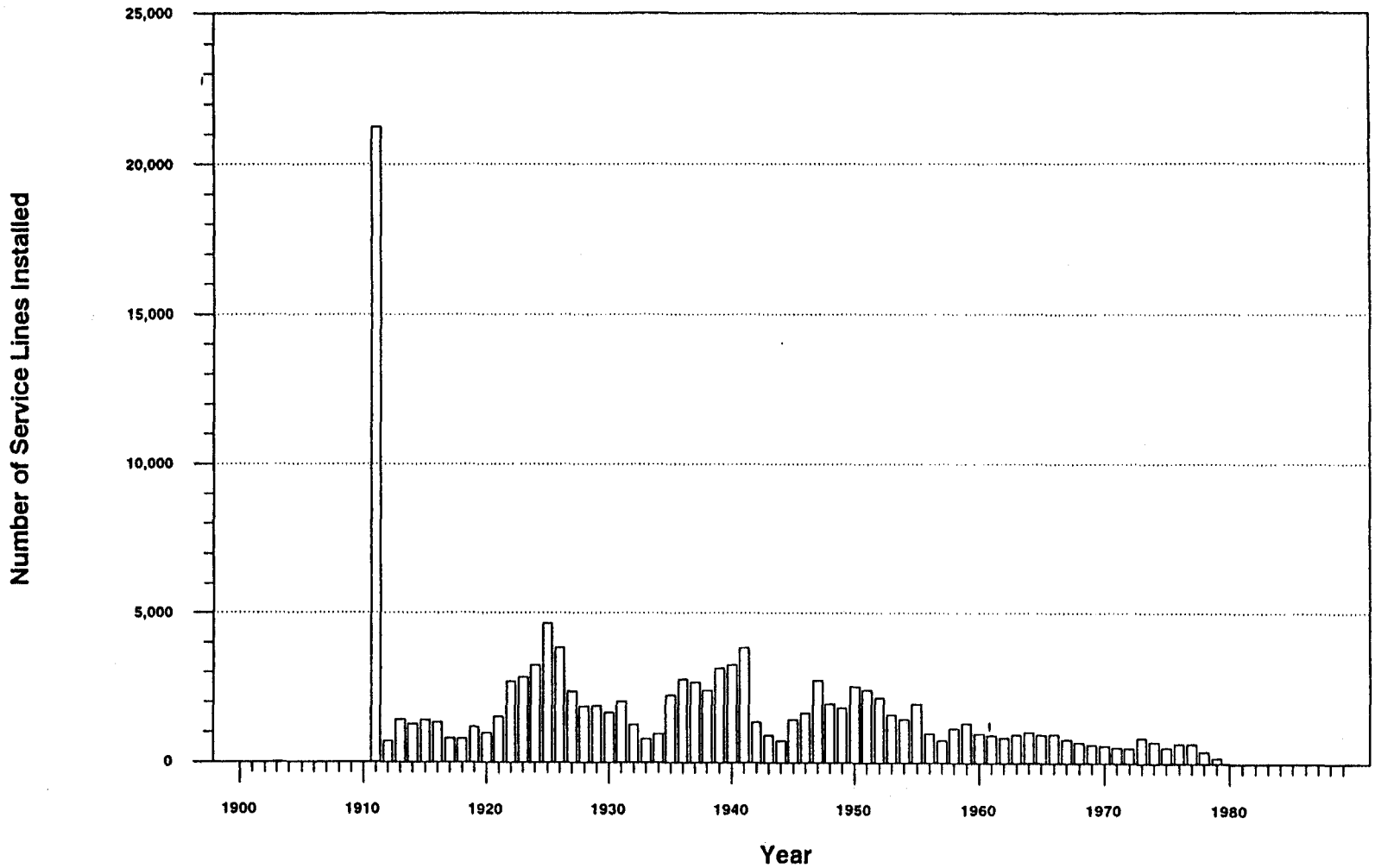
Table 4-3

Priorities Among Data Sources

Indicator		
BWMB Tap File	Project Locator File	Material Assigned
Lead	Lead	Lead
Copper Iron Other Unknown	Lead	Lead
Lead	Copper Iron Unknown	Lead
Copper	Copper	Copper
Copper	Iron	Iron

YEAR	WARD 1 TOTAL SERVICES	WARD 1 KNOWN SERVICES	WARD 1 UNKNOWN SERVICES	WARD 1 % KNOWN	WARD 1 LEAD SERVICES	WARD 1 % LEAD	WARD 1 ASSUM LEAD	WARD 1 TOTAL LEAD	WARD 2 TOTAL SERVICES	WARD 2 KNOWN SERVICES	WARD 2 UNKNOWN SERVICES	WARD 2 % KNOWN	WARD 2 LEAD SERVICES	WARD 2 % LEAD	WARD 2 ASSUM LEAD	WARD 2 TOTAL LEAD
1900	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1901	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1902	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1903	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1904	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1905	0	0	0	0.00	0	0.00	0	0	1	1	0	1.00	0	0.00	0	0
1906	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1907	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1908	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1909	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1910	0	0	0	0.00	0	0.00	0	0 **	0	0	0	0.00	0	0.00	0	0 **
1911	5260	1090	4170	0.21	356	0.33	1362	1718	4387	872	3515	0.20	196	0.22	790	986
1912	159	15	144	0.09	14	0.93	134	148	101	1	100	0.01	0	0.00	0	0
1913	464	61	403	0.13	7	0.11	46	53	162	7	155	0.04	1	0.14	22	23
1914	324	33	291	0.10	9	0.27	79	88	110	6	104	0.05	0	0.00	0	0
1915	319	42	277	0.13	4	0.10	26	30	142	10	132	0.07	4	0.40	53	57
1916	180	16	164	0.09	5	0.31	51	56	141	12	129	0.09	2	0.17	22	24
1917	68	12	56	0.18	3	0.25	14	17	86	4	82	0.05	0	0.00	0	0
1918	46	7	39	0.15	0	0.00	0	0	105	11	94	0.10	3	0.27	26	29
1919	157	47	110	0.30	8	0.17	19	27	76	9	67	0.12	4	0.44	30	34
1920	156	43	113	0.28	12	0.28	32	44 **	82	4	78	0.05	2	0.50	39	41 **
1921	239	101	138	0.42	26	0.26	36	62	92	12	80	0.13	4	0.33	27	31
1922	293	74	219	0.25	18	0.24	53	71	170	21	149	0.12	3	0.14	21	24
1923	264	105	159	0.40	27	0.26	41	68	230	58	172	0.25	10	0.17	30	40
1924	179	55	124	0.31	9	0.16	20	29	263	33	230	0.13	2	0.06	14	16
1925	180	74	106	0.41	13	0.18	19	32	209	39	170	0.19	2	0.05	9	11
1926	213	145	68	0.68	12	0.08	6	18	161	76	85	0.47	6	0.08	7	13
1927	73	52	21	0.71	21	0.40	8	29	174	111	63	0.64	46	0.41	26	72
1928	72	59	13	0.82	27	0.46	6	33	111	89	22	0.80	39	0.44	10	49
1929	67	54	13	0.81	14	0.26	3	17	77	45	32	0.58	10	0.22	7	17
1930	40	30	10	0.75	6	0.20	2	8 **	81	70	11	0.86	18	0.26	3	21 **
1931	52	48	4	0.92	3	0.06	0	3	80	57	23	0.71	13	0.23	5	18
1932	42	36	6	0.86	3	0.08	1	4	67	44	23	0.66	10	0.23	5	15
1933	44	41	3	0.93	0	0.00	0	0	68	51	17	0.75	4	0.08	1	5

FIGURE 4-1 SAMPLE OF PORTION OF SUMMARY SPREADSHEET OF SERVICE LINE INSTALLATIONS



Service line installations indicated for 1911 include years up to and including 1911.

FIGURE 4-2 DISTRIBUTION OF SERVICE LINE INSTALLATIONS FOR THE DISTRICT

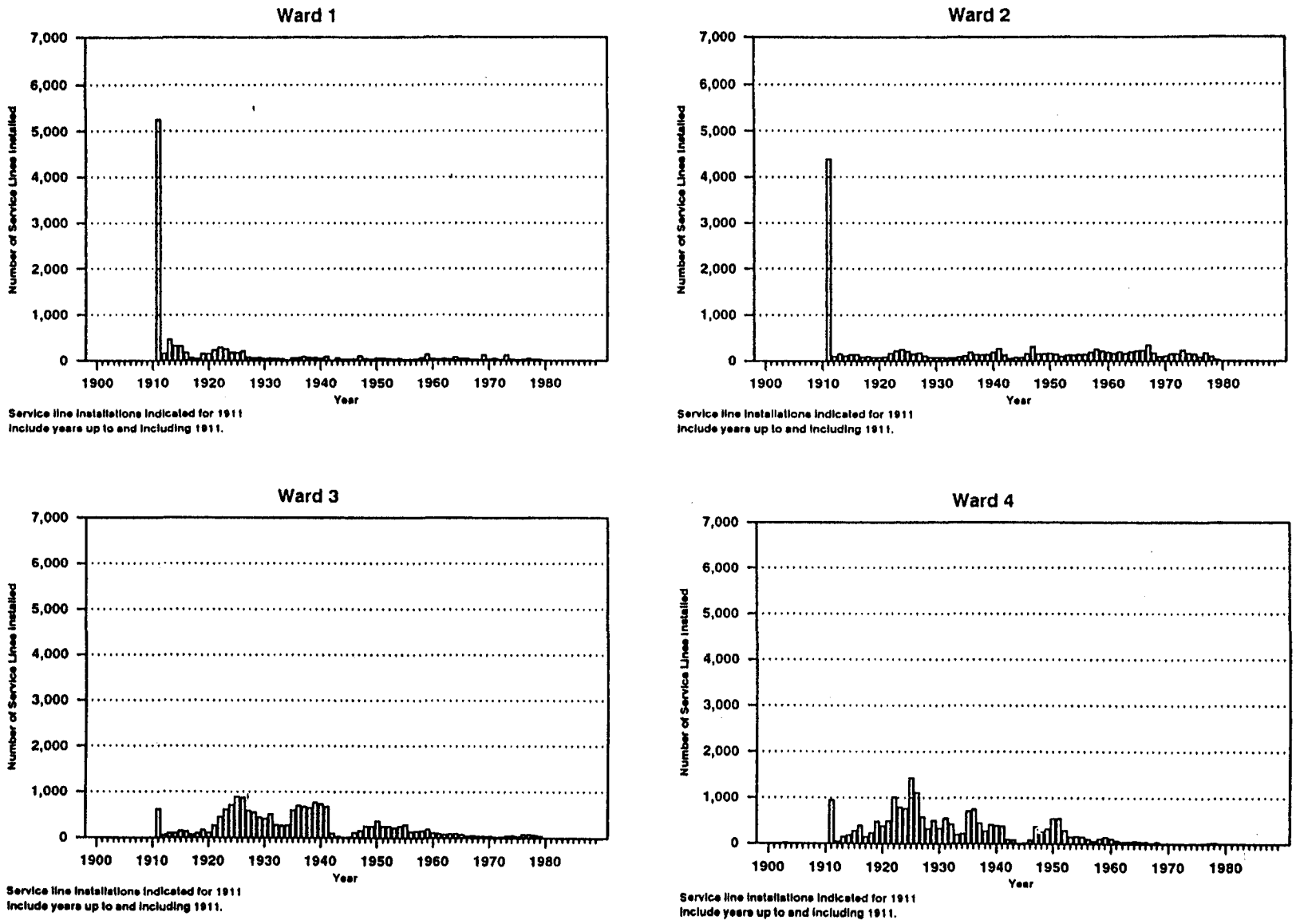
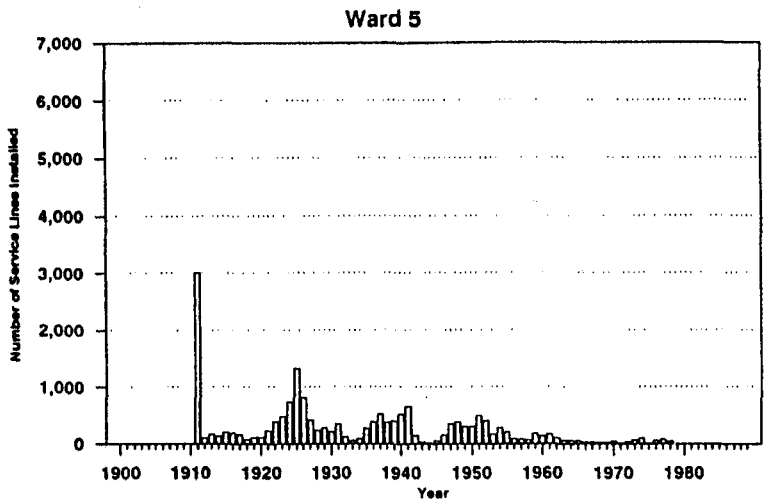
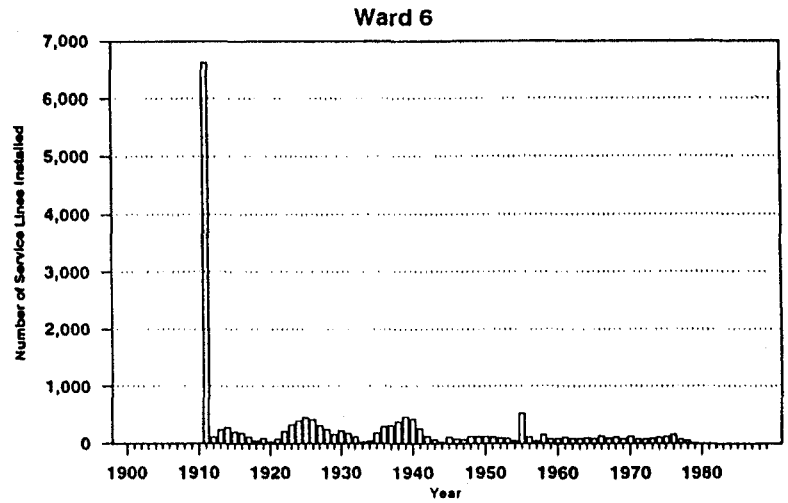


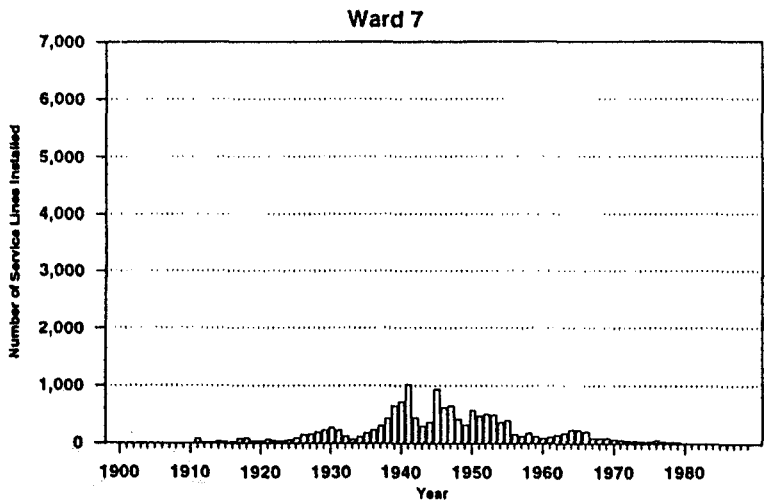
FIGURE 4-3 DISTRIBUTION OF SERVICE LINE INSTALLATIONS BY WARD (WARDS 1 THROUGH 4)



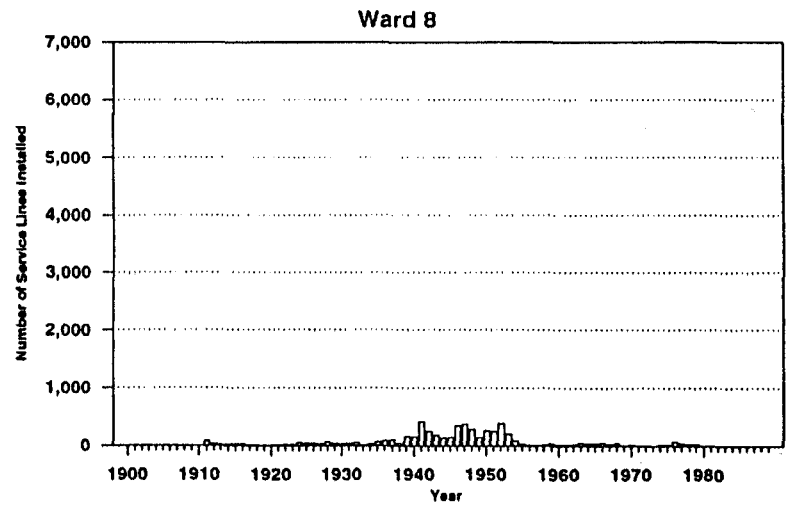
Service line installations indicated for 1911 include years up to and including 1911.



Service line installations indicated for 1911 include years up to and including 1911.



Service line installations indicated for 1911 include years up to and including 1911.



Service line installations indicated for 1911 include years up to and including 1911.

FIGURE 4-4 DISTRIBUTION OF SERVICE LINE INSTALLATIONS BY WARD (WARDS 5 THROUGH 8)

Next, it was necessary to examine the distribution of the Ratio of Known Service Lines over time. Figure 4-5 shows the Ratio of Known Service Lines to Total Number of Service Lines for the District as a whole. The Ratio of Known Service Lines over the period 1927 to 1968 was consistently greater than 0.80. Outside of this time period, however, the Ratio of Known Service Lines was generally less than 0.20. It is not surprising that the Ratio of Known Service Lines during the early part of the century is low, given the age of the data and the fact that many early Tap Cards (from which the database was collected) were unavailable because they had been incorporated into the Maintenance File. However, the sudden drop-off in the Ratio of Known Service Lines in 1970 must be explained. To do so, it is necessary to review briefly the data entry procedure.

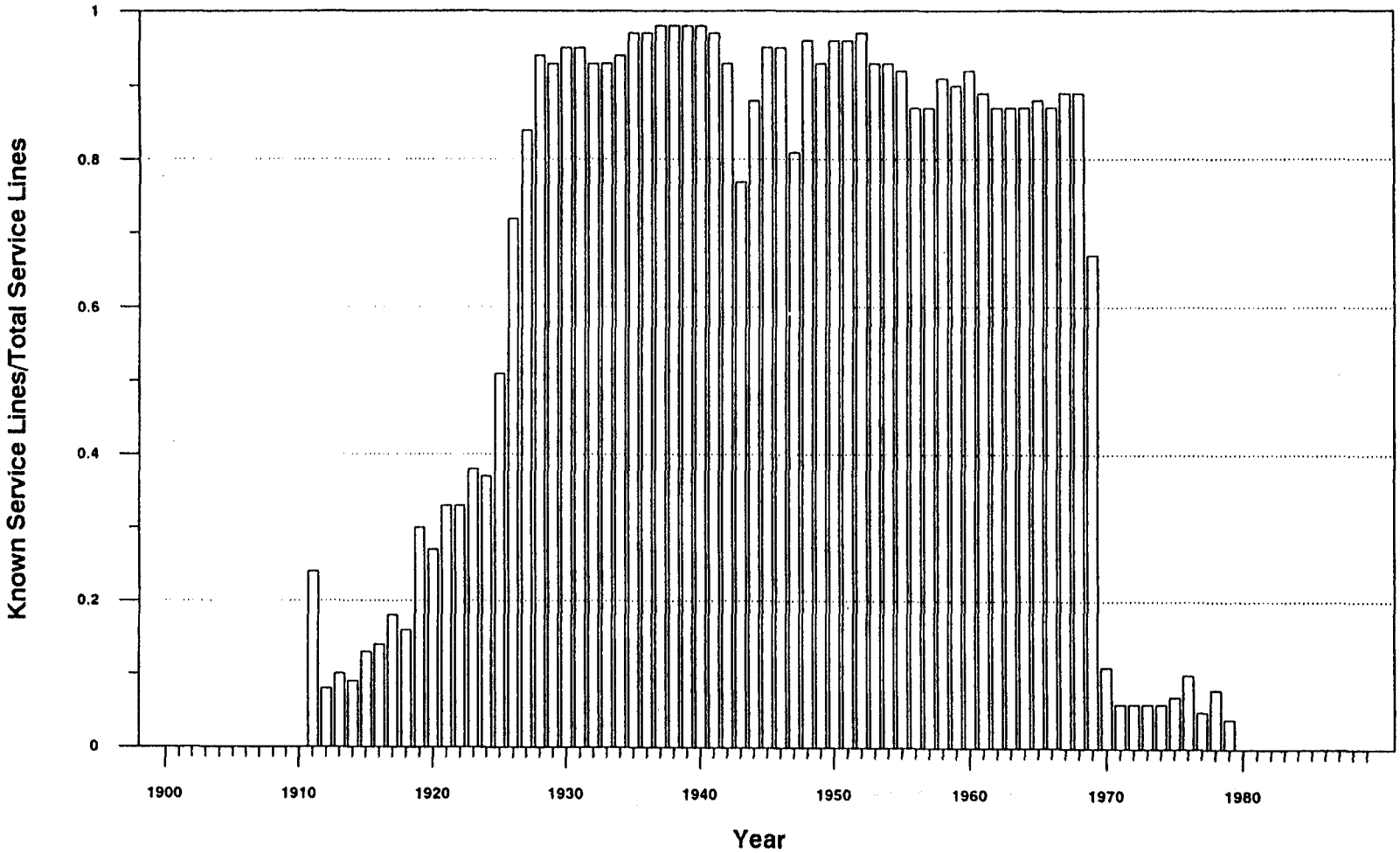
The major source of data on service line material was the Tap Card. These Tap Cards from the 1920s through the 1960s often had an indication of pipe material written somewhere on the card. Cards from 1970 onward rarely had such an indication. It is unknown whether this is because of some formal reason, or whether the practice was simply dropped. It also should be noted that service lines installed in the period after 1970 can probably be assumed to be nonlead.

Table 4-4 summarizes the service line installations by ward. Wards 1,2, and 6 show the smallest Ratio of Known Service Lines. These wards also correspond to the older areas of the District (as shown in Figure 4-3). Table 4-4 also shows that approximately 65 percent of the service lines in the database have a known material.

Having established this background, the examination of Known Lead Service Lines can begin. Figure 4-6 shows plots of the ratio of Known Lead Service Lines to Known Service Lines over time for the District. This plot shows a general trend of lead service line installation ending at approximately 1935, beginning again during the early 1940s, and then ending again by 1946. The apparent significant usage of lead service lines beginning again in 1970 can best be explained by reexamining Figure 4-5. Because there are so few Known Service Lines during the 1970s, even a very few Known Lead Service Lines will cause Figure 4-6 to show a relatively significant amount of lead usage during this period.

Figures 4-7 and 4-8 show the same breakdown of Known Lead Service Lines by ward. It is interesting to note that the same basic pattern of lead usage is repeated in each ward.

It is important to note that the aforementioned plots (Figures 4-6, 4-7, and 4-8) show only the ratio between Known Lead Service Lines and Total Known Service Lines. It is necessary at this point to examine the actual number of lead service lines installed.



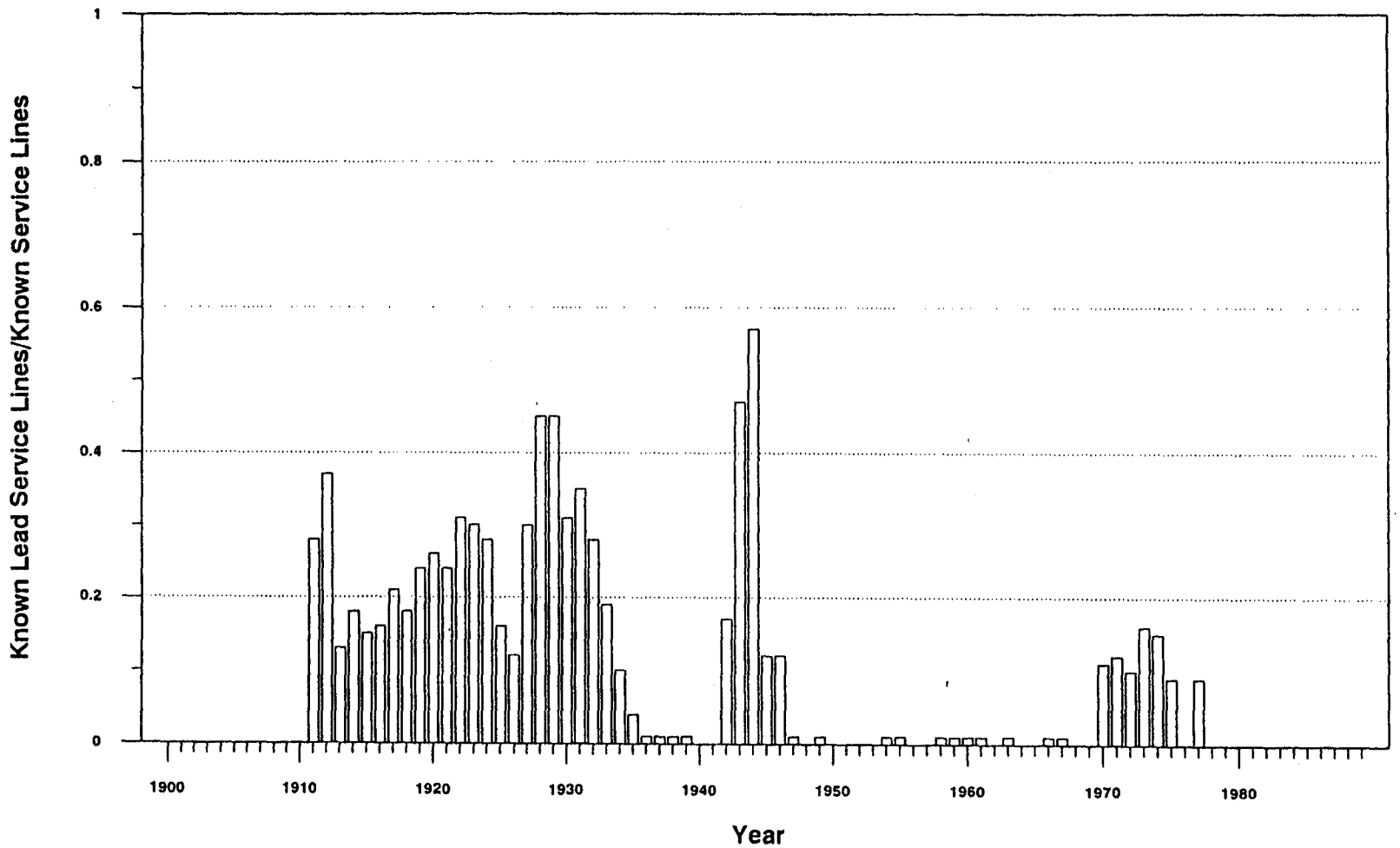
Service line installations indicated for 1911 include years up to and including 1911.

FIGURE 4-5 DISTRIBUTION OF KNOWN SERVICE LINES FOR THE DISTRICT

Table 4-4

Summary of Service Line Installations

Ward	Total Number of Service Lines	Number of Known Service Lines	Percent of Known Service Lines
1	11,082	3,779	34
2	14,655	6,633	45
3	17,996	14,423	80
4	19,518	13,564	69
5	18,369	12,196	66
6	17,851	9,668	54
7	15,004	13,579	91
8	5,549	4,816	87
Ward not indicated	6,045	2,698	45
	126,069	81,356	65



Service line installations indicated for 1911 include years up to and including 1911.

FIGURE 4-6 RATIO OF KNOWN LEAD SERVICE LINES TO KNOWN SERVICE LINES FOR THE DISTRICT

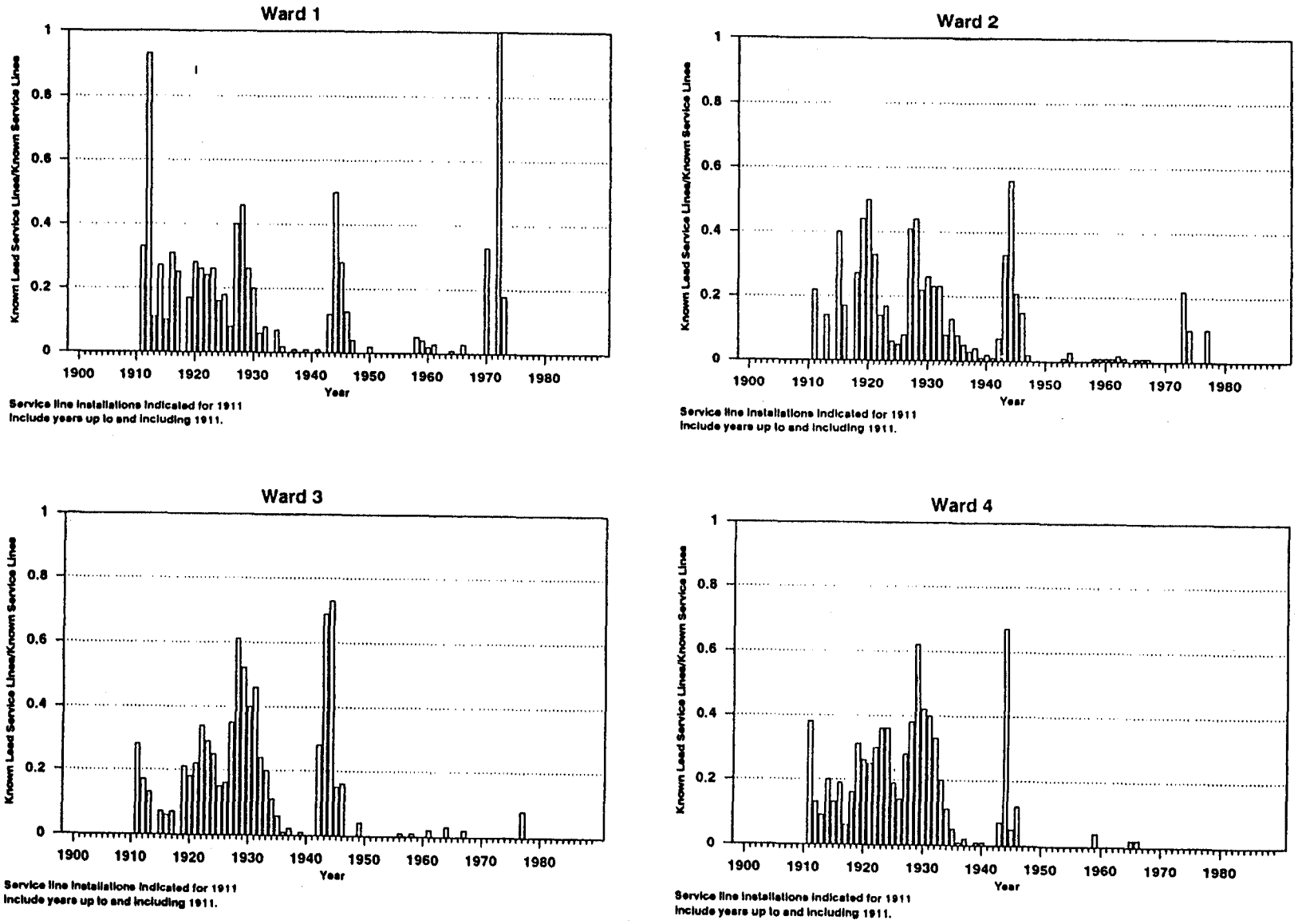


FIGURE 4-7 RATIO OF KNOWN LEAD SERVICE LINES TO KNOWN SERVICE LINES BY WARD (WARDS 1 THROUGH 4)

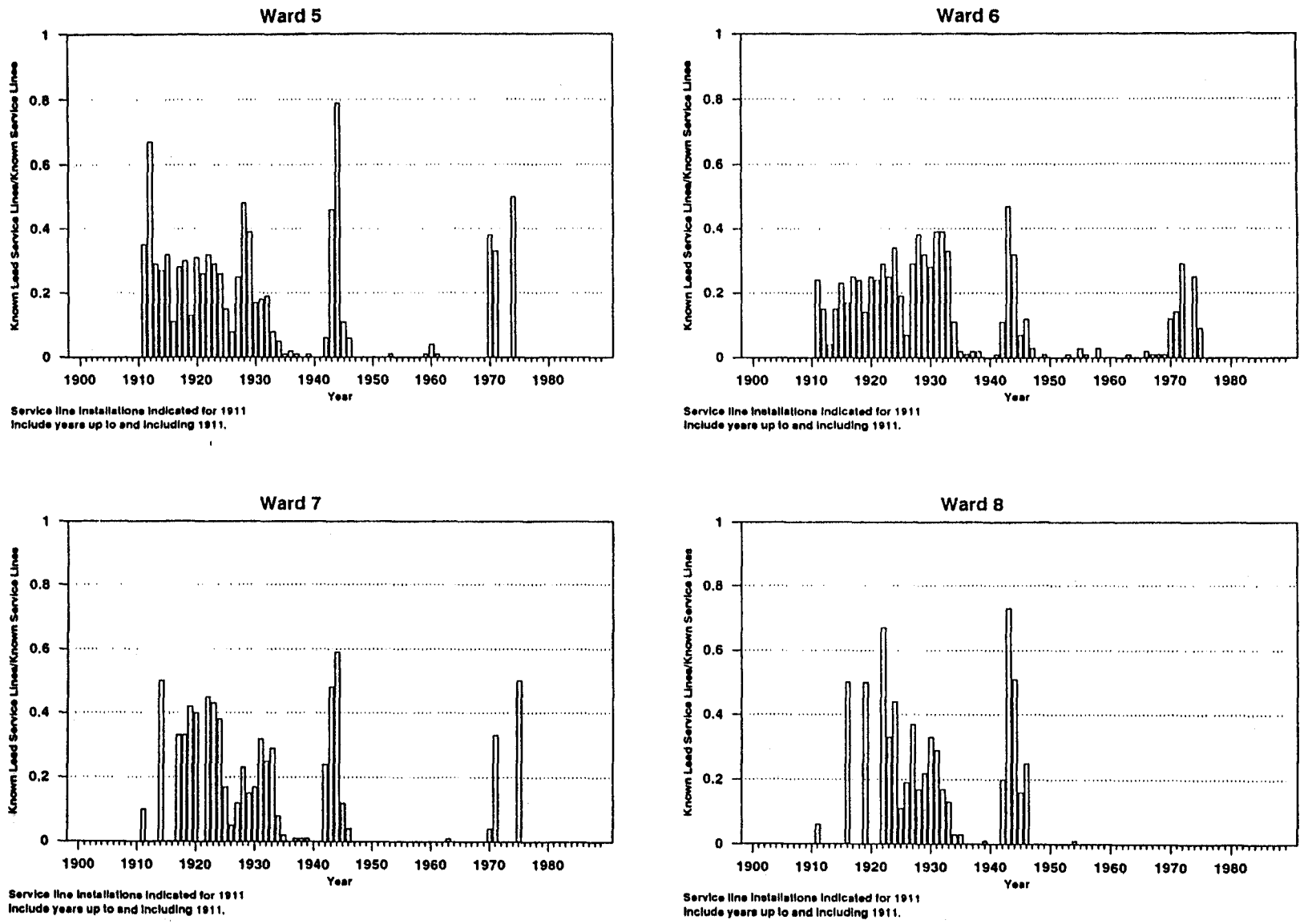


FIGURE 4-8 RATIO OF KNOWN LEAD SERVICE LINES TO KNOWN SERVICE LINES BY WARD (WARDS 5 THROUGH 8)

Figure 4-9 shows the number of Known Lead Service Lines installed in each year. Again, the same basic pattern emerges: relatively high lead usage in the 1920s and early 1930s (with a peak around 1930), followed by a drop-off in usage through the 1930s, and another peak during the 1940s. Note that the peaks in lead usage shown for the 1970s in previous figures do not appear in Figure 4-9. This is because the actual number of Known Lead Service Lines indicated for these years is small in comparison to other time periods.

Figures 4-10 and 4-11 show similar breakdowns of Known Lead Service Line installations by ward. Once again, the same basic pattern of lead usage appears in each ward. It is also interesting to note that in the older Wards 1, 2, 5, and 6, the majority of lead usage occurred in 1911 (i.e., 1911 and prior) and the early 1920s; while for the newer Wards 3, 4, 7, and 8, the majority of lead usage occurred in the late 1920s, early 1930s, and 1940s.

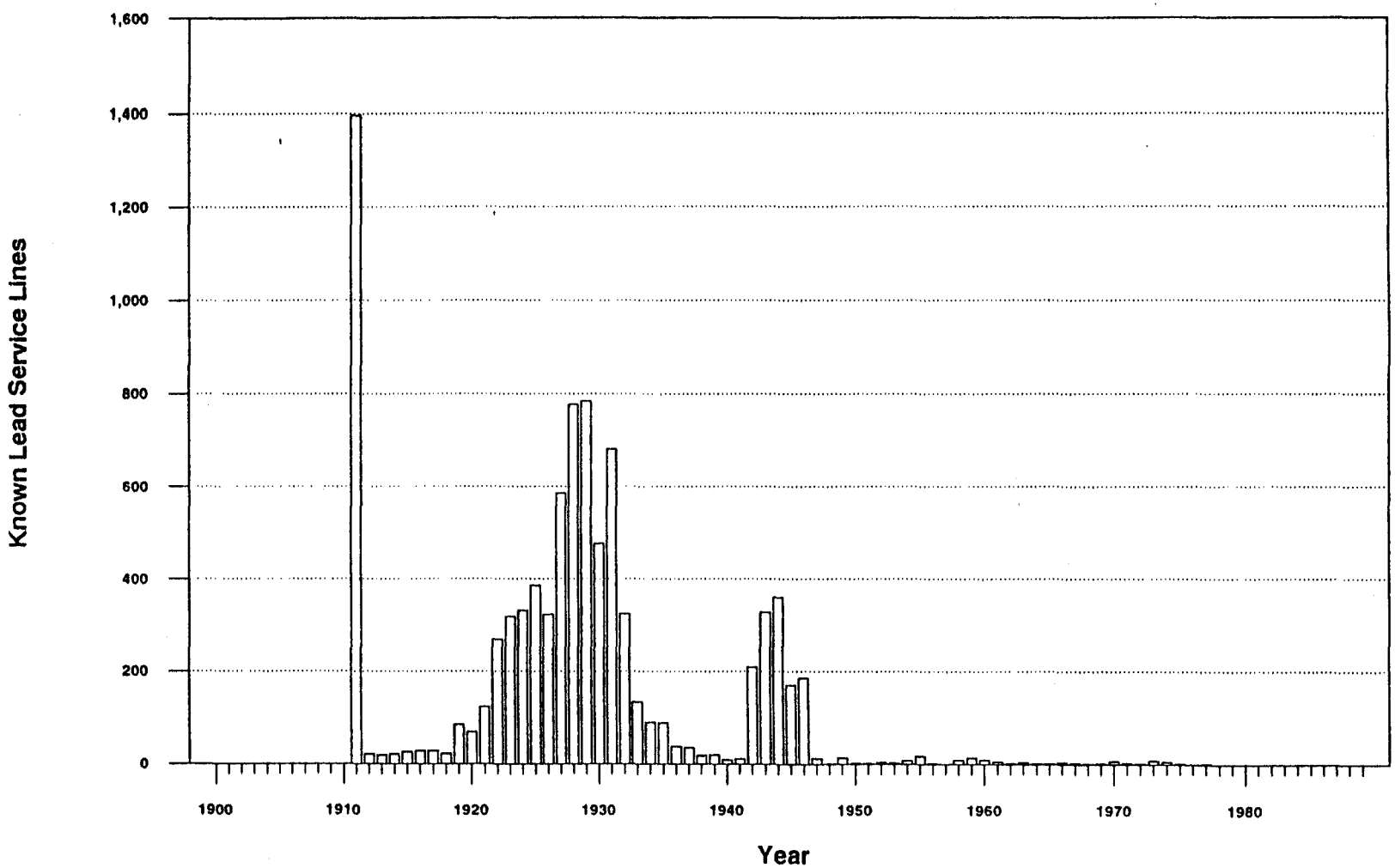
A summary of Known Lead Service Line data in relation to the Ratio of Known Service Lines is given in Table 4-5 for each ward.

The previous analyses focus on Known Service Lines. At this point it may be useful to take a different approach and examine the distribution of Unknown Service Lines. Figure 4-12 is a plot of the ratio of Unknown Service Lines to Total Service Lines over time for the District. This plot emphasizes the time periods in which additional work should be concentrated to fill in missing lead service line data. It should be emphasized once again that the large numbers of unknowns in the 1970s could be eliminated by assuming that they are all nonlead.

Another consideration that was investigated was the location of a house having a Known Lead Service Line with respect to other addresses having Unknown Service Lines and installed during the same time period. It was thought that in many cases whole blocks of homes may have had their service lines installed at the same time. Thus, if one or more of these addresses had a Known Lead Service Line, there is a good probability that some or all of the Unknown Service Lines would also be lead.

This approach was used to select addresses for excavation conducted to calibrate the methodology. The Tap File Database was examined manually by looking at groups of addresses and selecting an address that was surrounded by houses having Known Lead Service Lines. This technique works well when attempting to select a small number of addresses because it is relatively easy to identify a likely address when looking at a group of addresses. However, this technique is difficult to quantify, and even more difficult to convert to a computer application.

However, the concept of a proximity criterion is sound; and an attempt was made to analyze the Tap File Database on this basis. In this case, rather than look at individual addresses along a



Service line installations indicated for 1911 include years up to and including 1911.

FIGURE 4-9 DISTRIBUTION OF KNOWN LEAD SERVICE LINES FOR THE DISTRICT

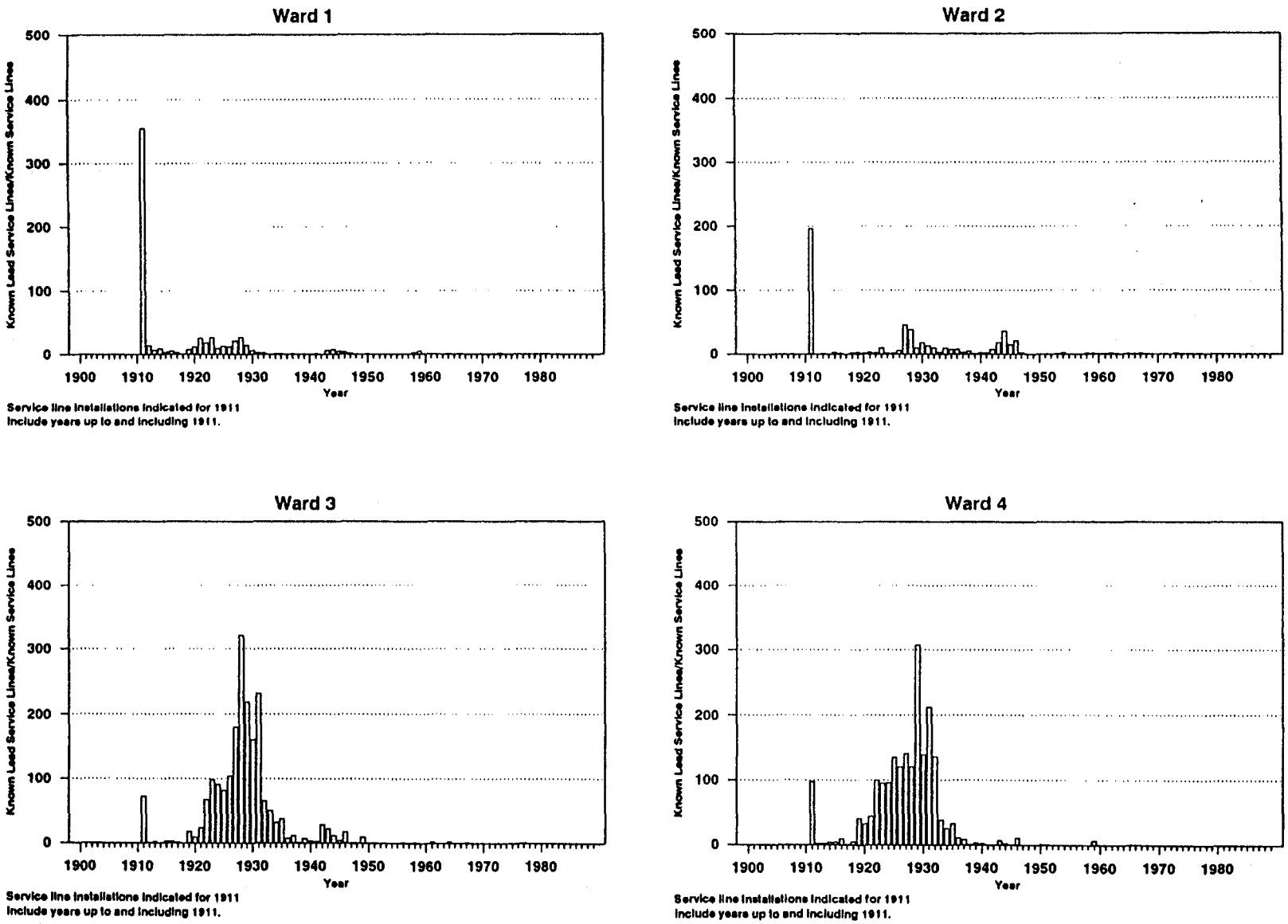


FIGURE 4-10 DISTRIBUTION OF KNOWN LEAD SERVICE LINES BY WARD (WARDS 1 THROUGH 4)

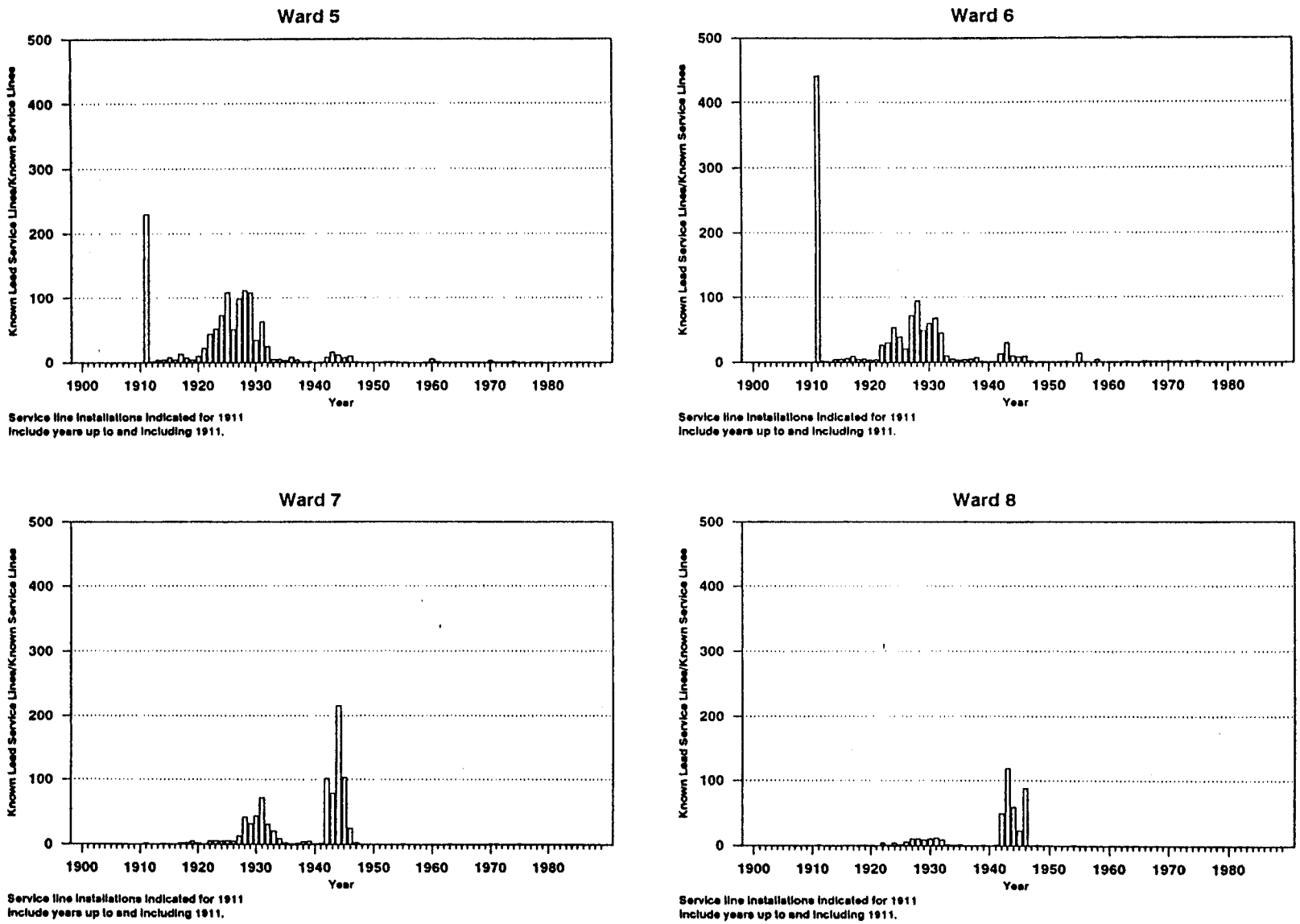


FIGURE 4-11 DISTRIBUTION OF KNOWN LEAD SERVICE LINES BY WARD (WARDS 5 THROUGH 8)

given street, the entire city block was used to group addresses considered to be in proximity to one another. In the District, blocks are identified by a unique number known as a square.

The Tap File Database was first sorted by installation date and square. Using the installation date in combination with the square ensures that addresses in proximity to one another also had service lines installed during the same time period. Next, the number of Known Service Lines and Known Lead Service Lines for each distinct combination of installation date and square was determined. Then a probability could be assigned to each installation date/square combination, calculated as the number of Known Lead Service Lines divided by the number of Known Service Lines for each combination. This procedure, illustrated in Figure 4-13, was performed for each square in the Tap File Database.

A total of 24,892 combinations of installation date and square was identified. Predicted lead probabilities for these combinations ranged from 0.0 (i.e., no Known Lead Service Lines in a given square installed in a given year) to 1.0 (i.e., all of the Known Service Lines in a given square installed in a given year were known to be lead).

4.3.2 Water Quality Database

The Water Quality Database consisted of a total of 2,271 addresses at which water quality sampling was performed. Of this total, 1,050 had a Known Service Line. Only 213 of these had a Known Lead Service Line. Of the 1,221 addresses with Unknown Service Lines, 762 were unknown because the address was not a part of the Tap File Database. The remaining 459 were found in the Tap File Database, but had Unknown Service Lines.

The analysis focused on those addresses for which first flush data were available and for which the service line material was known. First flush data were available for 154 Known Lead Service Lines, and for 524 Known Nonlead Service Lines. The average, minimum, and maximum lead concentrations for the Known Lead and Known Nonlead Service Lines are summarized in Table 4-6.

Two different approaches were followed in attempting to use water quality results to identify lead service lines. One focused solely on the lead concentration in Sample B. The second examined the relationship between Sample B and Sample A. Neither approach proved completely adequate in predicting the presence of a lead service line based on the available data. The two approaches were used, however, to select service lines for excavation as described in Subsection 4.4.

Initially, an attempt was made to determine a lead concentration in the Sample B that would indicate the presence of a lead service line since Sample B represents water standing in the service line. However, because of the difficulties inherent in relying on the

C	L	C	C	I
1923	1923	1923	1923	1948
SQUARE 102				
L	L	U	C	L
1942	1942	1942	1942	1942

Installation Date/ Square Combination	# of Known Service Lines	# of Known Lead Service Lines	Lead Probability
1923/102	4	1	25%
1948/102	1	0	0
1942/102	4	3	75%

L	C	C	C	L
1943	1943	1948	1951	1928
SQUARE 103				
L	L	L	U	L
1943	1943	1943	1943	1943

Installation Date/ Square Combination	# of Known Service Lines	# of Known Lead Service Lines	Lead Probability
1943/103	6	5	83%
1928/103	1	1	100%
1951/103	1	0	0
1948/103	1	0	0

KEY

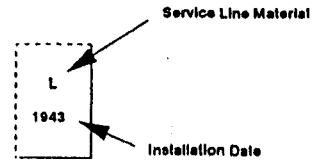


FIGURE 4-13 EXAMPLE OF PROCEDURE FOR CALCULATING INSTALLATION DATE/SQUARE LEAD PROBABILITIES

Table 4-6

Summary of Water Quality Data for Known Service Lines[1]

	Sample A		Sample B		Sample C	
	Known Lead	Known Nonlead	Known Lead	Known Nonlead	Known Lead	Known Nonlead
Avg[2]	20.00	10.75	19.56	8.21	2.00	1.61
Min	<2	<2	<2	<2	<2	<2
Max	390	558	134	308	53	47

[1]All results are in ug/L.

[2]Average values calculated using a value of 1 ug/L for all samples less than the detection limit of 2 ug/L.

homeowner to collect the sample, there is no way to determine which samples actually represent water from the service line. Also, because of variable water quality parameters such as temperature, pH, alkalinity, etc., lead concentrations contributed by a lead service line might vary from day to day, or even from house to house on a given day.

Ideally, one would expect the Sample B result to be greater than the Sample A result for houses having a Known Lead Service Line, again since Sample B represents water that has been standing in the service line. This does not appear to be the case, however, as the average of Sample A results for Known Lead Service Lines (20.00 ug/L) is actually greater than the average of Sample B results (19.56 ug/L). Additionally, the number of Known Lead Service Lines for which Sample B > Sample A (45 out of 154, or 29 percent) is only slightly larger than that for Known Nonlead Service Lines (89 out of 524, or 17 percent).

4.4 SERVICE LINE EXCAVATION SUMMARY

To test the validity of the basic conclusions drawn from the analysis of the Tap File Database and Water Quality Database, a group of 120 addresses was selected to have their service lines excavated and the service line material identified. All 120 addresses were to have Unknown Service Lines. The addresses were to be equitably distributed throughout the District.

The first step in selecting the addresses was to determine how many service lines were to be excavated in each ward. It was decided that the number of excavations in each ward would be based on the ratio of Unknown Service Lines to Total Service Lines for that ward. Thus, a ward with the highest percentage of Unknown Service Lines would have the most excavations.

Next, specific addresses were selected to meet the following criteria discovered during the database analyses:

- **Installation Date** -- Addresses were selected in each ward based on their service line installation date. Typically, 3 years that had the highest ratio of Known Lead Service Lines to Known Service Lines were chosen. Addresses were then selected in each ward that had an Unknown Service Line and an installation date in one of these years.

- **Proximity to Known Lead Service Lines** -- Addresses with Unknown Service Lines were chosen that were located on the same block and same side of the street as addresses with Known Lead Service Lines provided that they had the same installation date.

- **Water Quality Results** -- Addresses were selected that had an Unknown Service Line and showed the first flush Sample B result greater than 2 times the Sample A result, or

where lead levels were relatively high (>40 ug/L). In Wards 7 and 8 there were no addresses that met this criterion.

A list of 120 addresses was then generated using these criteria. An additional 60 addresses were also selected as backups in case one of the original 120 could not be excavated. The next step was to obtain excavation permits for the 120 sites. It was at this point that difficulties were encountered.

It was hoped to limit the excavations to the grassy tree space area to facilitate the process. Therefore, addresses were eliminated from the original list of 120 that required excavation outside this area. (Ultimately, 11 excavations were done in concrete sidewalks, and 2 more were done in brick sidewalks.) In addition, since most of the excavations were to be done at older addresses, some of the addresses that had been selected from the Tap File Database no longer existed, or were now commercial rather than residential. Again, these addresses were eliminated from the list.

As addresses were eliminated from the original list, other addresses were substituted. However, the original list of 180 addresses (120 plus 60 backups) was an ideal list. Addresses that were substituted for these did not always match the selection criteria as well as the originals. It was also necessary to change the distribution of excavations between wards as it became difficult to locate suitable residential locations in some wards.

Finally, service lines could not always be located during excavation. As a result, 124 excavations were performed, but only 119 service lines were identified.

Table 4-7 summarizes the 119 successful excavations. This table shows the address, square, ward, installation date, service line material, reason for excavation, and whether the address was on the original list. It also shows the predicted lead probability resulting from the installation date/square technique discussed in Subsection 4.3.1.

4.5 PREDICTIVE TECHNIQUES

Three approaches for predicting the probability of a lead service line were identified upon examining the data collected during the review of water distribution system records. Two of the approaches are based on trends observed in the Tap File Database. The third evolved from examination of the Water Quality Database. The three approaches are described in detail in the following subsections.

Each of these approaches, examined individually, has shortcomings that prevent its sole use in predicting the occurrence of lead service lines throughout the District. The final methodology developed combines features of the three approaches, and certain other basic assumptions, to determine lead service line probabilities.

WESTON

Table 4-7

Excavation Summary

EXCAVATION NUMBER	SQUARE	WARD	INSTALLATION DATE	SERVICE LINE MATERIAL	REASON FOR EXCAVATION	ORIGINAL LIST? (YES OR NO)	PREDICTED PROBABILITY **
1	1741	3E	1928	COPPER	DATE	YES	9.99
2	3334	4B	1931	LEAD	DATE	YES	0.17
3	3107	5C	1911	LEAD	PROXIMITY	YES	0.92
4	1097	6B	1924	LEAD	DATE	YES	0.29
5	3501	5C	1918	COPPER	DATE	YES	0.50
6	2848	1A	1911	LEAD	PROXIMITY	YES	0.53
7	5150	7C	1919	LEAD	PROXIMITY	YES	0.50
8	3921	5A	1925	LEAD	WQSAMP	YES	0.33
9	3031	1A	1920	LEAD	DATE	YES	0.13
10	2835	1A	1911	LEAD	PROXIMITY	YES	0.47
11	2722	4A	1912	LEAD	WQSAMP	YES	9.99
12	2836	1A	1911	LEAD	PROXIMITY	YES	0.42
13	3551	5C	1928	LEAD	DATE	YES	9.99
14	2869	1B	1912	LEAD	DATE	YES	1.00
15	2865	1B	1911	LEAD	PROXIMITY	YES	0.38
16	2800	1E	1920	COPPER	DATE	YES	0.20
17	2841	1A	1911	LEAD	PROXIMITY	YES	0.56
18	3150	4D	1925	LEAD	PROXIMITY	YES	0.63
19	4127	5B	1920	COPPER	DATE	YES	9.99
20	3958	5C	1918	LEAD	DATE	YES	9.99
21	4213	5B	1928	LEAD	DATE	YES	0.56
22	4061	5B	1925	LEAD	PROXIMITY	YES	0.38
23	3557	5C	1921	LEAD	PROXIMITY	YES	0.25
24	4339	5A	1916	LEAD	WQSAMP	YES	9.99
25	1851	3E	1925	LEAD	WQSAMP	YES	0.08
26	1748	3G	1921	LEAD	WQSAMP	YES	0.00
27	3174	4B	1911	COPPER	WQSAMP	YES	1.00
28	155	2B	1911	IRON	DATE	YES	0.20
29	1908	3C	1928	COPPER	DATE	YES	9.99
30	1031	6A	1915	COPPER	PROXIMITY	YES	0.67
31	4060	5B	1925	LEAD	PROXIMITY	YES	0.29
32	2702	4C	1915	LEAD	WQSAMP	YES	9.99
33	2806	4C	1919	IRON	WQSAMP	YES	0.00
34	5787	8A	1925	LEAD	PROXIMITY	YES	0.50
35	2866	1B	1912	LEAD	DATE	YES	9.99
36	2580	1C	1914	COPPER	WQSAMP	YES	0.00
37	65	2B	1911	COPPER	PROXIMITY	YES	0.00
38	133	2B	1911	COPPER	PROXIMITY	YES	0.43
39	1257	2E	1911	IRON	PROXIMITY	YES	0.43
40	923	6B	1911	IRON	WQSAMP	YES	0.27
41	3254	4D	1927	LEAD	PROXIMITY	YES	0.82
42	2954	4A	1922	LEAD	WQSAMP	YES	9.99
43	3252	4D	1931	COPPER	DATE	YES	0.00

* P NONLEAD represents addresses that are in proximity to addresses with a nonlead service line.

** Addresses with a Predicted Probability equal to 9.99 had "no match" in the Installation Date/Square database.

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Table 4-7
(continued)

EXCAVATION NUMBER	SQUARE	WARD	INSTALLATION DATE	SERVICE LINE MATERIAL	REASON FOR EXCAVATION	ORIGINAL LIST? (YES OR NO)	PREDICTED PROBABILITY **
44	2964	4A	1920	LEAD	WQSAMP	YES	9.99
45	1873	3G	1912	LEAD	WQSAMP	YES	9.99
46	5573	6C	1926	COPPER	PROXIMITY	YES	0.29
47				COPPER	PROXIMITY	YES	9.99
48	1289	2E	1911	LEAD	PROXIMITY	YES	0.67
49	1284	2E	1911	IRON	WQSAMP	YES	0.27
50				LEAD	PROXIMITY	YES	9.99
51	1072	6B	1911	LEAD	WQSAMP	NO	0.33
52	5835	8A	1950	LEAD	DATE	NO	9.99
53	309	2C	1911	LEAD	PROXIMITY	NO	0.50
54	3112	5C	1911	COPPER	PROXIMITY	NO	0.67
55	3504	5C	1920	COPPER	DATE	NO	9.99
56	851	2D	1911	LEAD	PROXIMITY	NO	0.27
57	2602	1E	1911	LEAD	PROXIMITY	NO	0.58
58	2891	1A	1920	LEAD	DATE	NO	9.99
59	3311	4C	1922	LEAD	PROXIMITY	NO	0.75
60	2856	1B	1911	LEAD	PROXIMITY	NO	0.86
61	3252	4D	1931	IRON	DATE	NO	0.00
62	1075	6B	1911	COPPER	PROXIMITY	NO	0.31
63	3047	1A	1923	COPPER	PROXIMITY	NO	0.50
64	3034	1A	1920	LEAD	DATE	NO	0.50
65	2990	4B	1922	LEAD		NO	0.00
66	957	6A	1911	LEAD		NO	0.60
67	1053	6A	1924	COPPER	DATE	NO	0.60
68	1352	3B	1928	COPPER	DATE	NO	0.88
69	2598	1E	1915	LEAD		NO	0.00
70		1		COPPER	DATE	NO	9.99
71	514	2C	1911	LEAD		NO	0.00
72	2884	1B	1911	COPPER	P NONLEAD*	NO	0.25
73	2971	4B	1925	LEAD		NO	0.00
74	2818	1E	1922	LEAD	PROXIMITY	NO	0.25
75	4070	5B	1918	LEAD	DATE	NO	0.40
76	4063	5B	1918	LEAD	DATE	NO	0.50
77	4009	5A	1918	COPPER	DATE	NO	1.00
78	4016	5A	1928	IRON	DATE	NO	0.00
79	3873	5C	1918	LEAD	DATE	NO	0.00
80	3927	5A	1918	LEAD	DATE	NO	9.99
81	3639	5C	1920	LEAD	DATE	NO	9.99
82	4341	5A	1918	LEAD	DATE	NO	0.00
83	3501	5C	1920	LEAD	DATE	NO	0.25
84	3920	5A	1920	COPPER	DATE	NO	0.20
85	5125	7C	1919	COPPER		NO	9.99
86	5160	7C	1920	LEAD	DATE	NO	9.99

* P NONLEAD represents addresses that are in proximity to addresses with a nonlead service line.

** Addresses with a Predicted Probability equal to 9.99 had "no match" in the Installation Date/Square database.

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Table 4-7
(continued)

EXCAVATION NUMBER	SQUARE	WARD	INSTALLATION DATE	SERVICE LINE MATERIAL	REASON FOR EXCAVATION	ORIGINAL LIST? (YES OR NO)	PREDICTED PROBABILITY **
87	3933	5A	1918	LEAD	DATE	NO	9.99
88	3927	5A	1918	LEAD	DATE	NO	9.99
89		7		COPPER		NO	9.99
90	5129	7D	1926	COPPER	DATE NON	NO	9.99
91	5690	8C	1925	LEAD		NO	9.99
92	5672	8C	1925	LEAD		NO	9.99
93	4064	5B	1925	COPPER	P NONLEAD*	NO	0.25
94				LEAD	P NONLEAD*	NO	9.99
95	5945	8E	1925	COPPER	P NONLEAD*	NO	0.00
96	5624	8C	1925	LEAD		NO	0.00
97	5602	8C	1924	LEAD	DATE	NO	0.67
98				LEAD		NO	9.99
99	1100	6B	1924	LEAD	DATE	NO	0.25
100	1102	6B	1924	LEAD	DATE	NO	0.27
101	1062	6B	1911	COPPER	PROXIMITY	NO	0.45
102	1110	6B	1924	COPPER	DATE	NO	1.00
103	1088	6B	1924	LEAD	DATE	NO	0.00
104	1091	6B	1946	LEAD	DATE	NO	0.00
105	1055	6A	1924	IRON	DATE	NO	0.25
106	5150	7C	1925	IRON		NO	0.00
107	5580	7B	1919	LEAD	DATE	NO	9.99
108	5691	7B	1937	IRON	P NONLEAD*	NO	0.00
109	5773	8C	1924	LEAD	DATE	NO	9.99
110	5603	8C	1924	LEAD	DATE	NO	0.67
111	5577	8C	1950	COPPER	DATE	NO	0.00
112	5777	8C	1924	COPPER	DATE	NO	9.99
113	589		1969	COPPER	DATE	NO	9.99
114	240	2C	1927	LEAD	DATE	NO	9.99
115	523	2C	1966	COPPER	DATE	NO	0.00
116	XXXX		1973	LEAD	DATE	NO	0.28
117				LEAD		NO	9.99
118	1288	2E	1911	COPPER		NO	9.99
119	151	1C	1911	LEAD	PROXIMITY	NO	0.82

* P NONLEAD represents addresses that are in proximity to addresses with a nonlead service line.

**Addresses with a Predicted Probability equal to 9.99 had "no match" in the Installation Date/Square database.

The results of the service line excavations will be used to assess the accuracy of lead probabilities predicted by the three methods. The addresses selected for excavations were originally chosen using the basic parameters of installation date, proximity, and water quality results. However, because of circumstances encountered in the field, not all of the originally selected addresses could be excavated. For this reason, only 105 of the 119 addresses excavated successfully could be used in this analysis.

4.5.1 Installation Date

It was the opinion of District personnel that the use of lead service lines generally stopped sometime during the 1950s. An examination of the Tap File Database developed previously generally confirmed this opinion, and also showed that there were fairly distinct periods of lead service line use within each ward. This fact allowed the development of a simple predictive technique based solely on the installation date and ward given in the Tap File Database.

The spreadsheet described in Subsection 4.3.1 was used to make a rough approximation of the total number of lead service lines in the District. The Ratio of Lead Service Lines for each year in each ward was applied to the Unknown Service Line value for that year and in that ward. The resulting value, referred to as Assumed Lead Service Lines, was then added to the number of Known Lead Service Lines to give the Total Lead Service Lines for each year in each ward. This analysis results in an approximation of 18,525 lead service lines in the District. This represents approximately 15 percent of the 126,099 service lines in the database.

The trend of lead service line installation is fairly consistent throughout the District and over time; and, therefore, extrapolation of the ratio of Lead Service Lines to Unknown Service Lines is appropriate for a rough estimate. However, it cannot be applied as successfully to individual addresses.

A total of 52 service lines were excavated based on their installation dates. Of these, 44 were excavated because their installation dates indicated a relatively high probability of a lead service line. These probabilities were based on the installation date and ward of the particular address (as shown in Appendix D). The remaining eight service lines were excavated because their installation dates indicated a low probability of a lead service line (see Appendix D).

Of the 44 expected lead service lines, 28 were actually lead. Thus, the installation date method correctly predicted approximately 64 percent of the lead service lines. Of the 8 expected nonlead service lines, 5 actually turned out to be nonlead.

4.5.2 Proximity to Known Lead Service Lines

The basic premise of this technique is that a house located near another house that has a lead service line also is likely to have a lead service line, provided that the service lines were installed at the same time. To analyze the records in the Tap File Database, houses were considered to be in proximity if they were located in the same square. To ensure that these same houses all had service lines installed at approximately the same time, the installation date for each was also considered. Thus, this approach is basically a refinement of the simple installation date method.

As described in Subsection 4.3.1, the 81,356 records with Known Service Lines were examined to develop installation date/square combination lead probabilities. The resulting 24,892 combinations were then applied to the 44,734 records with Unknown Service Lines. This was done by examining each of the addresses with an Unknown Service Line, taking the installation date and square for this address, and searching the 24,892 installation date/square combinations for a match. The corresponding lead probability was then assigned to the address with the Unknown Service Line. Table 4-8 summarizes the results of this analysis.

The large number of records listed as having no match represents addresses whose particular installation date/square combination did not exist in the installation date/square combination database. There are several reasons why this might occur. First, there are addresses in the Tap File Database that do not have a square assigned to them. Second, all addresses in a given square for a given installation date may be Unknown Service Lines, thus making it impossible to assign a probability to the installation date/square combinations.

If it is assumed that addresses with predicted lead probabilities of greater than 0.5 have lead service lines, this technique predicts 4,946 lead service lines among the 44,734 remaining addresses with Unknown Service Lines. It should be noted that this is a minimum figure, as there may be lead service lines among the 15,905 addresses with no match against the installation date/square combination database.

Examination of the 15,905 addresses with no match shows that 10,253 fall in the time period 1900 to 1925 and another 3,142 fall in the time period 1970 to 1989. These time periods correspond to the periods of high Unknown Service Lines (as shown in Figure 4-12). Again, service lines installed in the period after 1970 can be assumed to be nonlead.

A total of 38 addresses was selected for excavation based on their proximity to Known Lead Service Lines. These addresses were selected after a very detailed examination of the Tap File Database. Thus, these 38 addresses are ideal examples of the proximity method. Of the 38, 26 (or 68 percent) had the expected service line material.

Table 4-8

Summary of Installation Date/Square Analysis

Probability Range	Number of Records
0.0 to 0.1	12,085
0.1 to 0.2	3,018
0.2 to 0.3	3,170
0.3 to 0.4	2,654
0.4 to 0.5	2,956
0.5 to 0.6	845
0.6 to 0.7	1,244
0.7 to 0.8	512
0.8 to 0.9	334
0.9 to 1.0	2,011
No match	15,905
	44,734

The new proximity method, which is based on installation date and square, was also applied to the 119 excavations. A summary of the results of this analysis is given in Table 4-9.

The results of the excavations show that this technique alone cannot be used to accurately predict the existence of a lead service line. Of the 49 lead service lines excavated for which a lead probability could be assigned, only 15 had a probability of >0.5. At the same time, 10 of these 49 addresses had a predicted probability of 0.0.

One explanation for this is that the technique relies on Known Service Lines and Known Lead Service Lines within each square. Thus, if there is only one Known Service Line in a square for a given installation date, and it is nonlead, then the predicted lead service line probability for all other addresses in that square with that installation date will be 0.0.

The results of the excavation program can be used to calibrate the installation date/square method for predicting service line material. Table 4-10 is a reproduction of Table 4-9 that includes a column entitled "Actual Probability." This column represents the actual probability found in the excavation program, and is calculated as the number of lead service lines found divided by the total number of service lines within each predicted probability range.

For calibration of predicted probabilities obtained from installation date/square combinations, the actual probabilities are then plotted against the predicted probabilities as shown in Figure 4-14. A regression line is plotted using the midpoint of each predicted probability range, and excluding the point for the predicted probability range 0.9 to 1.0. The line relates calibrated probability with predicted probability, and results in the following equation:

$$\text{Calibrated Probability} = 0.46 + (0.49 \times \text{Predicted Probability}) \quad \text{(Eq. 4.1)}$$

4.5.3 Water Quality

The DCRA Water Quality Database is too small to be of use in predicting lead service lines throughout the District. However, the excavation data were used to verify whether lead levels in water could be used to indicate a lead service line. A total of 14 service lines were excavated based on water quality sampling results. All 14 were expected to be lead.

Table 4-11 shows the lead levels found at the 14 addresses, along with the service line material identified during excavation.

Table 4-9

Results of Installation Date/Square Method Applied to Excavation Sites

Predicted Probability	Actual Material: Lead	Actual Material: Nonlead	Total
0.0 to 0.1	11	11	22
0.1 to 0.2	2	3	5
0.2 to 0.3	9	6	15
0.3 to 0.4	5	1	6
0.4 to 0.5	7	5	12
0.5 to 0.6	5	1	6
0.6 to 0.7	4	2	6
0.7 to 0.8	1	0	1
0.8 to 0.9	3	1	4
0.9 to 1.0	2	3	5
	49	33	82*

*Does not include 37 records for which an installation date/square combination did not exist.

Table 4-10

Calibration of Installation Date/Square Method Using Excavation Sites

Predicted Probability	Actual Material: Lead	Actual Material: Nonlead	Total	Actual Probability
0.0 to 0.1	11	11	22	0.50
0.1 to 0.2	2	3	5	0.40
0.2 to 0.3	9	6	15	0.60
0.3 to 0.4	5	1	6	0.83
0.4 to 0.5	7	5	12	0.58
0.5 to 0.6	5	1	6	0.83
0.6 to 0.7	4	2	6	0.67
0.7 to 0.8	1	0	1	1.00
0.8 to 0.9	3	1	4	0.75
0.9 to 1.0	2	3	5	0.40
	49	33	82*	

*Does not include 37 records for which an installation date/square combination did not exist.

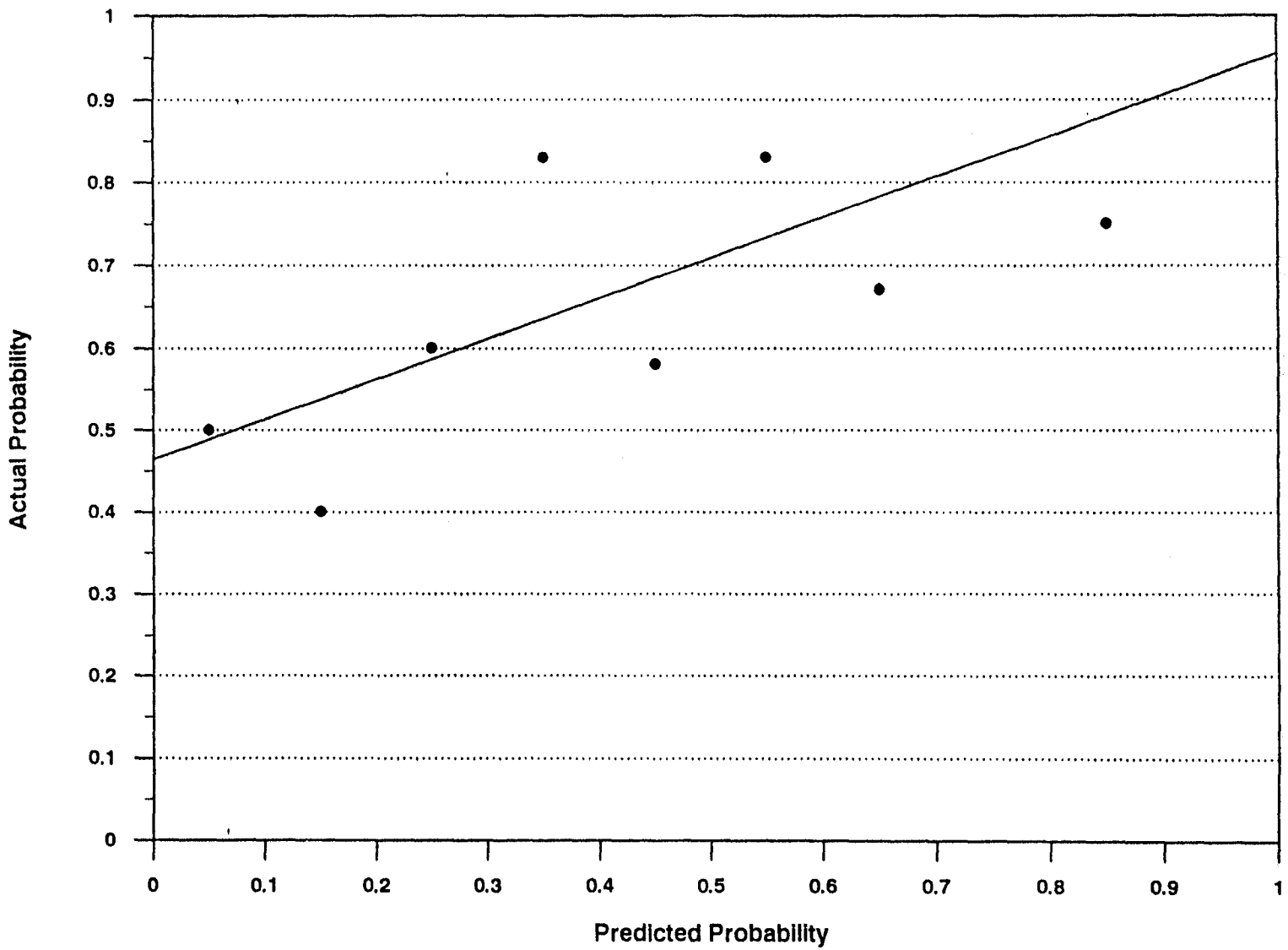

FIGURE 4-14 PLOT OF PREDICTED VERSUS ACTUAL LEAD PROBABILITIES

Table 4-11

Comparison of Lead Levels with Service Line Material

Excavation Number	Sample A (ug/L)	Sample B (ug/L)	Sample C (ug/L)	Service Line Material
13	59	75	0	Lead
18	13	45	0	Lead
34	50	152	0	Lead
35	11	91	0	Lead
36	11	30	0	Lead
38	24	74	0	Copper
46	4	12	0	Lead
47	10	24	0	Iron
55	5	10	0	Copper
62	77	108	0	Iron
64	77	292	0	Lead
67	5	15	0	Lead
103	46	255	0	Lead
115	19	324	0	Iron

4.6 GEOGRAPHIC BREAKDOWN OF LEAD SERVICE LINES

Using the techniques described in Subsection 4.5 it is now possible to estimate the number of lead service lines that are currently in place in the District. It is necessary to examine the number of lead service lines that have been replaced over the last several years. The Tap File Database tracks this information in the REPLACED field. This is a logical field (i.e., true or false) that indicates whether a service line has been replaced (true) or not (false).

At this time, the Tap File Database contains 716 records for which the REPLACED field indicates that a lead service line has been replaced. This number should be updated continually as additional lead service lines are replaced through the Meter Replacement and Street Replacement Programs. A breakdown of these replaced lead service lines is given in Table 4-12.

Now it is necessary to examine the 44,734 Unknown Service Lines. Subsection 4.5.2 describes the basic installation date/square combination technique and the refinement based on the results of the excavation program. Using Equation 4.1 for the midpoint range of predicted probability values, corresponding calibrated probability values were calculated and are shown in Table 4-13. This refined installation date/square technique results in 17,098 probable lead service lines (as shown in Table 4-13). A breakdown by ward of these probable lead service lines is given in Table 4-14. However, this technique could not match 15,905 addresses for which no probability could be assigned.

Out of the 15,905 addresses that could not be assigned a probability, a total of 4,428 addresses had a service line installation date between 1947 and the present. These are assumed to be nonlead based upon previous analysis of lead service line installation trends. Thus, 11,477 addresses remain that must be assigned as lead or nonlead.

These 11,477 addresses will be assigned a service line material by examining the installation date and ward for each address as discussed in Subsection 4.5.1. While this technique is not refined enough to predict service line materials for particular addresses, it will provide an overall approximation of the number of lead service lines by ward. Applying this technique to the 11,477 addresses results in a total of 2,795 additional addresses that can be predicted to have lead service lines. A breakdown by ward of these probable lead service lines is given in Table 4-15.

It is now possible to combine Tables 4-12, 4-14, and 4-15 to obtain an estimate of the distribution of the remaining lead service lines throughout the District as shown in Table 4-16. The values in the column titled "Number of Lead Service Lines" is simply the sum of the "Number of Lead Service Lines Remaining" from

Table 4-12

Breakdown of Lead Service Line Replacements

Ward	Number of Known Lead Service Lines	Number of Known Lead Service Lines Replaced	Number of Known Lead Service Lines Remaining
1	644	85	559
2	545	88	457
3	1,997	141	1,856
4	1,990	89	1,901
5	1,174	121	1,053
6	1,186	134	1,052
7	854	43	811
8	430	5	425
Ward not indicated	167	10	157
	8,987	716	8,271

Table 4-13

Summary of Probable Lead Service Lines Using Equation 4.1

Predicted Probability	Calibrated Probability[1]	Number of Records[2]	Number of Probable Lead Service Lines
0.0 to 0.1	0.48	12,085	5,801
0.1 to 0.2	0.53	3,018	1,600
0.2 to 0.3	0.58	3,170	1,839
0.3 to 0.4	0.63	2,654	1,672
0.4 to 0.5	0.68	2,956	2,010
0.5 to 0.6	0.73	845	617
0.6 to 0.7	0.78	1,244	970
0.7 to 0.8	0.83	512	425
0.8 to 0.9	0.88	334	294
0.9 to 1.0	0.93	2,011	1,870
			17,098

[1]Using Equation 4.1 and midpoint of range.
[2]From Table 4-8.

Table 4-14

Breakdown of Probable Lead Service Lines Using the Installation Date/Square Method

Ward	Number of Probable Lead Service Lines
1	3,184
2	2,393
3	1,068
4	2,417
5	2,657
6	3,644
7	302
8	87
Ward not indicated	1,343
	17,095*

*Total does not match Table 4-13 due to rounding.

Table 4-15

Breakdown of Remaining Probable Lead Service Lines Using Installation Date and Ward

Ward	Number of Probable Lead Service Lines
1	510
2	475
3	234
4	427
5	437
6	317
7	142
8	65
Ward not indicated	188
	2,795

Table 4-16

Distribution of Lead Service Lines

Ward	Total Number of Service Lines	Number of Lead Service Lines*	Percent Lead	Percent of Total
1	11,082	4,253	38.4	15.1
2	14,655	3,325	22.7	11.8
3	17,996	3,158	17.5	11.2
4	19,518	4,745	24.3	16.8
5	18,369	4,147	22.6	14.7
6	17,851	5,013	28.1	17.8
7	15,004	1,255	8.4	4.5
8	5,549	577	10.5	2.0
Ward not indicated	6,045	1,688	27.9	6.0
	126,069	28,161	22.3	100

*Includes Known Lead Service Lines and Probable Lead Service Lines.

Table 4-12, plus the "Number of Probable Lead Service Lines" from Table 4-14, plus the "Number of Probable Lead Service Lines" from Table 4-15.

4.7 PROCEDURE FOR IDENTIFYING SERVICE LINE MATERIAL

Having examined the various data sources available to the District, it is now possible to outline a procedure for identifying addresses that have a high probability of possessing a lead service line. Specifically, a method is presented that will allow the District to examine addresses on a case-by-case basis in planning for service line replacement programs. A flow diagram of this method is given in Figure 4-15, and is explained in detail in the remainder of this subsection.

The first step is to check the address in the Tap File Database. In some cases, the address may not exist because of a variety of reasons, e.g., street names that have changed over time, or errors in the keypunching process. If the address cannot be found in the Tap File Database, additional information about the address (i.e., installation date, square, ward, service line material, etc.) may be obtained from the files of BWMB.

Once the address is located in the Tap File Database, two fields should be examined to determine the service line material. Either the PIPEMATL field or CUSTSERV field may indicate the service line material. Again, the PIPEMATL indication was obtained from the BWMB Tap File, while the CUSTSERV came from the Project Locator File. If either of these fields indicate that the service line is nonlead, the procedure is complete. If either indicates a lead service line, or there is no indication, then the procedure continues accordingly.

If the Tap File Database indicates a lead service line, the next step is to make sure that the service has not already been replaced. Currently, the Tap File Database indicates 716 replaced service lines as recorded in the REPLACED field. If this field is "true" (i.e., the service has been replaced) the service line can be considered nonlead. If this field is "false," further examination of other lead replacement program records must be done because not all replaced service lines have been updated in the Tap File Database at the present time. If no indication of replacement is found, then the service line can be considered lead.

If there is no indication in the Tap File Database of service line material, then the predictive techniques discussed in Subsection 4.4 must be used. First, the Tap File Database is used to identify the installation date, square, and ward of the address. Next, a search is made of the installation date/square combination database for the particular address's installation date and square. Again, it is possible that the installation date and square for the address will not exist in the installation date/square combination database.

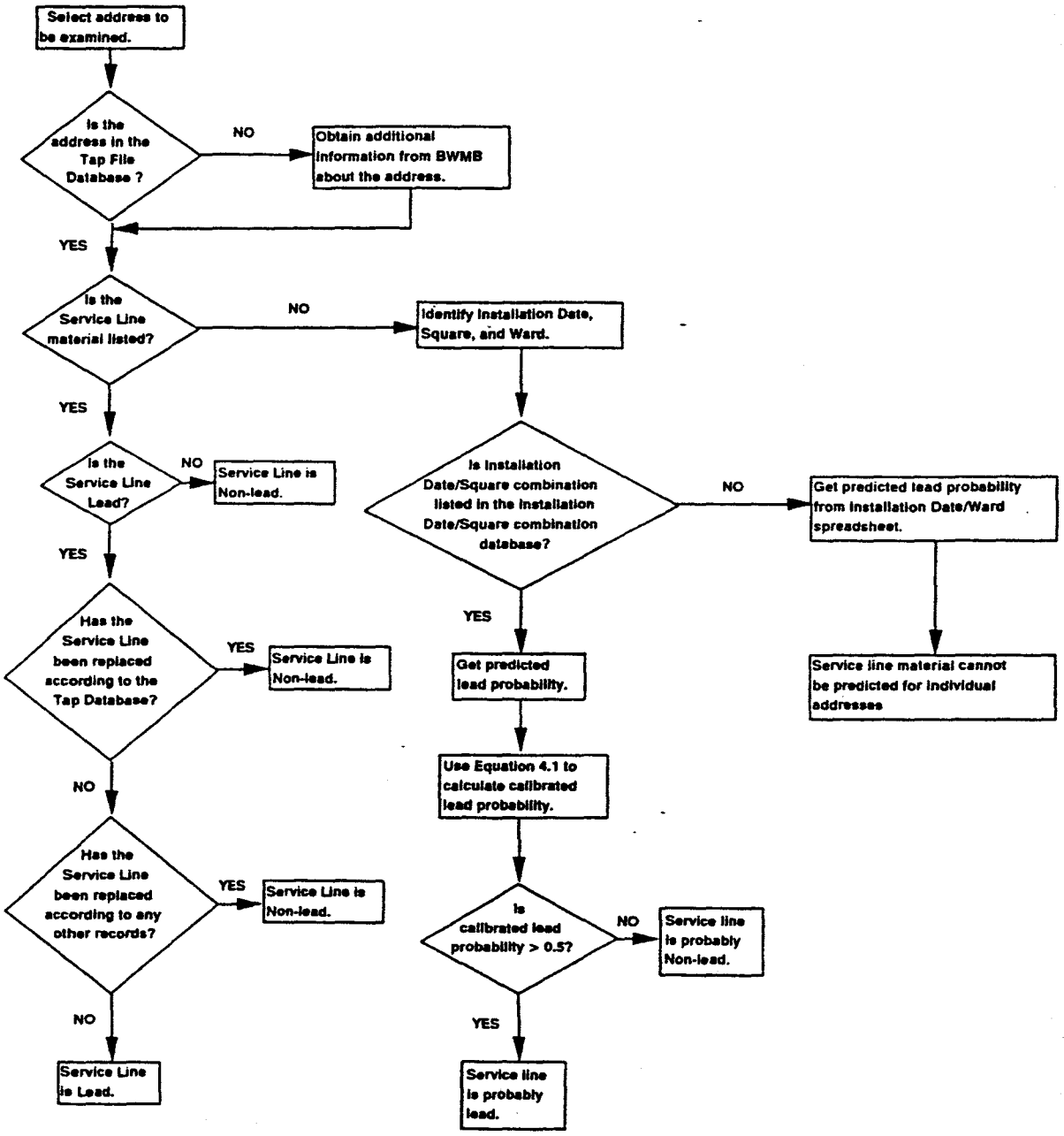

FIGURE 4-15 METHODOLOGY FOR IDENTIFYING SERVICE LINE MATERIAL

Assuming that the installation date/square combination does exist, a predicted lead probability can be obtained. Equation 4.1 can then be used to calculate the calibrated lead probability.

If the installation date/square combination does not exist, then the next step is to use the combination of installation date and ward to determine a predicted lead probability. These probabilities can be obtained from the spreadsheet given in Appendix D. It must be noted that this approach is much less refined than the installation date/square approach, since it considers probabilities within wards rather than the much smaller square. Predicted lead probabilities for a given installation date rarely exceed 50 percent within a ward. It is not possible, therefore, to predict the service line material for specific addresses following this approach.

The use of the Water Quality Database in determining service line material has not been included in the method presented in Figure 4-14. Because of the relatively small size of this database, and the difficulties involved in predicting service line material based on lead in water concentrations, it is unlikely that water quality results could be of significant use at the present time in determining service line material.

4.8 SUMMARY AND CONCLUSIONS

The databases that were developed previously were used extensively in determining the number and distribution of lead service lines in the District, as well as developing a methodology for identifying lead service lines. Both the Tap File Database, which included data on service line installations, and the Water Quality Database, which included data from previous DCRA sampling programs, were used in this effort.

The Tap File Database was used to examine the history of service line installations in the District and, in particular, lead service line installations over time. Overall, the service line material is known (i.e., identified as lead or nonlead) for approximately 65 percent of the 126,069 records in the Tap File Database. This percentage is generally close to 90 for the years 1927 to 1969.

Lead service line installations followed the same basic pattern in each ward over time, i.e., increasing lead usage beginning around 1920 and continuing to a peak around 1930. Lead usage also was significant in the pre-1911 period; however, it is difficult to segregate it into individual years. Lead usage then drops off to a fairly insignificant amount in the mid-1930s, then peaks again for about 5 years during World War II. Though few in number, the Tap File Database did show lead service line installations continuing through 1977.

The technique for predicting lead service lines that evolved from this analysis is called the Proximity Technique. The basic premise

is that groups of service lines were often installed on the same block at the same time, by the same contractor, and of the same material. Thus, one can assign a probability of a service line being lead to an address based on the ratio of Lead Service Lines to Known Service Lines in the area.

The Water Quality Database also was examined in an attempt to identify trends that would indicate the occurrence of a lead service line. No such trends were found. Even if they had, this database is too small to draw broad conclusions about the number and distribution of lead service lines in the District. However, water quality data were one factor considered when selecting sites for service line excavations.

Excavations were made at 124 addresses throughout the District, and service line materials identified at 119. These sites were originally chosen on the basis of installation date, proximity to Known Lead Service Lines, and water quality data. The results of the excavation task were then used to calibrate the Proximity Technique for predicting lead service lines.

The previous analyses show the difficulties in accurately predicting the existence of a lead service line at a specific address. Factors that must be considered when attempting such predictions include date of installation of the service line, location of the address within the District (i.e., ward or square), proximity of the addresses to Known Lead Service Lines, and water quality data. Examining all of these factors is necessary to achieve a relatively accurate prediction of the occurrence of lead service lines.

While predicting for individual addresses is an inexact science at best, the techniques developed should work better on a larger scale. Thus, the distribution of lead service lines on a ward-by-ward basis should be fairly accurate, even if individual addresses are not as predictable.

The total number of lead service lines remaining in the District is estimated at 28,161 using these techniques. This figure represents the total lead service lines remaining after the 716 service line replacements indicated in the Tap File Database are deducted. The number of lead service lines also should be reduced by any recent replacements.

The highest percentage of lead service lines appears in Ward 1, where 38.3 percent of all service lines are estimated to be lead. The largest number of lead service lines appears in Ward 6. The 5,013 lead service lines in Ward 6 represent almost 18 percent of the total service lines in the entire District.

SECTION 5

PRIORITIZED LEAD SERVICE REPLACEMENT PROGRAM

5.1 INTRODUCTION

Replacing lead service lines throughout the District is a massive undertaking. The number of lead service lines within the District has been estimated at more than 28,000 (see Section 4). The District is currently replacing approximately 375 of these service lines per year. At this rate, it would take approximately 75 years to replace all the lead service lines. The cost of replacing the District's portion of a single service line is approximately $2,890. This cost includes the labor cost of all employees involved in the program (including employee benefits), the cost of equipment needed (taking into account purchase price and useable life), and the cost of supplies needed.

Obviously, the Lead Service Replacement Program must be prioritized so that lead service lines are replaced as efficiently as possible. Those service lines that are replaced first should have the greatest impact on reducing lead levels in water to the populations at the greatest risk (i.e., children and pregnant women). After the replacement of these identified worst-case lead service lines, the replacement program should work to systematically replace lead service lines on a square-by-square basis.

Water sampling studies have shown that the presence of a lead service line does not always result in high lead levels in drinking water. The highest priority should, therefore, be placed on removing lead service lines at those addresses where the lead service line has been shown to contribute to high lead levels at the tap. The results of the previously conducted water quality sampling programs can be used to identify these addresses.

Any lead service replacement program should be coordinated closely with other ongoing construction programs within the District government. As an example, the Street Replacement Program calls for the replacement of all service lines along a street undergoing reconstruction. Careful scheduling of lead service line replacements can take advantage of this requirement.

The Lead Service Replacement Program should be organized so that a number of crews are continually working at systematically replacing lead service lines on a square-by-square basis. At least one crew, however, should be available to respond to customer requests for replacement, or to replace lead service lines at addresses which are subsequently found to have high lead concentrations at the tap.

Finally, some attention should be given to those addresses that showed a high concentration of lead in a water sample supposedly

representative of water in the service line, but for which records show that the service line is not lead. It is possible that the information available on service line material for these addresses may be incorrect. Another possibility may be that the information indicates the service line material for only a portion of the service line, and that the remaining portion of the service line is actually lead. Finally, it could be that the water sample was taken incorrectly (i.e., that the water sample is actually from the interior home plumbing system rather than the service line), and that the service line is not responsible for the high lead concentration.

5.2 METHODOLOGY

The basic methodology followed in prioritizing the lead service line replacement program is shown in Figure 5-1. The basic idea is to replace lead service lines on a square-by-square basis, starting with squares in which water quality sampling showed an effect on lead levels at the tap. Figure 5-1 also illustrates how blood lead data could also be utilized in this process, should they become available.

The first step was to use the methodology presented in Section 4 to identify the addresses of all Known and Probable Lead Service Lines in the District. A total of 25,590 such addresses was identified. An additional 2,795 lead service lines are predicted using the methodology described in Section 4. However, no specific address could be assigned for these service lines.

Simultaneously, the water quality data collected by both the District and WESTON (see Section 7) were used to rank addresses based on the lead concentrations. The addresses were assigned to one of four replacement categories based on lead levels found in any one sample at a particular address. That is, no differentiation was made between a Sample C result and a midday result, for example, even though the samples may actually represent water from different points in the home plumbing. The four replacement categories used were as follows:

- Replacement Category 1 -- all results <10 ug/L.
- Replacement Category 2 -- at least one result >10 ug/L but ≤ 20 ug/L.
- Replacement Category 3 -- at least one result >20 ug/L but ≤ 50 ug/L.
- Replacement Category 4 -- at least one result >50 ug/L.

The individual address replacement categories were then applied to each square. The replacement category for a square was taken as the largest replacement category for any individual address within

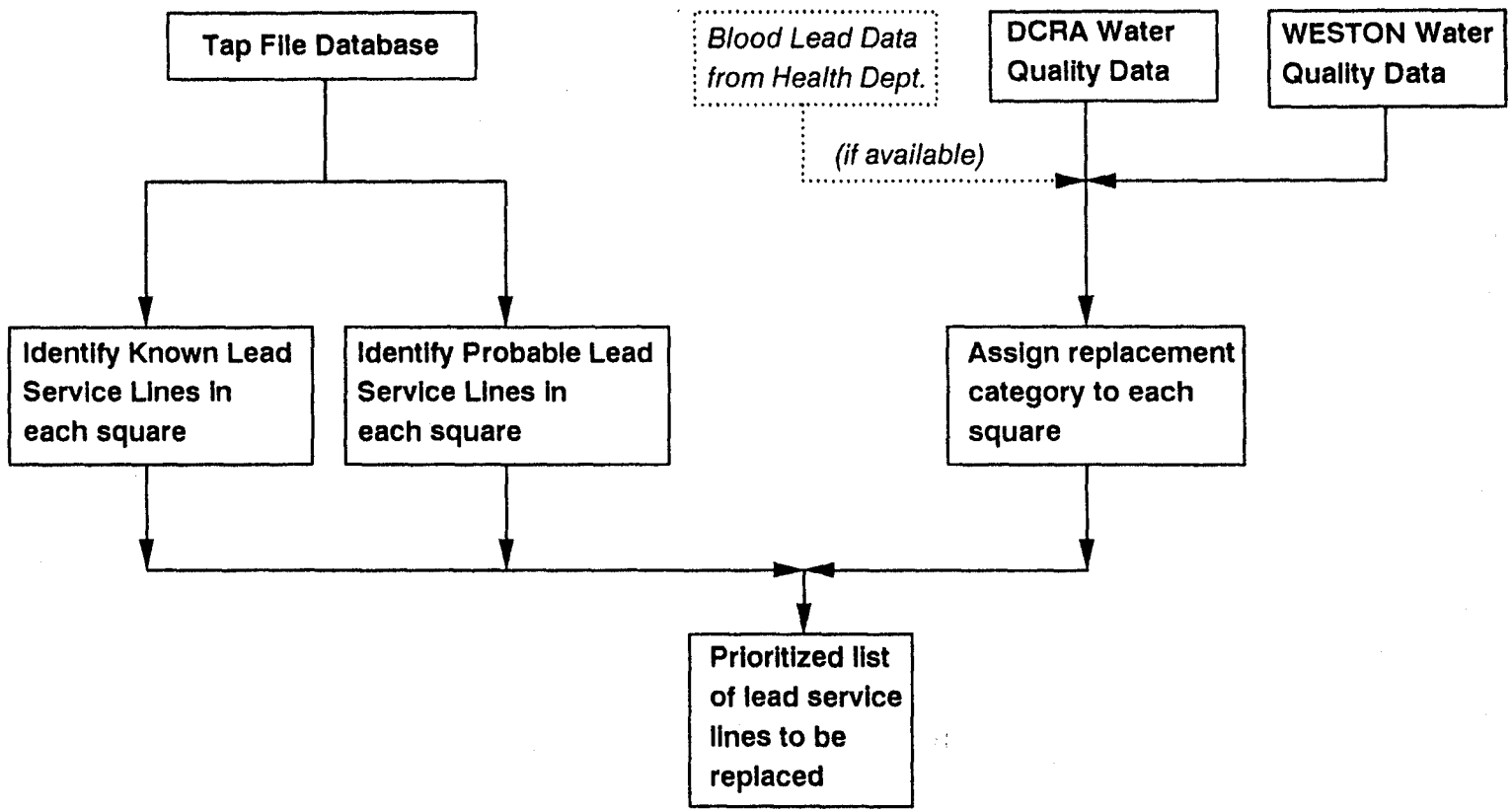

FIGURE 5-1 METHODOLOGY FOR PRIORITIZING THE LEAD SERVICE REPLACEMENT PROGRAM

that square. Thus, if a particular square had 10 homes for which water quality sampling results were available, and all results were <10 ug/L, the replacement category for that square would be 1. If, however, one of the homes had a lead concentration >50 ug/L for any one sample, the replacement category for the entire square would be 4.

Water quality sampling for lead has not been conducted in all portions of the District, however. For those squares for which no water quality results are available, the replacement category was left blank. Addresses with lead service lines in these squares are thus given a lower replacement priority than addresses in squares for which water quality data are available.

The replacement category information for each square was then combined with the database of Known and Probable Lead Service Lines to produce the final prioritized list of addresses for replacement. The final list is sorted by replacement category (with squares in Replacement Category 4 having the highest priority, followed by Replacement Category 3, etc.); square (squares with the greatest number of Known plus Probable Lead Service Lines having the greater priority); quadrant; street; and, finally, service line type (either Known Lead, L; or Probable Lead, pl). The complete list of addresses for replacement is presented in Appendix E.

A total of 1,273 addresses with lead service lines (Known plus Probable) fell into Replacement Category 4. These service lines are considered to be of the highest priority for replacement. Under the existing replacement rate of 375 services per year, it would take about 3.5 years to replace these services. The number of lead service lines in Replacement Categories 3, 2, and 1 are 1,625, 1,587, and 6,557, respectively. The remaining 14,548 lead service lines are located in squares in which no water quality data are available, and, thus, were not assigned to a replacement category.

This priority system should be considered flexible and should be modified during the implementation of the lead service line replacement program when other addresses are identified with high concentrations of lead in water. The program must also be closely coordinated with any other ongoing District activities, such as the Street Replacement Program. **Finally, those addresses listed as Probable Lead Service Lines should be inspected in the field prior to excavation to verify that they are actually lead.**

5.3 CONCLUSIONS AND RECOMMENDATIONS

The replacement of lead service lines throughout the District is a formidable task. The replacements must be scheduled so that homes exhibiting the greatest effect from the lead service line have the highest priority. However, with so many replacements to be performed, it is also very important that they be scheduled in the most efficient manner possible. For this reason it is recommended that the District follow the replacement schedule

presented herein. That is, replace all lead service lines within a square at the same time, thus saving on the cost of moving equipment and personnel around the District. Squares have been ranked based on water quality results so that those areas that have shown problems with lead in drinking water are considered first.

It is recommended that the District begin replacement of lead service lines in Replacement Categories 4 and 3 immediately. Replacement of the 2,898 lead service lines in these categories would cost approximately $8.4 million. The replacement of these 2,898 service lines should be completed over a 2-year time frame.

The remaining 25,263 lead service lines in the District (28,161 minus 2,898) should then be systematically replaced in the order presented in Appendix E. The time frame for these replacements will depend greatly on the content of EPA's final lead regulations, and on available funds within the District.

The District also must remain conscious of those customers who have shown an interest in replacing their portion of the lead service lines. Homes at which high lead concentrations in drinking water are subsequently found also should be given higher priorities for replacement. The priorities developed here can be changed in response to specific cases in which: (1) the homeowner is willing to replace his/her portion of the lead service line, (2) unusually high lead in water concentrations are found, (3) high blood lead levels are identified, or (4) other unusual circumstances occur.

It is also recommended that the District obtain blood lead data collected by the Health Department and incorporate the information into a database. These data could then be compared to the list of Known and Probable Lead Service Line addresses in order to assign a higher priority to those homes for which the blood lead data showed a problem with lead in children. Although it cannot be proven what, if any, contribution the lead service line may have made to overall blood lead levels to people at the house, common sense dictates that the lead service line should be removed.

The District should conduct additional water quality sampling at houses with Known or Probable Lead Service Lines located in squares for which, at present, no water quality results are available. Low existing priorities assigned to these addresses should be changed when water quality data are available.

SECTION 6

EVALUATION OF FINANCIAL ALTERNATIVES

6.1 INTRODUCTION

The purpose of this analysis is to identify potential mechanisms of financing the costs of replacing lead service lines both within the jurisdiction of the District and for individual homeowners. Since the lead service lines can be found in both the public and private (i.e., homeowner) sectors, the mechanisms available to finance these service line replacements need to be broad-based to enable large public investments and individual homeowner service line replacement. This section, therefore, addresses the financing issue from the perspective of both the District and homeowners.

The total cost of the District's portion of the lead service line replacement (i.e., that portion of the service line within the direct responsibility of the District) has been estimated in this study at approximately $80 million. This estimate is based on the current cost of replacement of $2,890 per service line, and an approximate total of 24,000 lead service lines in the District. It is important to note that the estimated cost includes replacement of only those lead service lines that can be located at a specific address, and for those addresses that can be assigned to a particular ward. This obviously represents a large expenditure of District funds.

In order to finance the cost of a project such as this, a determination needs to be made as to whether the lead service line replacement should be accomplished in a short time frame (i.e., within the next 3 or 5 years), or be extended over a longer time frame (i.e., over the next 20 years). The decision on the time frame to be adopted is a function of the total project cost, as well as a number of other factors, such as:

- The urgency to replace lead service connections, determined by the threat to human health, or required by regulations.
- The ability of the District to absorb the costs as part of its operating budget (i.e., whether outside sources of financial aid are available).
- The ability of the District to develop a complete replacement program that provides the mechanism for replacing lead service line connections on both District and private property (i.e., to achieve a complete lead service line replacement).
- The compatibility of the Lead Service Replacement Program with other projects within the District.

6.2 FINANCING OF WATER SERVICE IN THE DISTRICT

Water service in the District is financed through customer service charges. In past years, water and sewer services have been subsidized by the District's general funds. However, in an attempt to make the water and sewer services become more self-sufficient, an enterprise fund concept was adopted in 1984 and subsequent increases in water and sewer rates were approved.

In an enterprise fund service concept, the revenue from utility operations must be sufficient to cover the cost of debt service (or borrowing) and operating costs. That is, it must be self-sustaining. As such, the District cannot use property taxes as a source of revenue. In the case of water supply service, the District sets its water rates to meet the expected demand for debt services and operating costs.

According to the District's financial reports, the Water and Sewer Enterprise Fund has been operating in a net positive balance in fiscal years 1987, 1988, and 1989. This positive situation has continued without a rate increase since 1987. The positive balances will be used for capital expenditures on a "pay-as-you-go" basis, and for emergency requirements. A planned 10-percent rate increase, originally scheduled to be effective in October 1988, has been cancelled by decision of the Mayor and the Council.

At issue, therefore, is whether the District can afford to pay for the needed lead service line replacements out of its existing fund balance, or finance the costs through a capital improvement project. This depends on the competition for available funds that exists at that time among the other water and sewer projects. The estimated cost of replacing the District's portion of the lead service lines is estimated to be in the range of $70 to $80 million.

6.2.1 Capital Improvements

The District identifies and plans for new facility construction, infrastructure improvements, and repair and replacement through the District government's Capital Improvement Program (CIP).[1] The CIP consists of projects authorized in fiscal year 1990, as well as projects authorized in prior years that are still in progress. In fiscal year 1990, there are 17 water supply projects out of 536 total active capital improvement projects. The water supply projects represent a capital budget allocation of $75 million and account for 3 percent of the total capital project budgets in the CIP.

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[1]Information on the District's Capital Improvement Program can be found in INDICES: A Statistical Index to District of Columbia Services.

About two-thirds of all capital improvements work in the District is funded with long-term borrowing. General obligation bonds are the principal method used by the District to borrow money for capital improvement projects. Debt service costs, however, are rapidly growing each year, and there is great concern that future debt be entered into for only the most critically needed projects. The District's criteria for determination of need consist of factors such as health and safety issues, project feasibility, and project costs and benefits in relation to the District's Comprehensive Plan. In an effort to address the statutory limit on the District government's appropriated spending on debt service, the use of revenue bonds for long-term borrowing is currently under consideration.

6.2.2 Federal Grants

Federal grants are a major source of funding for the District's capital improvement projects. Currently, there is no major Federal grant (or loan) program available to assist in the financing of lead service replacement lines.[2] The District does operate a Community Development Block Grant (CDBG) Program (funded in the past by the U.S. Department of Housing and Urban Development). Housing assistance programs for single-family rehabilitation and multifamily rehabilitation is provided through the District's Department of Housing and Community Development and Department of Public and Assisted Housing. Competition for these funds for housing rehabilitation is significant. These programs would be more geared toward the financing of the homeowner lead service line replacements than the District's portion of the lead service lines.

EPA, however, is in the process of finalizing its proposed rule regarding lead service line replacement. The proposed rule is expected to be finalized later this year. Once the rule becomes final, a request to Congress to fund a Lead Service Replacement Program on a national basis may be possible. At that time, a determination of sources of Federal financial assistance should be accomplished. Without Federal assistance, the District will have to finance the cost of lead service line replacement on its own.

6.2.3 Financing Options

The options available to the District to finance the entire project are as follows:

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[2] Contacts were made with the U.S. Department of Housing and Urban Development, the U.S. Department of Health and Human Services, the U.S. Environmental Protection Agency, the National League of Cities, the Association of Metropolitan Agencies, and the American Water Works Association.

- Incorporate the project as part of the District operations to be financed through its operating budget (i.e., the pay-as-you-go approach, within 20 years).

- Designate the project as a major infrastructure replacement to be financed as part of the District's Capital Improvement Program (within 5 years).

The first option can be accomplished over the longer term (i.e., 10 to 20 years) since the current District operating budget cannot accommodate a major project without some form of capitalization effort. The second option is a project that can be accomplished in the short-term and would be capitalized (i.e., through the issuance of bonds to raise the necessary capital).

6.3 HOMEOWNER FINANCING OPPORTUNITIES

As stated in the previous subsection, the homeowner is responsible for the replacement of the lead service line that is situated on his/her property. Currently, there are no identified source(s) of financial aid available to homeowners to finance the cost of the lead service line replacement (which could include not only the service line to the home but internal piping as well). Should the costs for homeowner service line replacement be carried solely by the homeowner, then alternative means of financial assistance must be made available by the District to provide the necessary incentive for homeowner cooperation. It should be noted, however, that the District's share of the costs for a financial assistance program to homeowners would be raised as part of the water utility budget. Therefore, future water rates would account for the costs of establishing and administering a program such as this one.

There are many potential financing mechanisms available to the District for assisting homeowners in the replacement of household lead service lines. The financing mechanisms have been arranged in a tabular form (see Table 6-1), with comments concerning each mechanism's advantage(s) and disadvantage(s). The financing mechanisms are divided into four categories: grants and rebates, loans and interest subsidies, direct revenue streams, and other.

The CDBG Program is one potential source of homeowner financial assistance. CDBGs are provided annually to communities by the U.S. Department of Housing and Urban Development (HUD) to carry out a wide range of community development activities directed toward neighborhood revitalization, economic development, and improved community facilities and services. CDBGs are provided annually to the District on a formula basis, and could be used for rehabilitation of residential properties by low- and middle-income persons. Lead service line replacement is a type of rehabilitation activity under the CDBG program. It should be noted, however, that CDBG funds are generally earmarked in advance for certain activities.

Table 6-1

Summary of Types of Financing Mechanisms

Financing Mechanisms	Description	Party for Replacement Work	Advantage	Disadvantage
GRANTS AND REBATES				
DIRECT GRANT	Cash grant made to property owner to cover cost of repair, in whole or in part. The property owner does not repay the grant.	Property owner could use a contractor provided by the District or use a contractor chosen by the property owner.	• Direct grant may be a necessity for those in low-level income group. • The property owner does not have to repay. • May be able to obtain grants from HUD's Community Development Block Grant Program (CDBG).	• May be difficult to obtain HUD CDBG funds, putting the cost burden directly on the District.
PARTIAL GRANT OR REBATE (OR PRINCIPAL REDUCTION GRANT)	Paid directly to the property owner to be applied to the replacement cost. Typically, this is deposited in an escrow account prior to performance of the work. The partial grant reduces the amount of principal or loan required, which reduces the monthly payments for the property owner. The grant can be made on a deferred basis; i.e., a lien is placed on the property for the amount of the grant. The lien is reduced gradually as payments are made.	Property owner could use a contractor provided by the District or use a contractor chosen by the property owner.	• Deferred partial grant encourages people to remain in the neighborhood. • Reduces the amount the owner must borrow. • Reduces monthly payments that the owner must make.	• Does not always account for varying income levels.
a. Flat percentage grant	Amount of grant computed as a flat percentage of the cost of the work.			
b. Percentage grant based on income	Links percentage of grant directly to the income of the owner.			
c. Grant adjusted to income and housing costs	Ties grant to housing costs and percentage of monthly income of the owner.			
d. Interest reduction grant	Makes a grant to reduce the amount the owner has to borrow from a private lender.			

Table 6-1
(continued)

Financing Mechanisms	Description	Party for Replacement Work	Advantage	Disadvantage
GRANT PROPERTY TAX REBATE	District could reduce the amount of property taxes that the owner must pay by a fixed percentage.	Property owner could use a contractor provided by the District or use a contractor chosen by the property owner.	• Good mechanism for property-rich but cash-poor people such as the elderly.	• Lag time between paying for repair and receiving benefits. • Administration costs may outweigh the benefits.
DIRECT REBATE	Full or partial costs paid directly to the homeowner after replacement and repair on their own initiative.	Property owner would secure repair services on his/her own.	• Would be relatively easy for the District to administer. • District would eliminate any possibility of liability connected with providing its own contractors.	• Excludes income groups that cannot finance on their own initiative upfront.
LOANS AND INTEREST SUBSIDIES				
DIRECT LOAN	Direct loan made to property owner to cover the cost of repair, in whole or in part.	Property owner could use a contractor provided by the District or use a contractor chosen by the property owner.	• Can vary the interest rates, depending on the income of the owner (i.e., below-market interest rates). • The loans could carry a below-market interest rate and a longer term of repayment than available from private lenders. • Loan repayments may be used to make new loans (revolving feature).	• The cost of administrating a direct loan program may outweigh the benefits. • Places significant administrative burden on the District.
DEFERRED PAYMENT LOAN	A front-end cash distribution to the property owner for part or all of the cost of repair, secured by a promissory note and mortgage. Essentially, this is a loan against future equity in the property. The loan comes due in a lump sum (or balloon payment) when the borrower sells/vacates or otherwise disposes of the property.	Property owner could use a contractor provided by the District or use a contractor chosen by the property owner.	• No monthly payments by property owners. • Good mechanism for property-rich but cash-poor people, such as the elderly. • Can be used to supplement a direct loan.	• Available only to homeowners. • Places significant administrative burden on the District.

Table 6-1
(continued)

Financing Mechanisms	Description	Party for Replacement Work	Advantage	Disadvantage
INTEREST SUBSIDIZED LOAN	A subsidy is paid directly to the lender to induce the lender to make a below-market interest rate loan to the owner to cover full cost of the work. A subsidy prepaid in a lump sum when the loan is issued is a Prepaid Interest Subsidy.	Property owner could use a contractor provided by the District or use a contractor chosen by the property owner.	• The monthly payments are reduced because of a reduced interest rate. • Interest rates could be set to address varying income levels.	• This mechanism has a higher rate of loan rejections since the lender must approve the loan.
LOAN GUARANTEE OR COMPENSATION BALANCE	Under the HUD CDBG program, CDBG funds are placed in an account with a private lending institution and are used to guarantee, either in full or in part, conventional home improvement loans made to property owners at below-market interest rates. The amount of funds used is equal to either the full guaranteed amount of the outstanding principal balance of all guaranteed loans, or a percentage of the guaranteed amount.	Property owner could use a contractor provided by the District or could use contractor chosen by the property owner.	• The guarantee fund can earn a substantial amount of interest while on deposit with the lender. • Loan repayments may be used to make new loans.	• May be difficult to obtain HUD and CDBG funds.
TAX-EXEMPT CREDIT PAYMENT	Interest paid to the private financing institutions by a public agency is exempt from Federal income taxation. Therefore, funds may be borrowed at below-market interest rates. This would enable the District to make loans to property owners at below-market interest rates. The loan repayment may be guaranteed by a loan guarantee fund or by FHA Title I Property Improvement Loan Insurance.	Property owner could use a contractor provided by the District or could use a contractor chosen by the property owner.	• Potentially provides a program with access to a virtually unlimited supply of private capital. • Attractive alternative for raising very large amounts of private capital.	• FHA Title I Property Improvement Loans are not provided by any banks in the District. • Local lenders have limited private capital for credit agreement because of limits on the amount of tax-exempt investments that can be absorbed and because banks need to diversify investments.
FULL PRIVATE FINANCING -- INSTALLMENT LOAN	Loan obtained by property owner.	Property owner could use a contractor provided by the District or use a contractor chosen by the property owner.	• District would not be involved in administering the financing of the program. • Private lender handles all of the loan processing.	• Have to pay market interest rates. • Excludes many property owners who do not have sufficient credit rating.

Table 6-1
(continued)

Financing Mechanisms	Description	Party for Replacement Work	Advantage	Disadvantage
DIRECT REVENUE STREAMS				
FEES (e.g., water rates)	Includes various fees imposed on local governments (e.g. water rates set by the District).	District would have to provide a contractor since it would receive the fees to pay for the lead service line replacement.	• Provide alternatives for raising very large amounts of private capital. • Potential adjunct to District's water conservation program.	• Probably would be difficult to raise substantial sums to pay for entire homeowner service line replacement costs.
TAX-EXEMPT REVENUE BONDS	Private capital borrowed on tax-exempt and revenue secured basis; these funds are used to make loans for repair or replacement.	Property owner could use a contractor provided by the District or could use a contractor chosen by the property owner.	• Publicly issued bonds provide access to unlimited supply of private capital. • Can raise very large amounts of private capital. • Allows program to borrow at a lower interest rate. • Can be financed by FHA Title I Insurance.	• FHA insurance funds may not be available. • FHA only extends insurance when both the borrower and the property meet stringent underwriting standards.
OTHER				
LOW-COST REPLACEMENT LABOR	Replacement work would be performed at prices below the market rate.	District would need to provide contractors who would perform work at below-market prices or the District would provide the labor source directly.	• Meets cash flow needs of some low- and moderate-income persons.	• This method may increase the District's potential liability connected with providing contractors.

Additionally, efforts to make CDBG funds available for homeowner replacement of lead service lines would also require the approval of the District's Council. Additional funding for CDBGs is provided through income received from the repayment of CDBG loans and from the sale of urban renewal land. In fiscal year 1989, CDBG expenditures to the District were more than $43.7 million, of which $10.8 million was used for housing rehabilitation.

In analyzing the various financing mechanisms available for household lead service line replacement, emphasis needs to be placed on the use of appropriate financing mechanisms for different income groups involved in the Lead Service Replacement Program. For example, families with household incomes less than the poverty level may be reasonably addressed with some form of financing that does not require repayment in order to provide sufficient incentive to participate in the service line replacement program. In such cases, a **direct grant** program is appropriate. Families with incomes above the poverty level should be served exclusively by private lenders (i.e., reserving the subsidy for lower income groups), and a **full private financing installment loan** may be appropriate. In such a case, the District would not be involved in administering the program and the lender would handle all of the loan processing. If a family in this category cannot obtain financing because of credit problems, perhaps a loan guarantee could be provided.

6.3.1 Costs for Service Line Replacement

The cost to the District in replacing the homeowner's side of the lead service connections has been worked out in greater detail as follows. The most recent and published income distribution of the District is the 1980 census. Thus, data from the census were used to perform the financial analysis. In 1980, the average family size in the District was 2.4, and the poverty threshold for a family size of 2 and 3 was $4,723 and $5,787 in yearly household income, respectively.[3] Assuming the family size to be 2.4, the poverty threshold worked out to approximately $5,000 in 1980. Thus, $5,000 was used as a cut-off figure in determining the poverty level. Tables 6-2 and 6-3 show the income distribution in each ward per the 1980 census. Table 6-2 shows that 15 percent of the population is below the poverty level. This is the population that would require help from the government in the replacement program. An assumption made here is that the ratio of the population below and above the poverty level has not altered drastically in 1990. Once the data for the 1990 census are published, this fact can be verified and the cost estimates may be reevaluated, if needed, by just changing some key figures.

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[3]Information from Indices: A Statistical Index to District of Columbia Services.

WESTON

Table 6-2

Distribution of Household Incomes (1980) Below the Poverty Level (<$5,000)

WARD	TOTAL # OF SERVICE LINES (1)	TOTAL # OF LEAD SERVICE LINES (2)	# OF HOUSEHOLDS WITH ANNUAL INCOMES OF ...			PERCENTAGE BELOW THE POVERTY LEVEL(3)
			< $2,500	$2,500 to $4,999	TOTAL	
1A	3,498	1,510	801	770	1,571	22
1B	3,643	1,133	1,095	1,370	2,465	27
1C	1,828	754	671	731	1,402	14
1D	591	146	62	80	142	9
1E	1,528	504	420	363	783	17
2A	1,356	118	494	454	948	14
2B	2,218	416	550	467	1,017	11
2C	6,311	1,541	1,577	2,271	3,848	30
2D	1,537	124	452	810	1,262	17
2E	3,235	686	148	105	253	6
3B	2,480	838	264	240	504	7
3C	2,886	635	266	413	679	7
3D	3,043	379	98	58	156	4
3E	3,189	270	169	143	312	7
3F	2,004	279	271	233	504	6
3G	4,395	378	189	256	445	8
4A	3,859	445	299	365	664	9
4B	6,234	697	258	284	542	7
4C	4,106	1,331	400	448	848	14
4D	5,319	1,738	619	494	1,113	13
5A	8,439	827	467	776	1,243	12
5B	4,630	625	973	1,308	2,281	24
5C	5,301	2,419	796	980	1,776	20
6A	7,664	2,548	801	745	1,546	14
6B	6,532	2,080	505	747	1,252	13
6C	3,658	523	839	876	1,715	19
7A	1,451	107	239	376	615	20
7B	3,688	142	268	317	585	9
7C	3,414	376	496	640	1,136	23
7D	2,538	187	395	553	948	19
7E	2,956	52	459	621	1,080	17
7F	957	54	377	330	707	19
8A	1,000	91	429	374	803	25
8B	1,046	116	633	703	1,336	24
8C	1,240	85	357	343	700	12
8D	1,038	100	404	365	769	15
8E	1,225	66	455	524	979	19
TOTAL	120,037	24,320	17,996	20,933	38,929	15

(1) There are 6,062 addresses which could not be assigned to a ward, and are therefore not included in this table.

(2) Includes only those lead service lines which could be located at a specific address.

(3) Taken from 1980 Census Data

Table 6-3

Distribution of Household Incomes (1980) Above the Poverty Level (>$5,000)

WARD	TOTAL # OF SERVICE LINES (1)	TOTAL # OF LEAD SERVICE LINES(2)	# OF HOUSEHOLDS WITH ANNUAL INCOMES OF ...																PERCENTAGE ABOVE THE POVERTY LEVEL(3)
			$5,000 to $7,499	$7,500 to $9,999	$10,000 to $12,499	$12,500 to $14,999	$15,000 to $17,499	$17,500 to $19,999	$20,000 to $22,499	$22,500 to $24,999	$25,000 to $27,499	$27,500 to $29,999	$30,000 to $34,999	$35,000 to $39,999	$40,000 to $49,999	$50,000 to $74,999	> $75,000	TOTAL	
1A	3,496	1,610	787	842	586	576	530	403	335	332	217	178	366	151	200	141	49	5,693	78
1B	3,643	1,133	1,137	920	963	611	531	532	386	281	269	159	361	135	241	118	60	6,724	73
1C	1,826	754	940	899	1,200	812	710	570	659	357	393	316	567	329	451	432	196	8,821	86
1D	591	146	46	105	94	106	43	97	71	46	71	51	97	97	106	133	277	1,440	91
1E	1,526	504	334	481	384	414	303	206	196	193	144	151	172	107	340	241	66	3,731	83
2A	1,356	118	400	362	472	480	599	554	460	300	320	238	424	253	381	463	296	6,004	86
2B	2,218	416	630	831	954	883	746	591	602	375	337	327	413	369	308	283	186	7,835	89
2C	6,311	1,541	1,095	1,307	1,240	1,010	844	585	639	434	409	269	391	283	204	201	151	9,062	70
2D	1,537	124	481	496	514	472	445	514	439	339	318	313	471	306	546	514	189	6,359	83
2E	3,235	686	150	135	201	132	240	235	247	156	223	181	269	215	403	540	541	3,868	94
3B	2,480	838	374	355	540	451	572	460	444	289	309	207	494	393	458	639	356	6,341	93
3C	2,888	635	468	656	734	728	668	563	620	430	480	244	710	496	605	946	845	9,225	93
3D	3,043	379	100	128	170	128	119	102	139	122	153	97	305	219	360	725	920	3,786	96
3E	3,189	270	215	254	189	264	243	202	179	168	205	161	386	306	436	638	218	4,064	93
3F	2,004	279	304	334	503	430	673	540	461	492	461	349	533	358	642	808	476	7,364	94
3G	4,396	376	223	285	274	207	266	301	241	146	235	143	406	357	746	1,135	496	5,461	92
4A	3,859	445	288	517	506	406	483	338	437	327	352	208	492	266	586	832	380	6,418	91
4B	6,234	697	350	543	494	417	610	503	527	386	403	336	582	519	666	410	140	6,886	93
4C	4,106	1,331	360	490	458	432	461	323	339	286	317	222	431	264	401	264	84	5,132	86
4D	5,319	1,738	545	692	729	824	771	605	553	519	404	323	486	407	374	217	80	7,529	87
5A	8,439	827	491	554	515	522	736	643	639	426	588	558	937	737	933	562	84	8,925	88
5B	4,630	625	908	1,012	832	822	772	578	542	360	333	313	348	157	288	149	11	7,425	76
5C	5,301	2,419	930	660	911	709	616	552	540	264	357	293	451	306	270	205	70	7,133	80
6A	7,664	2,548	986	743	885	768	676	710	557	448	548	334	753	514	634	464	141	9,161	86
6B	6,532	2,060	644	572	636	430	717	512	487	400	476	308	771	467	730	766	272	8,188	87
6C	3,858	523	675	886	920	826	635	680	536	415	392	326	424	254	211	143	0	7,321	81
7A	1,451	107	338	331	251	277	186	194	160	94	173	131	101	67	110	53	15	2,481	80
7B	3,888	142	368	449	589	562	503	491	561	364	377	213	489	347	526	369	57	6,265	91
7C	3,414	376	433	528	505	412	334	325	238	281	149	134	214	182	107	20	9	3,871	77
7D	2,538	187	379	464	418	478	365	352	273	184	172	178	250	145	181	101	12	3,932	81
7E	2,956	52	494	647	653	517	578	325	399	305	351	201	363	224	195	107	32	5,391	83
7F	957	54	277	355	406	415	360	193	292	156	168	89	147	117	66	47	12	3,100	81
8A	1,000	91	215	297	296	310	334	165	173	94	128	97	96	66	106	28	0	2,405	75
8B	1,046	116	618	597	629	461	417	336	257	229	155	97	204	89	30	34	6	4,159	76
8C	1,240	85	399	524	708	597	476	506	443	315	266	117	179	149	161	97	7	4,944	88
8D	1,038	100	386	615	666	468	546	405	325	128	216	198	135	125	101	28	7	4,349	85
8E	1,225	66	521	512	582	428	492	382	353	181	187	154	261	121	89	41	5	4,309	81
TOTAL	120,037	24,320	18,289	20,380	21,627	18,765	18,598	15,603	14,747	10,622	11,056	8,213	14,469	9,899	13,172	12,894	6,748	215,102	85

(1) There are 6,062 addresses which could not be assigned to a ward, and are therefore not included in this table.

(2) Includes only those lead service lines which could be located at a specific address.

(3) Taken from 1980 Census Data

After the ratio of households in the two income categories was established, the total lead service lines in each subward was divided by the same ratio to determine the number of lead service lines in each category on a subward basis. Furthermore, Tables 6-4 through 6-8 show the suggested replacement schedule. The replacement program would typically last for 5 years if it were to be funded by a Capital Improvement Program. A reasonable starting period for the replacement program could be 1992, and, thus, the program would continue until 1996 as shown in the calculations. The cost of lead service line replacement on the homeowner's side was taken as $2,290. The present cost for the District in replacing the lead service line on the public side is $2,890, which includes $600 for repair of the roadway. Since on the homeowner's side there would be no cost for repavement of the sidewalk and the other costs would more or less remain the same, the cost to replace the lead service line on the homeowner's side on an average can be assumed as $2,890 - $600 = $2,290.

As an example, in Table 6-4, there are 291 lead service lines to be replaced in Ward 1A in the first year. There are 63 (i.e., 22 percent) homes below the poverty level in Ward 1A for which direct government assistance would be required in replacing the lead service lines. Seventy-eight percent of the population, or the remaining 228 homes above the poverty level, would be responsible for replacing their own lead service lines. The table also shows the District's and the homeowner's portions of the cost involved in replacing the lead service lines.

Table 6-9 gives a summary of the costs involved, assuming that the Lead Service Replacement Program starts in 1992. The public side of the service line would have to be replaced by the District at $2,890 per service line. The last column shows the District's total cost if it were to replace all lead service lines on the public side, which would amount to $70,284,800, and also the homeowner's side of some homes, when the household income is less than the poverty level, which would amount to $8,807,340. Thus, the total cost for the District would amount to $79,092,140, or approximately $80 million. The sum total of the homeowners' share of the replacement cost will be $46,100,000. The District has two options in spreading the costs over the years. It can initiate a Capital Improvement Program, as described earlier, or bear the cost through its operations and maintenance budget. A Capital Improvement Program would normally take 5 years to accomplish. Thus, the District would require a maximum of $16 million (in 1990 dollars) per year for 5 years. If the District decides to fund the replacement of lead service lines through its operations and maintenance budget it could spread the costs over a longer term (e.g., a 20-year period), which would bring the cost of replacement to a maximum of $4 million (in 1990 dollars) per year for 20 years. All the dollar figures shown in the tables refer to 1990 dollars. The dollar figures will change over time due to inflation, but the annual cost of lead service line replacement for any year later than 1990 can always be calculated by using the known inflation rate at that time and using 1990 as the base index.

WESTON

Table 6-4

Five-Year Lead Service Line Replacement Schedule for the Homeowner's Side (Year 1)

WARD	# OF LEAD SERVICE LINES REPLACED	PERCENTAGE BELOW THE POVERTY LEVEL	REPLACEMENT COSTS FOR HOMEOWNER'S SIDE			
			ABOVE POVERTY LEVEL		BELOW POVERTY LEVEL	
			# OF LEAD SERVICE LINES	COST (1) (HOMEOWNER)	# OF LEAD SERVICE LINES	COST (1) (DISTRICT)
1A	291	22	228	$522,120	63	$144,270
1B	77	27	56	$128,240	21	$48,090
1C	291	14	251	$574,790	40	$91,600
1D	32	9	29	$66,410	3	$6,870
1E	227	17	188	$430,520	39	$89,310
2A	21	14	18	$41,220	3	$6,870
2B	104	11	92	$210,680	12	$27,480
2C	86	30	60	$137,400	26	$59,540
2D	60	17	50	$114,500	10	$22,900
2E	156	6	146	$334,340	10	$22,900
3B	564	7	522	$1,195,380	42	$96,180
3C	301	7	280	$641,200	21	$48,090
3D	133	4	128	$293,120	5	$11,450
3E	136	7	126	$288,540	10	$22,900
3F	146	6	137	$313,730	9	$20,610
3G	197	8	182	$416,780	15	$34,350
4A	189	9	171	$391,590	18	$41,220
4B	196	7	182	$416,780	14	$32,060
4C	145	14	124	$283,960	21	$48,090
4D	289	13	252	$577,080	37	$84,730
5A	88	12	77	$176,330	11	$25,190
5B	1	24	1	$2,290	0	$0
5C	242	20	194	$444,260	48	$109,920
6A	544	14	465	$1,064,850	79	$180,910
6B	469	13	407	$932,030	62	$141,980
6C	51	19	41	$93,890	10	$22,900
7A	0	20	0	$0	0	$0
7B	1	9	1	$2,290	0	$0
7C	80	23	62	$141,980	18	$41,220
7D	1	19	1	$2,290	0	$0
7E	0	17	0	$0	0	$0
7F	0	19	0	$0	0	$0
8A	0	25	0	$0	0	$0
8B	0	24	0	$0	0	$0
8C	0	12	0	$0	0	$0
8D	0	15	0	$0	0	$0
8E	0	19	0	$0	0	$0
TOTAL	5,118	15	4,471	$10,238,590	647	$1,481,630

(1) The cost of replacing the homeowner's portion of a lead service line has been estimated at $2,290 (1990 $'s).

Table 6-5

Five-Year Lead Service Line Replacement Schedule for the Homeowner's Side (Year 2)

WARD	# OF LEAD SERVICE LINES REPLACED	PERCENTAGE BELOW THE POVERTY LEVEL	REPLACEMENT COSTS FOR HOMEOWNER'S SIDE			
			ABOVE POVERTY LEVEL		BELOW POVERTY LEVEL	
			# OF LEAD SERVICE LINES	COST (1) (HOMEOWNER)	# OF LEAD SERVICE LINES	COST (1) (DISTRICT)
1A	382	22	299	$684,710	83	$190,070
1B	326	27	239	$547,310	87	$199,230
1C	224	14	193	$441,970	31	$70,990
1D	21	9	19	$43,510	2	$4,580
1E	117	17	97	$222,130	20	$45,800
2A	13	14	11	$25,190	2	$4,580
2B	157	11	139	$318,310	18	$41,220
2C	281	30	197	$451,130	84	$192,360
2D	0	17	0	$0	0	$0
2E	263	6	247	$565,630	16	$36,640
3B	215	7	199	$455,710	16	$36,640
3C	135	7	126	$288,540	9	$20,610
3D	41	4	39	$89,310	2	$4,580
3E	24	7	22	$50,380	2	$4,580
3F	40	6	37	$84,730	3	$6,870
3G	0	8	0	$0	0	$0
4A	101	9	92	$210,680	9	$20,610
4B	114	7	106	$242,740	8	$18,320
4C	187	14	160	$366,400	27	$61,830
4D	204	13	178	$407,620	26	$59,540
5A	97	12	85	$194,650	12	$27,480
5B	67	24	51	$116,790	16	$36,640
5C	574	20	460	$1,053,400	114	$261,060
6A	722	14	618	$1,415,220	104	$238,160
6B	551	13	478	$1,094,620	73	$167,170
6C	87	19	70	$160,300	17	$38,930
7A	47	20	38	$87,020	9	$20,610
7B	0	9	0	$0	0	$0
7C	62	23	48	$109,920	14	$32,060
7D	31	19	25	$57,250	6	$13,740
7E	0	17	0	$0	0	$0
7F	0	19	0	$0	0	$0
8A	0	25	0	$0	0	$0
8B	0	24	0	$0	0	$0
8C	22	12	19	$43,510	3	$6,870
8D	0	15	0	$0	0	$0
8E	13	19	11	$25,190	2	$4,580
TOTAL	5,118	15	4,303	$9,853,870	815	$1,866,350

(1) The cost of replacing the homeowner's portion of a lead service line has been estimated at $2,290 (1990 $'s).

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Table 6-6

Five-Year Lead Service Line Replacement Schedule for the Homeowner's Side (Year 3)

WARD	# OF LEAD SERVICE LINES REPLACED	PERCENTAGE BELOW THE POVERTY LEVEL	REPLACEMENT COSTS FOR HOMEOWNER'S SIDE			
			ABOVE POVERTY LEVEL		BELOW POVERTY LEVEL	
			# OF LEAD SERVICE LINES	COST (1) (HOMEOWNER)	# OF LEAD SERVICE LINES	COST (1) (DISTRICT)
1A	297	22	233	$533,570	64	$146,560
1B	265	27	194	$444,260	71	$162,590
1C	40	14	35	$80,150	5	$11,450
1D	16	9	15	$34,350	1	$2,290
1E	70	17	58	$132,820	12	$27,480
2A	8	14	7	$16,030	1	$2,290
2B	90	11	80	$183,200	10	$22,900
2C	532	30	373	$854,170	159	$364,110
2D	4	17	3	$6,870	1	$2,290
2E	23	6	22	$50,380	1	$2,290
3B	32	7	30	$68,700	2	$4,580
3C	111	7	103	$235,870	8	$18,320
3D	70	4	67	$153,430	3	$6,870
3E	50	7	46	$105,340	4	$9,160
3F	25	6	23	$52,670	2	$4,580
3G	77	8	71	$162,590	6	$13,740
4A	33	9	30	$68,700	3	$6,870
4B	51	7	47	$107,630	4	$9,160
4C	130	14	112	$256,480	18	$41,220
4D	367	13	320	$732,800	47	$107,630
5A	70	12	61	$139,690	9	$20,610
5B	70	24	54	$123,660	16	$36,640
5C	694	20	556	$1,273,240	138	$316,020
6A	320	14	274	$627,460	46	$105,340
6B	305	13	265	$606,850	40	$91,600
6C	61	19	49	$112,210	12	$27,480
7A	21	20	17	$38,930	4	$9,160
7B	21	9	19	$43,510	2	$4,580
7C	11	23	9	$20,610	2	$4,580
7D	2	19	2	$4,580	0	$0
7E	5	17	4	$9,160	1	$2,290
7F	7	19	6	$13,740	1	$2,290
8A	17	25	13	$29,770	4	$9,160
8B	60	24	45	$103,050	15	$34,350
8C	4	12	4	$9,160	0	$0
8D	7	15	6	$13,740	1	$2,290
8E	6	19	5	$11,450	1	$2,290
TOTAL	3,972	15	3,258	$7,460,820	714	$1,635,060

(1) The cost of replacing the homeowner's portion of a lead service line has been estimated at $2,290 (1990 $'s).

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Table 6-7

Five-Year Lead Service Line Replacement Schedule for the Homeowner's Side (Year 4)

WARD	# OF LEAD SERVICE LINES REPLACED	PERCENTAGE BELOW THE POVERTY LEVEL	REPLACEMENT COSTS FOR HOMEOWNER'S SIDE			
			ABOVE POVERTY LEVEL		BELOW POVERTY LEVEL	
			# OF LEAD SERVICE LINES	COST (1) (HOMEOWNER)	# OF LEAD SERVICE LINES	COST (1) (DISTRICT)
1A	379	22	297	$680,130	82	$187,780
1B	295	27	216	$494,640	79	$180,910
1C	109	14	94	$215,260	15	$34,350
1D	17	9	15	$34,350	2	$4,580
1E	33	17	27	$61,830	6	$13,740
2A	0	14	0	$0	0	$0
2B	19	11	17	$38,930	2	$4,580
2C	359	30	252	$577,080	107	$245,030
2D	0	17	0	$0	0	$0
2E	132	6	124	$283,960	8	$18,320
3B	0	7	0	$0	0	$0
3C	19	7	18	$41,220	1	$2,290
3D	47	4	45	$103,050	2	$4,580
3E	0	7	0	$0	0	$0
3F	0	6	0	$0	0	$0
3G	36	8	33	$75,570	3	$6,870
4A	0	9	0	$0	0	$0
4B	91	7	84	$192,360	7	$16,030
4C	620	14	532	$1,218,280	88	$201,520
4D	613	13	534	$1,222,860	79	$180,910
5A	66	12	58	$132,820	8	$18,320
5B	243	24	186	$425,940	57	$130,530
5C	597	20	478	$1,094,620	119	$272,510
6A	707	14	605	$1,385,450	102	$233,580
6B	427	13	370	$847,300	57	$130,530
6C	83	19	67	$153,430	16	$36,640
7A	21	20	17	$38,930	4	$9,160
7B	35	9	32	$73,280	3	$6,870
7C	23	23	18	$41,220	5	$11,450
7D	0	19	0	$0	0	$0
7E	0	17	0	$0	0	$0
7F	0	19	0	$0	0	$0
8A	20	25	15	$34,350	5	$11,450
8B	22	24	17	$38,930	5	$11,450
8C	0	12	0	$0	0	$0
8D	37	15	31	$70,990	6	$13,740
8E	0	19	0	$0	0	$0
TOTAL	5,050	553	4,182	$9,576,780	868	$1,987,720

(1) The cost of replacing the homeowner's portion of a lead service line has been estimated at $2,290 (1990 $'s).

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Table 6-8

Five-Year Lead Service Line Replacement Schedule for the Homeowner's Side (Year 5)

WARD	# OF LEAD SERVICE LINES REPLACED	PERCENTAGE BELOW THE POVERTY LEVEL	REPLACEMENT COSTS FOR HOMEOWNER'S SIDE			
			ABOVE POVERTY LEVEL		BELOW POVERTY LEVEL	
			# OF LEAD SERVICE LINES	COST (1) (HOMEOWNER)	# OF LEAD SERVICE LINES	COST (1) (DISTRICT)
1A	161	22	126	$288,540	35	$80,150
1B	170	27	124	$260,400	46	$105,340
1C	90	14	78	$163,800	12	$27,480
1D	60	9	55	$115,500	5	$11,450
1E	57	17	47	$98,700	10	$22,900
2A	76	14	66	$138,600	10	$22,900
2B	46	11	41	$86,100	5	$11,450
2C	283	30	199	$417,900	84	$192,360
2D	60	17	50	$105,000	10	$22,900
2E	112	6	105	$220,500	7	$16,030
3B	27	7	25	$52,500	2	$4,580
3C	69	7	64	$134,400	5	$11,450
3D	88	4	85	$178,500	3	$6,870
3E	60	7	56	$117,600	4	$9,160
3F	68	6	64	$134,400	4	$9,160
3G	68	8	63	$132,300	5	$11,450
4A	122	9	111	$233,100	11	$25,190
4B	245	7	227	$476,700	18	$41,220
4C	249	14	214	$449,400	35	$80,150
4D	265	13	231	$485,100	34	$77,860
5A	506	12	444	$932,400	62	$141,980
5B	244	24	187	$392,700	57	$130,530
5C	312	20	250	$525,000	62	$141,980
6A	255	14	218	$457,800	37	$84,730
6B	328	13	284	$596,400	44	$100,760
6C	241	19	195	$409,500	46	$105,340
7A	18	20	14	$29,400	4	$9,160
7B	85	9	78	$163,800	7	$16,030
7C	200	23	155	$325,500	45	$103,050
7D	153	19	123	$258,300	30	$68,700
7E	47	17	39	$81,900	8	$18,320
7F	47	19	38	$79,800	9	$20,610
8A	54	25	40	$84,000	14	$32,060
8B	34	24	26	$54,600	8	$18,320
8C	59	12	52	$109,200	7	$16,030
8D	56	15	48	$100,800	8	$18,320
8E	47	19	38	$79,800	9	$20,610
TOTAL	5,062	15	4,260	$8,969,940	802	$1,836,580

(1) The cost of replacing the homeowner's portion of a lead service line has been estimated at $2,290 (1990 $'s).

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Table 6-9

Summary of Total Costs to Replace Lead Service Connections

YEAR	# OF LEAD SERVICE LINES AT ADDRESSES		HOMEOWNER PORTION (1)		DISTRICT PORTION (2)	TOTAL COST TO THE DISTRICT FOR LEAD SERVICE LINE REPLACEMENT (3)
	ABOVE POVERTY LEVEL	BELOW POVERTY LEVEL	HOMEOWNER'S COST OF REPLACEMENT	DISTRICT'S COST OF REPLACEMENT	DISTRICT'S COST OF REPLACEMENT	
1992	4,471	647	$10,238,590	$1,481,630	$14,791,020	$16,272,650
1993	4,303	815	$9,853,870	$1,866,350	$14,791,020	$16,657,370
1994	3,258	714	$7,460,820	$1,635,060	$11,479,080	$13,114,140
1995	4,182	868	$9,576,780	$1,987,720	$14,594,500	$16,582,220
1996	4,260	802	$8,969,940	$1,836,580	$14,629,180	$16,465,760
TOTAL	20,474	3,846	$46,100,000	$8,807,340	$70,284,800	$79,092,140

(1) Replacement cost of homeowner's side assumed at $ 2,290 (1990 $'s)

(2) Replacement cost of District side assumed at $ 2,890 (1990 $'s)

(3) Total cost includes replacing District portion of lead service lines as well as contribution of funds to assist some homeowners (i.e., those below the poverty level) with replacement of their portion. The number of lead service lines used for this estimate is 24,320 (20,474 + 3,846), which is the number of lead service lines which can be identified at specific addresses and assigned to the appropriate subward.

6.3.2 Replacing Service Lines on Private Property

As mentioned previously, to achieve the full benefit of the Lead Service Replacement Program, it is desirable for both the District's portion of the service line and the homeowner's portion to be replaced. Presumably it would be cost-effective to perform the replacements at the same time. In order to accomplish the goal of simultaneous replacements, it is necessary to coordinate the replacement efforts and provide a mechanism for homeowners to access the services of competent technicians to perform the work.

The options available to the homeowners include:

- Having District personnel perform the replacement (at the same time that the District's portion is done).
- Hiring a private contractor to perform the replacement.

Should the District perform the replacement for the homeowner the issue of liability to the District for performing work on private property can be significant. The District is currently examining the liability issue through its Water Conservation Retrofit Program. In this program, the District would conduct a water conservation audit and then make the necessary repairs or improvements to the household plumbing to achieve the desired conservation goals.

Providing the opportunity for contractor involvement in the Lead Service Replacement Program could help avoid many of the liability concerns, but could also raise other problems associated with contractor procurement, quality of work, and availability to perform the replacement at the same time that the District's lines are replaced. The following issues would need to be addressed:

- Who will hire the contractor? The District or the homeowner?
- How will the contractors be selected?
- What will be the nature of the agreement between the District and the contractor?
- What operational procedures will be employed in dealing with the contractors to ensure proper service and conduct in the field?

The District has an established program that is satisfactorily dealing with assisting District homeowners with public utility issues. It is the D.C. Energy Office (DCEO). The DCEO, created in 1981, is the lead agency for all energy policy and programs in the District. The DCEO programs that are relevant to the lead service line replacement needs for homeowners in the District include:

- **Low-Income Home Energy Assistance Program (LIHEAP)** helps needy District residents pay their heating and cooling bills, and provides emergency assistance to households that have had their electric or gas service disconnected, or have been denied fuel oil delivery. The amount of assistance is based on family size, income, and type of dwelling. (The DCEO uses Federal grants from the Department of Health and Human Services for this program.)

- **Complementary Energy Assistance Program (CEAP)** provides monthly financial assistance to eligible low-income working families participating in the subsidized Adoption Program, the Vocational Rehabilitation Program, or the Foster Care Program.

- **Utility Discount Programs** offer special rates on utility services for District customers who are certified as eligible by the DCEO:

  - **Residential Aid Rider (RAR)** offers a discount to income-eligible Potomac Electric Power Company customers on their monthly electric bill.

  - **Residential Essential Service (RES)** offers qualifying District of Columbia Natural Gas customers a discount rate on natural gas used during the months of December through March.

- **Residential Conservation Service (RCS)** offers free on-site home energy audits to District residents. The audit, performed by the electric and gas utility companies, identifies ways to reduce energy costs in single-family homes, apartment buildings of up to four units, and individually metered apartments of five or more units.

- **Multifamily Demonstration Program** provides grants and loans for conservation improvements to low-income apartment buildings.

- **Weatherization Assistance Program (WAP)** makes free weatherization improvements such as caulking, weatherstripping, and insulation on the homes of low-income persons; DCEO accepts applications for this program, which is administered by the District Department of Housing and Community Development.

- **Energy Bank Program** provides grants and loan subsidies to eligible District residents to install energy conservation measures identified in RCS home energy audits. The DCEO issues contracts to nonprofit groups [Community Based Organizations (CBOs)] to make the energy system replacements or improvements. The CBOs then

select private contractors to perform the energy system retrofits. In this way, the District does not become directly involved in performing utility improvements on private property.

- **Energy Extension Service (EES)**, the educational component of DCEO, seeks to provide useful information to small-scale users of energy through the following programs:

  - **Energy Conservation Workshops** feature low-cost/no-cost techniques that homeowners or renters can use to lower their fuel bills. Sessions are held at the DCEO, on request, to groups and organizations throughout the city.

  - **Small Grants Program** provides funds to local groups and individuals for energy conservation outreach activities such as energy fairs, publications, and the demonstration of new technologies.

As shown previously, DCEO has an effective multifaceted program for providing not only energy system retrofits and replacements on private properties, but financial assistance to homeowners to meet energy bills. Such a program serves as a readily adaptable model for the implementation of a District-wide Lead Service Replacement Program.

6.4 RECOMMENDATIONS

An evaluation of the adequacy of the District's current water rate structure and user fee system should be performed to determine the most cost-effective plan for financing the Lead Service Replacement Program. A rate study is needed to fully analyze the cost implications of this project on the District's operating budget and Capital Improvement Program.

There are several methods outlined in this section that can be applied effectively to assist homeowners in financing the costs of lead service line replacement on private property. The determination of the precise financing mechanism to be used is a function of the degree to which the District wishes to or can afford to assist homeowners. The District should consider providing funding to homeowners whose income is below the poverty level to assist them in replacing their portion of the lead service line. As recommended earlier, a water rate study that fully addresses the costs to the District for implementing a homeowner assistance program needs to be prepared.

SECTION 7

WATER QUALITY SAMPLING

7.1 INTRODUCTION

Water quality samples were collected from a total of 163 homes (159 full-scale sampling, and 4 detailed sampling) throughout the District with two goals in mind. One goal was to identify, if possible, the relationship between lead service lines and concentrations of lead in water at the kitchen tap. The second goal was to attempt to quantify the contributions of various sources to lead concentrations at the kitchen tap, that is, the amount of lead contributed by the sink fixtures, solder joints, service lines, and distribution system water.

Sample bottles and instructions were delivered to the homes. The first flush water samples were then collected by the homeowners. The samples were subsequently collected and sent to a laboratory for analysis. Unmarked blank and spiked samples were included with each shipment of samples as a quality control check on the laboratory.

The results of this sampling program were compared to the results of earlier sampling efforts. Several houses that had been sampled during previous studies and showed high levels of lead were sampled again. The average values for the various sample types were compared in an attempt to find differences in results over time, or because of differences in sampling technique.

Prior to beginning the full-scale sampling, four homes were sampled in detail. This detailed sampling involved entering each home and measuring the diameter and length of pipe from the service line to the kitchen sink. A series of twenty 500-ml, first flush samples were then collected from the kitchen faucet. The source of each sample could be located using the pipe diameter and length measurements, and calculating the volume of water held in the pipes. The objective of this detailed sampling was to identify sources of lead and to develop a sampling protocol for large-scale sampling.

7.2 PURPOSE

The two main purposes of the water sampling program were: (1) to identify the relationship between a lead service line and lead concentrations at the kitchen tap, and (2) to determine the contributions of lead at the tap from various sources. The results of the sampling could then be used to aid in the development of a lead service line replacement schedule. A third purpose was to resample some homes that had shown very high concentrations of lead during previous water quality sampling.

Lead service lines may or may not contribute significant quantities of lead to water at the tap, depending on the particular water quality. Identifying lead concentrations in water at the tap that would indicate the presence of a lead service line would allow the District to locate lead service lines without having to resort to test excavations.

Lead can be introduced to drinking water at several points before it reaches the customer's tap. Lead can be present in water in the distribution main, it can leach from lead service lines, it can leach from lead solder joints, or it can leach from brass faucets and fittings. Water in the District's distribution mains is generally free of any significant concentrations of lead (typically less than 5 ug/L). Therefore, the main contributors to lead at the tap are lead service lines, solder joints, and brass fixtures. The age of the house will also affect the contribution of lead from the various sources, as lead leaching rates from lead solder and brass fixtures are generally reduced after a period of approximately 5 years.

The District has conducted several water quality sampling studies in the last several years to assess the problem of lead at the tap. Several of these homes exhibited extremely high concentrations of lead in water (greater than 100 ug/L). A few of these homes were resampled to determine whether lead levels changed in the intervening years.

7.3 DESCRIPTION OF THE DETAILED SAMPLING

Four employees of the District volunteered their homes for use in the detailed sampling effort. Two of the homes had lead service lines, while the other two had nonlead service lines. Interior plumbing from the point at which the service line enters the house to the kitchen sink was sketched and measured. The length of the service line from the curb to the outside of the house was also measured, or estimated when this was not feasible. The volume of water contained in the interior plumbing and the service line was then calculated.

The residents of each home were instructed to avoid any water use for at least 8 hours overnight. Each home was visited early in the morning, and twenty 500-ml samples were collected from the kitchen sink. Using the volumes calculated from measuring the pipes, it was possible to locate where the water in each sample had been standing overnight. Thus, it was possible to verify that samples had been taken from both the service line and the distribution main.

The water samples were analyzed for lead using the LEADTRAK 100 kit manufactured by the Hach Company. Duplicate and spike samples were analyzed for each set for quality assurance. The results of the detailed sampling effort are presented in Table 7-1.

Table 7-1

Detailed Sampling Results

SAMPLE NUMBER	HOUSE # 1 (NON-LEAD)	HOUSE # 2 (NON-LEAD)	HOUSE # 3 (LEAD)	HOUSE # 4 (LEAD)
1	ND	ND	12	ND
2	ND	ND	3	ND
3	ND	ND	18	ND
4	ND	ND	9	ND
5	ND	ND	5	ND
6	ND	17	3	ND
7	ND	9	5	ND
8	ND	8	4	ND
9	ND	ND	ND	ND
10	ND	ND	ND	ND
11	ND	ND	ND	ND
12	ND	ND	2	ND
13	ND	ND	ND	ND
14	ND	ND	ND	ND
15	ND	ND	ND	ND
16	ND	ND	ND	ND
17	ND	ND	ND	ND
18	ND	ND	ND	ND
19	ND	ND	ND	ND
20	ND	ND	ND	ND
SPIKE OF 1	10	–	–	–
SPIKE OF 4	–	–	–	6
SPIKE OF 6	–	31	–	–
SPIKE OF 15	–	–	10	–
DUPLICATE OF 2	–	–	13	–
DUPLICATE OF 8	–	8	–	–
DUPLICATE OF 10	ND	–	–	–
DUPLICATE OF 13	–	–	–	ND

Shaded areas represent samples taken from the service line.
All sample results given in ug/L (parts per billion).
Values listed as "ND" were less than the detection limit of 2 ug/L.
Spike samples should read 10 ug/L greater than original sample result.

The detailed sampling effort illustrated some specific points about the issue of lead in drinking water in the District, as well as several general points about water quality sampling in private homes. Neither of the two homes that had lead service lines showed any lead concentrations above the detection limit of 2 ug/L for any of the samples that represented water standing in the service line. This shows that a lead service line does not always result in elevated lead concentrations in water.

The first general observation is that there is no such thing as a "typical" house. The diameters and lengths of pipe within each house varied a great deal. This makes it difficult to establish a common set of sampling instructions that will ensure a valid sample taken from the service line. Second, there are an infinite variety of situations that may arise which can affect the sample collection. It must be remembered that these are private homes, and even though the homeowners were most cooperative, unexpected problems often arose that required flexibility in response to get a proper sample. Homeowners collecting the samples on their own, however, cannot be expected to make those sorts of adjustments to make the sample collection match the specific circumstances.

7.4 DESCRIPTION OF THE FULL-SCALE SAMPLING PROGRAM

A set of four samples was collected from each home to analyze contributions of lead from the various sources. The four samples, labeled A, B, C, and D, were collected to represent water from the tap, the pipe below the sink, the service line, and the distribution main, respectively. To account for the age of the plumbing and the service line material, homes were assigned to one of four risk categories. The four risk categories were defined as follows:

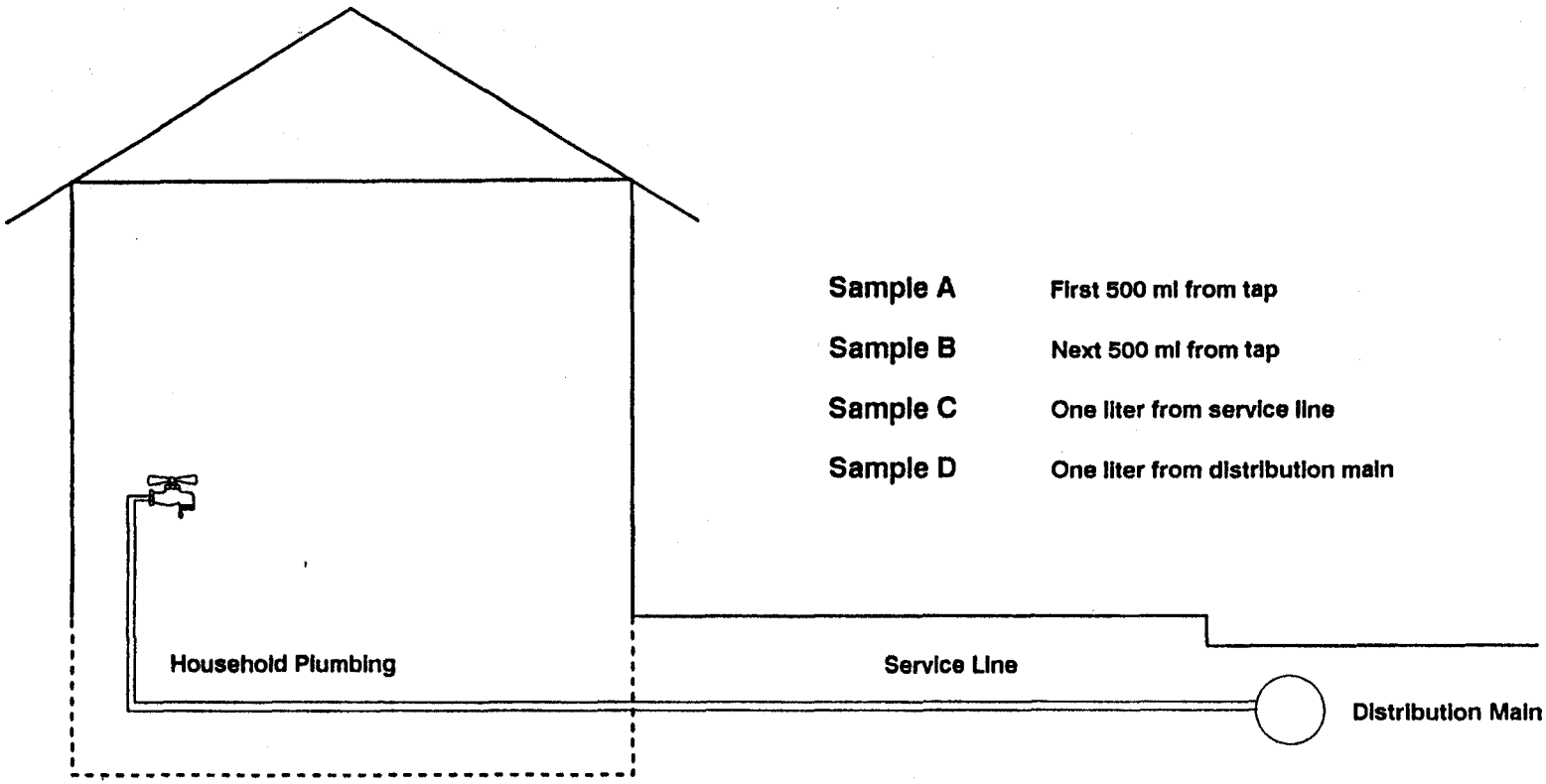
- **Risk Category 1** -- Homes that are less than 2 years old. These are assumed to have a nonlead service line and lead-free solder joints.

- **Risk Category 2** -- Homes that are between 2 and 5 years old. These are assumed to have a nonlead service line, but may have lead solder joints.

- **Risk Category 3** -- Homes that are more than 5 years old, and are known to have a nonlead service line and lead solder joints.

- **Risk Category 4** -- Homes that are more than 5 years old, and are known to have a lead service line and lead solder joints.

The set of water samples was collected by the homeowner in the morning before any water had been used in the house. The four samples are shown schematically in Figure 7-1 and are described as follows:



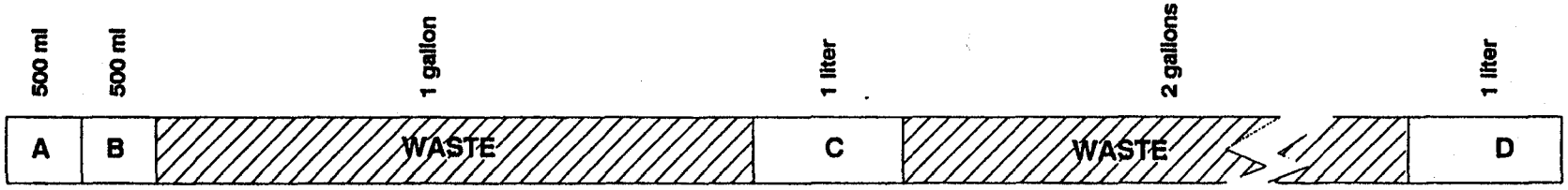


FIGURE 7-1 SCHEMATIC OF SAMPLING PROTOCOL

- Sample A -- The first 500 ml of water from the kitchen tap.
- Sample B -- The next 500 ml of water from the kitchen tap.
- Sample C -- A 1-liter sample taken after collecting Samples A and B, and after allowing 1 additional gallon of water to be wasted.
- Sample D -- A 1-liter sample taken after collecting Samples A, B, and C, and after allowing 2 additional gallons of water to be wasted.

To obtain a representative sampling, homes were selected at random from throughout the District. It was originally proposed that an equal number of homes in each risk category be sampled in each ward. Thus, 5 homes in each of the 4 risk categories in each of the 8 wards would be sampled, for a total of 160 homes. More than 400 addresses were selected at random from the Tap File Database. The owners of these homes were then identified and the list approved by the District prior to contacting homeowners.

The first step was to send a letter to each of the 400+ homeowners asking for their cooperation in collecting water samples. A self-addressed, stamped postcard was included with the letter to allow the homeowners to respond. After 2 weeks time, approximately 120 positive responses were received. At this point, a reminder letter was sent to those homeowners who had yet to respond to the original letter, and a list of District employees willing to participate in the sampling program was obtained. From the reminder letter and the employee list, a sufficient number of homes for sampling was obtained.

The desired distribution among the eight wards and four risk categories could not be achieved, however. Most of the homes were located in Wards 3 and 4, and there was a far greater number of homes in Risk Categories 3 and 4. This is to be expected since these risk categories represent the older (greater than 5 years old) homes in the District. Rather than delay the sampling effort further while attempting to locate willing participants in other wards and risk categories, the sampling was conducted on the first 160 homes that had responded. The resulting distribution of sampled homes is shown in Table 7-2.

The sampling was conducted in two parts. The first round consisted of the 120 homes that responded within the first 2 weeks after the mass mailing. A letter was sent to these homeowners advising them of when they would receive the sample bottles, along with detailed instructions on how and when to collect the samples. On the appropriate day, a sampling kit was delivered to each home that consisted of the four sample bottles, a 1-gallon plastic bucket, a set of sampling instructions (shown in Appendix F), and a short questionnaire (shown in Appendix G). The samples were collected

Table 7-2

Distribution of Homes in the Full-Scale Sampling Program

WARD	RISK CATEGORY				TOTAL
	1	2	3	4	
1	2	2	8	8	20
2	2	2	5	3	12
3	3	0	10	13	26
4	2	4	13	10	29
5	3	0	8	8	19
6	1	3	9	5	18
7	1	2	13	6	22
8	0	0	8	5	13
TOTAL	14	13	74	58	159

by the homeowner the following morning, and the sample bottles were picked up for delivery to the laboratory.

The second sampling round occurred about 2 weeks after the completion of the first round. These 40 homeowners were contacted by telephone rather than through the mail. Again, a sampling kit was delivered to each home, and the filled sample bottles were collected the next day.

The sample bottles were packed in coolers and delivered by overnight mail to the laboratory for analysis. Upon arrival at the laboratory, the samples were preserved by the addition of acid. Acid preservation at the laboratory, rather than prior to sample collection, was conducted in previous sampling efforts, and proved effective. It also eliminates the possibility of a homeowner coming in contact with the acid.

The sampling program was affected by inevitable delays as homeowners either forgot to collect the samples, or forgot to leave the bottles where they could be collected. Sometimes the bottles could not be collected on the arranged day, since the bottles had been put out after the home was visited in the morning. However, most of the homeowners were contacted by telephone to make alternate arrangements to collect the sample bottles. The homeowner was instructed to redo the sampling if the bottles could not be picked up within a reasonable time after the original sampling had occurred. Ultimately, samples were collected from 159 of the 160 homes and sent by overnight mail to the laboratory for analysis.

7.5 RESULTS

The laboratory results of the 159 sampled homes are given in Table 7-3. It is important to note that results given as "ND" represent samples that were less than the detection limit of 3.0 ug/L.

The data were analyzed by risk category and ward. These results are summarized in Tables 7-4 through 7-7. It should be noted that all samples below the detection limit of 3.0 ug/L were treated as being 1.5 ug/L for performing calculations.

7.6 QUALITY CONTROL

Included with each shipment of samples to the laboratory was a set of four sample bottles for quality control (QC) purposes. These QC samples were given sample IDs of the same form as the actual samples so that the laboratory could not distinguish between the two. Two of the four bottles in the QC set contained distilled water with no lead, while the other two were spiked with a known amount of lead solution.

Table 7-3

Laboratory Results for the 159 Full-Scale Sampling Homes

SAMPLE ID	WARD	RISK CAT.	SAMPLE DATE	SAMPLE RESULTS			
				A	B	C	D
111	1	1	April 18, 1990	3.0	ND	ND	ND
112	1	1	April 18, 1990	24.0	7.0	3.0	3.0
121	1	2	April 18, 1990	39.0	8.0	4.0	3.0
122	1	2	April 18, 1990	6.0	3.0	6.0	ND
131	1	3	April 18, 1990	5.0	ND	ND	ND
132	1	3	April 18, 1990	ND	ND	ND	ND
133	1	3	April 18, 1990	ND	ND	3.0	ND
134	1	3	April 18, 1990	5.0	5.0	3.0	ND
135	1	3	May 4, 1990	ND	ND	3.7	ND
136	1	3	May 2, 1990	ND	ND	ND	ND
137	1	3	May 3, 1990	ND	ND	ND	ND
138	1	3	May 11, 1990	ND	ND	ND	ND
141	1	4	April 20, 1990	4.8	ND	ND	ND
142	1	4	April 18, 1990	14.0	5.0	5.0	4.0
143	1	4	April 18, 1990	3.0	5.0	4.0	ND
144	1	4	April 18, 1990	ND	ND	ND	ND
145	1	4	April 18, 1990	48.0	36.0	14.0	4.0
146	1	4	April 18, 1990	3.0	ND	ND	ND
147	1	4	April 18, 1990	27.0	50.0	11.0	11.0
149	1	4	May 1, 1990	ND	ND	ND	ND
211	2	1	April 25, 1990	30.0	6.4	ND	ND
212	2	1	May 3, 1990	3.3	3.4	ND	ND
221	2	2	April 18, 1990	3.0	ND	ND	ND
222	2	2	May 1, 1990	3.6	ND	ND	ND
231	2	3	April 17, 1990	ND	ND	ND	ND
232	2	3	April 17, 1990	ND	ND	8.0	ND
233	2	3	May 1, 1990	8.2	ND	ND	ND
234	2	3	April 17, 1990	ND	ND	ND	ND
235	2	3	May 2, 1990	ND	ND	ND	ND
241	2	4	April 17, 1990	ND	ND	ND	ND
242	2	4	April 17, 1990	6.0	ND	ND	ND
243	2	4	April 17, 1990	48.0	8.0	5.0	8.0
311	3	1	April 17, 1990	3.0	ND	ND	ND
312	3	1	April 17, 1990	ND	ND	ND	ND
313	3	1	May 2, 1990	ND	ND	ND	ND
331	3	3	April 17, 1990	10.0	10.0	ND	ND
332	3	3	April 17, 1990	ND	ND	ND	ND
333	3	3	April 18, 1990	4.1	ND	ND	ND
334	3	3	April 26, 1990	ND	ND	ND	ND
335	3	3	April 26, 1990	ND	ND	ND	ND
336	3	3	April 17, 1990	ND	ND	ND	ND
337	3	3	April 26, 1990	ND	ND	ND	ND
338	3	3	April 21, 1990	ND	ND	ND	ND
3310	3	3	April 17, 1990	ND	ND	ND	ND
3311	3	3	April 17, 1990	13.0	6.0	7.0	6.0

All values given in ug/L.

Values listed as "ND" represent samples below the detection limit of 3.0 ug/L.

the homeowner the following morning, and the sample bottles were ked up for delivery to the laboratory.

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7-3
(nued)

	SAMPLE DATE
4	ril 17, 1990
	ril 17, 1990
	ril 17, 1990
4	ril 26, 1990
4	ril 17, 1990
	pril 17, 1990
4	pril 17, 1990
4	pril 26, 1990
	pril 17, 1990
	pril 17, 1990
	April 18, 1990
	April 17, 199
	May 3, 1990
	April 18, 1990
	May 4, 1990
	April 18, 199
	April 18, 1990
	April 18, 199
	April 19, 199
	April 18, 1990
	May 8, 1990
	May 2, 1990
	May 2, 1990
	May 2, 1990
	April 18, 199
	April 18, 199
	April 17, 1990
	April 18, 199
	April 19, 199
	April 18, 1990
	May 2, 1990
	May 17, 1990
	April 18, 199
4	April 25, 1990
4	April 18, 19
4	April 18, 19
4	April 18, 1990
4	April 18, 19
4	April 18, 19
4	April 27, 1990
4	April 18, 1990
4	May 2, 1990
1	April 19, 19
5 1	April 19, 1990
5 1	April 25, 19

n u
ND" resent samples bel

Table 7-3
(continued)

SAMPLE ID	WARD	RISK CAT.	SAMPLE DATE	SAMPLE RESULTS A	B	C	D
531	5	3	April 19, 1990	70.0	50.0	70.6	96.7
532	5	3	April 19, 1990	ND	ND	ND	ND
533	5	3	April 25, 1990	ND	ND	ND	ND
534	5	3	April 19, 1990	ND	ND	ND	ND
535	5	3	April 25, 1990	ND	ND	ND	ND
536	5	3	April 25, 1990	ND	ND	ND	ND
537	5	3	May 2, 1990	ND	ND	ND	ND
538	5	3	May 2, 1990	ND	5.0	ND	ND
541	5	4	April 18, 1990	ND	ND	ND	ND
542	5	4	April 19, 1990	ND	ND	ND	ND
543	5	4	April 19, 1990	ND	ND	ND	ND
545	5	4	May 2, 1990	ND	ND	ND	ND
546	5	4	May 2, 1990	ND	ND	ND	ND
547	5	4	May 2, 1990	14.1	20.4	26.0	8.3
548	5	4	May 3, 1990	ND	ND	ND	ND
549	5	4	May 2, 1990	ND	ND	ND	ND
611	6	1	April 19, 1990	11.9	5.2	ND	ND
621	6	2	April 19, 1990	52.4	18.1	6.5	5.5
622	6	2	April 19, 1990	128.0	44.0	13.9	4.9
623	6	2	May 1, 1990	ND	ND	ND	ND
631	6	3	April 18, 1990	ND	ND	ND	ND
632	6	3	April 19, 1990	4.8	ND	ND	ND
633	6	3	April 19, 1990	ND	ND	ND	ND
634	6	3	April 19, 1990	12.6	14.2	16.9	20.6
635	6	3	April 25, 1990	ND	ND	ND	ND
636	6	3	April 19, 1990	ND	ND	ND	ND
637	6	3	April 19, 1990	ND	ND	22.4	ND
638	6	3	May 3, 1990	ND	ND	ND	ND
639	6	3	May 4, 1990	ND	ND	ND	ND
641	6	4	April 19, 1990	4.9	3.4	10.4	3.8
642	6	4	April 19, 1990	10.9	12.5	3.6	ND
643	6	4	April 25, 1990	ND	ND	ND	ND
644	6	4	April 19, 1990	ND	ND	ND	ND
645	6	4	April 19, 1990	ND	ND	ND	ND
711	7	1	April 20, 1990	ND	ND	ND	ND
721	7	2	April 20, 1990	ND	ND	ND	ND
722	7	2	April 19, 1990	ND	ND	ND	ND
731	7	3	April 20, 1990	ND	ND	ND	ND
732	7	3	April 21, 1990	3.2	ND	ND	ND
733	7	3	April 20, 1990	ND	ND	ND	ND
734	7	3	April 20, 1990	ND	ND	ND	ND
735	7	3	April 19, 1990	ND	ND	ND	ND
736	7	3	April 19, 1990	ND	ND	ND	ND
737	7	3	April 19, 1990	ND	ND	ND	ND
738	7	3	April 20, 1990	ND	ND	ND	7.0

All values given in ug/L.

Values listed as "ND" represent samples below the detection limit of 3.0 ug/L.

Table 7-3
(continued)

SAMPLE ID	WARD	RISK CAT.	SAMPLE DATE	SAMPLE RESULTS			
				A	B	C	D
739	7	3	May 2, 1990	ND	ND	ND	ND
7310	7	3	May 3, 1990	ND	ND	43.2	24.6
7311	7	3	May 2, 1990	ND	ND	ND	ND
7312	7	3	May 2, 1990	ND	ND	ND	ND
7313	7	3	May 1, 1990	ND	ND	ND	ND
741	7	4	April 20, 1990	ND	ND	ND	ND
742	7	4	April 20, 1990	ND	ND	ND	ND
743	7	4	April 20, 1990	4.5	6.3	ND	ND
744	7	4	April 20, 1990	ND	ND	ND	ND
745	7	4	April 23, 1990	ND	ND	ND	ND
746	7	4	April 26, 1990	ND	ND	ND	ND
831	8	3	April 22, 1990	ND	ND	ND	ND
832	8	3	April 19, 1990	ND	ND	ND	ND
833	8	3	April 20, 1990	ND	ND	ND	ND
834	8	3	April 20, 1990	7.7	ND	ND	ND
835	8	3	May 2, 1990	ND	ND	4.6	ND
836	8	3	May 4, 1990	ND	ND	ND	ND
837	8	3	May 5, 1990	ND	ND	ND	ND
838	8	3	May 3, 1990	ND	ND	ND	ND
841	8	4	April 20, 1990	3.2	ND	ND	ND
842	8	4	April 20, 1990	ND	ND	ND	ND
843	8	4	April 26, 1990	ND	ND	ND	ND
845	8	4	May 2, 1990	ND	ND	ND	ND
846	8	4	May 2, 1990	5.8	ND	ND	3.9

All values given in ug/L.

Values listed as "ND" represent samples below the detection limit of 3.0 ug/L.

Table 7-4

Summary of Data for Risk Category 1

WARD	HOUSES SAMPLED	AVERAGE				MAXIMUM				MINIMUM			
		ARESULT	BRESULT	CRESULT	DRESULT	ARESULT	BRESULT	CRESULT	DRESULT	ARESULT	BRESULT	CRESULT	DRESULT
1	2	13.5	4.25	2.25	2.25	24	7	3	3	3	1.5	1.5	1.5
2	2	16.65	4.9	1.5	1.5	30	6.4	1.5	1.5	3.3	3.4	1.5	1.5
3	3	2	1.5	1.5	1.5	3	1.5	1.5	1.5	1.5	1.5	1.5	1.5
4	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
5	3	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
6	1	11.9	5.2	1.5	1.5	11.9	5.2	1.5	1.5	11.9	5.2	1.5	1.5
7	1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
8	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL	14	6.23	2.64	1.61	1.61	30	7	3	3	1.5	1.5	1.5	1.5
STD DEVIATION		8.95	1.95	0.39	0.39								

All values given in ug/L (parts per billion). Values given as 1.5 ug/L represent samples below detection limit of 3.0 ug/L.

Table 7-5

Summary of Data for Risk Category 2

WARD	HOUSES SAMPLED	AVERAGE				MAXIMUM				MINIMUM			
		ARESULT	BRESULT	CRESULT	DRESULT	ARESULT	BRESULT	CRESULT	DRESULT	ARESULT	BRESULT	CRESULT	DRESULT
1	2	22.5	5.5	5	2.25	39	8	6	3	6	3	4	1.5
2	2	3.3	1.5	1.5	1.5	3.6	1.5	1.5	1.5	3	1.5	1.5	1.5
3	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4	4	13.03	5.95	8.05	3.58	22.8	14.3	14.8	6.7	1.5	1.5	1.5	1.5
5	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6	3	60.63	21.2	7.3	3.97	128	44	13.9	5.5	1.5	1.5	1.5	1.5
7	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
8	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL	13	22.2	8.03	5.39	2.82	128	44	14.8	6.7	1.5	1.5	1.5	1.5
STD DEVIATION		34.26	11.60	5.20	1.83								

All values given in ug/L (parts per billion). Values given as 1.5 ug/L represent samples below detection limit of 3.0 ug/L.

Table 7-6

Summary of Data for Risk Category 3

WARD	HOUSES SAMPLED	AVERAGE				MAXIMUM				MINIMUM			
		ARESULT	BRESULT	CRESULT	DRESULT	ARESULT	BRESULT	CRESULT	DRESULT	ARESULT	BRESULT	CRESULT	DRESULT
1	8	2.38	1.94	2.15	1.5	5	5	3.7	1.5	1.5	1.5	1.5	1.5
2	5	2.84	1.5	2.8	1.5	8.2	1.5	8.7	1.5	1.5	1.5	1.5	1.5
3	10	3.76	2.8	2.05	1.95	13.2	10.5	7.7	6.5	1.5	1.5	1.5	1.5
4	13	6.38	5.57	7.42	3.39	41.2	35.1	42.5	14.1	1.5	1.5	1.5	1.5
5	8	10.06	8	10.14	13.4	70.2	50.1	70.6	96.7	1.5	1.5	1.5	1.5
6	9	3.1	2.91	5.53	3.62	12.6	14.2	22.4	20.6	1.5	1.5	1.5	1.5
7	13	1.63	1.5	4.71	3.7	3.2	1.5	43.2	24.6	1.5	1.5	1.5	1.5
8	8	2.28	1.5	1.89	1.5	7.7	1.5	4.6	1.5	1.5	1.5	1.5	1.5
TOTAL	74	4.08	3.31	4.8	3.82	70.2	50.1	70.6	96.7	1.5	1.5	1.5	1.5
STD DEVIATION		9.32	7.10	11.30	11.58								

All values given in ug/L (parts per billion). Values given as 1.5 ug/L represent samples below detection limit of 3.0 ug/L.

Table 7-7

Summary of Data for Risk Category 4

WARD	HOUSES SAMPLED	AVERAGE				MAXIMUM				MINIMUM			
		ARESULT	BRESULT	CRESULT	DRESULT	ARESULT	BRESULT	CRESULT	DRESULT	ARESULT	BRESULT	CRESULT	DRESULT
1	8	12.85	12.75	5.15	3.31	48	50	14	11	1.5	1.5	1.5	1.5
2	3	18.5	3.67	2.67	3.67	48	8	5	8	1.5	1.5	1.5	1.5
3	13	10.77	10.46	13.29	6.51	42	32.8	50	35.6	1.5	1.5	1.5	1.5
4	10	14.4	11.67	14.48	7.7	60	27.6	51	34.6	1.5	1.5	1.5	1.5
5	8	3.08	3.86	4.56	2.35	14.1	20.4	26	8.3	1.5	1.5	1.5	1.5
6	5	4.06	4.08	3.7	1.96	10.9	12.5	10.4	3.8	1.5	1.5	1.5	1.5
7	6	2.63	2.3	1.5	1.5	4.5	6.3	1.5	1.5	1.5	1.5	1.5	1.5
8	5	2.7	1.5	1.5	1.98	5.8	1.5	1.5	3.9	1.5	1.5	1.5	1.5
TOTAL	58	8.84	7.56	7.54	4.25	60	50	51	35.6	1.5	1.5	1.5	1.5
STD DEVIATION		12.60	9.95	12.60	6.42								

All values given in ug/L (parts per billion). Values given as 1.5 ug/L represent samples below detection limit of 3.0 ug/L.

The results of the QC samples are given in Table 7-8. This table also lists the concentrations of lead that were expected based upon the amount of lead solution added to each sample. Two of the four samples in each set were spiked with the lead solution to a concentration of 10 ug/L, while the other two were plain distilled water containing no lead. It should be noted that the lead solution was not added under strict laboratory conditions, and therefore, the concentration of lead in the final sample may have varied slightly from the expected concentration of 10 ug/L.

7.7 COMPARISON TO PREVIOUS SAMPLING EFFORTS

Table 7-9 compares the results for individual homes that had been sampled during previous studies. The earlier sampling efforts collected only three samples, rather than the four collected during this study. The 3 samples were each 1 liter in volume, and represented water from the faucet, the service line, and the distribution main. The three sample results were renamed A, C, and D to correspond to the current sampling program. Therefore, Table 7-9 lists NA (not applicable) for all B results for the previous studies.

Comparison of the results shows that 10 out of 13 homes showed significantly reduced lead levels for the current sampling effort. The other three homes exhibited similar lead concentrations during both sampling efforts.

The previous studies did not segregate homes into the four risk categories used in this study. It is possible, however, to identify most of the homes as having either a lead or nonlead service line. Average, maximum, and minimum values have been calculated for the results of the previous study for both lead and nonlead service lines. These results are summarized and compared to the results for Risk Category 3 and 4 homes of the current study in Table 7-10.

7.8 CONCLUSIONS AND RECOMMENDATIONS

Two important facts must be considered when assessing the results of the sampling program. The first is that it is impossible to guarantee that any individual sample was collected properly by the homeowner. However, the database as a whole will be reliable. Although the homeowners were very cooperative, there is no way to verify that they followed the sampling instructions properly. Second, all of the homes were sampled following the same directions. Specifically, 1 gallon of water was wasted between Samples B and C, and 2 gallons wasted between Samples C and D. Without actually inspecting and measuring the plumbing of each house, there is no way of knowing whether Samples C and D actually represented water from the service line and distribution main as desired.

Tables 7-4 through 7-7 show that Risk Category 4 did indeed have the highest average lead level for Sample C. This was expected, since Risk Category 4 represents those homes with Known Lead

Table 7-8

Laboratory Results for the QC Samples

SAMPLE	SAMPLE A		SAMPLE B		SAMPLE C		SAMPLE D	
	EXPECTED	OBSERVED	EXPECTED	OBSERVED	EXPECTED	OBSERVED	EXPECTED	OBSERVED
QC 1	10	7.7	0	ND	10	8.4	0	ND
QC 2	10	7.3	10	7.4	0	ND	0	ND
QC 3	0	ND	10	12.0	10	13.0	0	ND
QC 4	10	11.0	10	10.7	10	ND	0	ND
QC 5	0	ND	10	12.0	10	14.0	0	ND
QC 6	10	13.6	10	13.0	0	ND	0	ND
QC 7	10	11.1	0	ND	10	13.1	0	ND
QC 8	0	ND	10	11.8	10	12.1	0	ND
QC 9	10	10.0	10	12.5	0	ND	0	ND
QC 10	10	11.1	0	ND	10	12.2	0	ND

All values given in ug/L (parts per billion).

Values listed as "ND" represent samples below the detection limit of 3.0 ug/L.

Table 7-9

Lead Concentrations for Previously Sampled Homes

LOCATION	PREVIOUS STUDIES				CURRENT STUDY			
	A	B	C	D	A	B	C	D
1	50	NA	3	ND	ND	ND	ND	ND
2	558	NA	38	ND	70	50	70.6	96.7
3	13	NA	154	ND	ND	ND	8	ND
4	31	NA	138	ND	13	6	7	6
5	39	NA	125	ND	42	32.8	49.2	35.6
6	15	NA	279	ND	4.1	ND	ND	ND
7	399	NA	308	ND	ND	ND	ND	ND
8	1	NA	78	ND	ND	ND	ND	ND
9	50	NA	4	ND	10.8	7.6	37.5	13.5
10	35	NA	62	ND	41	35.1	42.5	14.1
11	20	NA	52	ND	26	14.9	51	14.4
12	5	NA	130	ND	9	12	23	6
13	123	NA	58	ND	8	7	7	3

All values given in ug/L (parts per billion)
NA = Not Applicable
ND = Less than Detection limit

Table 7-10

Comparison of Results to Previous Sampling Efforts

WATER SAMPLE	AVERAGE LEAD CONCENTRATION			
	PREVIOUS SAMPLING		CURRENT SAMPLING	
	LEAD SERVICES	NON-LEAD SERVICES	LEAD SERVICES	NON-LEAD SERVICES
First water from tap	20	10.75	8.84	4.08
Service line	19.56	8.21	7.54	4.8
Distribution main	2	1.61	4.25	3.82

All values given in ug/L.

Service Lines. However, when examined on a house-by-house basis, there are actually quite a few homes in Risk Category 3 (nonlead service lines) that have higher Sample C values than those in Risk Category 4. In fact, the highest Sample C value, 70.6 ug/L, was recorded at a Risk Category 3 home. Therefore, although, in general, homes with lead service lines show a higher lead concentration in Sample C on average, it would be difficult to use the sample results for an individual address to predict the existence of a lead service line.

Homes in Risk Categories 1 and 2 have their highest lead concentrations in Samples A and B. Risk Category 2 homes also show greater lead concentrations than Risk Category 1 homes. This may be because of the ban on lead-bearing plumbing materials that was enacted prior to the construction of Risk Category 1 homes.

The concentration of lead in Sample D was unexpectedly high in several of the homes sampled. Sample D should represent water from the distribution main, and should be relatively lead-free based on past examination of distribution system lead levels. In Risk Category 4 the high lead levels in Sample D may be explained by the fact that the water may actually have come from the lead service line because not enough water was wasted between samples. High Sample D lead levels in Risk Category 3 homes cannot be explained as easily since these are supposedly nonlead service lines. One possibility is that the District's portion of the service line is correctly recorded as nonlead, while the customer's side is actually lead. Another possibility is that the service line is galvanized iron, and lead is leaching from the 2- to 4-foot section of lead pipe used to connect the service line to the distribution main.

It is recommended that additional sampling of homes with lead service lines be conducted as funds allow. This will provide additional information to be used in prioritizing lead service line replacement.

SECTION 8

OPTIONS FOR REDUCING EXPOSURE TO LEAD IN DRINKING WATER

Section 2 identified techniques that can be used to reduce exposure to lead in drinking water. While all of these techniques are considered for evaluation, some can be eliminated as being too costly or impractical. The remaining techniques can then be combined to produce viable options for reducing consumers' exposure to lead in the District's drinking water.

Table 8-1 lists the techniques given to reduce the intake of lead in drinking water and rates them on the following four criteria:

- Feasibility -- Table 8-1 lists either YES or NO for the feasibility of a particular technique. Techniques that require actions clearly outside of the District's control were considered to be not feasible, and were removed from further consideration. All other techniques were considered feasible.

- Practicality -- The practicality of each technique was evaluated based on the ability of the District to implement the technique under current conditions. A ranking of 1 indicates that the technique could be acted on quite easily, while a ranking of 5 indicates that the technique would be difficult, if not impossible, to implement.

- Performance -- The performance of a particular technique was based on the extent to which lead intake from drinking water would be reduced upon implementation of the technique. A ranking of 1 indicates that the technique results in the virtual elimination of lead intake from drinking water. A ranking of 5 was given to techniques that result in only minor reductions in lead intake at the tap. Techniques for which the reduction in lead intake affected only a portion of the customers, or had an indefinite reduction were given a ranking between 1 and 5.

- Cost -- The capital and operating costs of each technique were given, when they were available. All costs were given on a per household basis by dividing the total technique cost by the number of residential customers in the District (approximately 126,000).

Table 8-1 can be used to help in developing program options for reducing the intake of lead from drinking water. The rankings in Table 8-1 must be used with caution. Current ongoing programs, as

Table 8-1

Rating of Techniques to Reduce Lead in Drinking Water

LEAD REDUCTION TECHNIQUES	FEASIBILITY (Note 1)	PRACTICALITY (Note 2)	PERFORMANCE (Note 3)	COST	
				CAPITAL ($/household)	OPERATING ($/household/yr)
CENTRALIZED TREATMENT					
1) Adjustment of pH and alkalinity	YES	1	3	$0	$0.10
2) Calcium carbonate precipitation	YES	1	2	$0	$0.10
3) Orthophosphate addition	YES	3	2	$16	$0.74
4) pH and control with orthophosphate addition	YES	4	1	NA	$7.81
POINT OF USE DEVICES					
1) Reverse osmosis	YES	5	1	$800	$50
2) Granular activated carbon	YES	5	5	$215	$48
3) Distillation	YES	5	1	$850	NA
REMOVAL OF LEAD MATERIAL					
1) Lead service line replacement (partial)	YES	3	2	$2,890	$0
2) Lead service line replacement (total)	YES	4	2	$5,780	$0
3) Replacement of soldered joints	NO	-	-	-	-
4) Replacement of brass faucets and fixtures	NO	-	-	-	-
PLUMBING CODE MODIFICATIONS AND ENFORCEMENT	YES	1	2	$0	$0
PUBLIC EDUCATION	YES	1	1	$2	$0
ALTERNATIVE DISTRIBUTION TECHNIQUES					
1) Bottled water	YES	2	1	$0	$2,000
2) Dual water distribution system	NO	-	-	-	-

Note 1. An option is considered feasible if the actions required are within the District's control.

Note 2. Practicality ranges from 1 (very practical - easily implemented) to 5 (very impractical - difficult to implement).

Note 3. Performance ranges from 1 (essentially eliminates lead intake from drinking water) to 5 (only minor reductions in lead intake from drinking water).

NA = Not available

well as the anticipated final lead regulations to be issued by EPA, must be taken into account. Therefore, three options for reducing lead intake through drinking water are proposed as follows:

- **Option 1** -- This option includes the continued replacement of lead service lines and the implementation of a public education program to instruct customers on ways to reduce their exposure to lead in drinking water.

- **Option 2** -- This option includes all components of Option 1, as well as changes in the treatment plant operation to increase the pH of treated water to above 8.0.

- **Option 3** -- This option calls for pH control and orthophosphate addition at the treatment plant, along with all components of Option 1.

These options take into account the latest version of EPA's proposed lead and copper regulations (August 1988), as well as the expected contents of the final regulations, which are not expected until sometime in 1990. As described in a previous subsection, the proposed rules set certain no-action levels that must be met to avoid taking action to reduce exposure to lead. Failure to meet other no-action levels requires the water system to develop and implement a public education program. One of the no-action levels calls for the pH to be greater than or equal to 8.0. The final regulations are expected to include a provision calling for mandatory replacement of lead service lines if it is shown that they are contributing to excessive levels of lead at the tap.

All three options include a public education program and the continued replacement of lead service lines. A public education program is probably the most effective way to eliminate the ingestion of significant quantities of lead through drinking water. Simple actions such as flushing standing water from faucets and pipes, and using only the cold water tap for drinking and cooking would basically eliminate the problem of lead corrosion. While not all lead service lines result in high lead levels at the tap, a prioritized lead service replacement program would eliminate one source of lead at those homes with high concentrations of lead at the tap.

Option 1

Water quality sampling has shown that there is very little lead present in water in the District's distribution system. High lead levels at the tap are the result of lead leaching from either a lead service line or lead solder joints and brass fixtures in interior home plumbing. The leaching of lead from these sources is highly variable and dependent on a number of factors, including water quality parameters, age, and composition of interior plumbing materials, and time of contact between the water and the lead. Option 1 attempts to reduce customers' exposure to lead at the tap by eliminating one possible source of lead (i.e., lead service

lines), and educating customers on how to avoid ingesting water with potentially high lead levels.

The District has an ongoing program to replace its portion of lead service lines. There are an estimated 28,385 lead service lines in use throughout the District. At the current rate of 375 lead service line replacements per year, it would take about 75 years to completely replace all of the lead service lines. However, not all lead service lines contribute to high lead levels at the tap, as shown by recent water quality sampling. Therefore, the prioritized program presented in Section 5 should be followed to first replace those service lines that have demonstrated, through water quality sampling results, that they are causing high lead levels at the tap.

Replacing the District's portion of a lead service line is only a partial solution, however. The District does contact the homeowner whenever it replaces a lead service line, and recommends that the homeowner replace his/her portion of the lead service line. However, the homeowner may or may not choose to replace his/her portion of the service line when it is identified as lead. Homeowners should be encouraged to replace their lead service lines when they are identified. One way to do this is as part of a public education program. The possible adverse health effects, especially for children and pregnant women, should be highlighted to stress the importance of the problem.

A public education program for lead in drinking water can be combined with other lead reduction education programs sponsored by the District. Lead from drinking water is only one way that lead is ingested. A comprehensive education program dealing with the overall problem of lead will have a greater impact than one focusing solely on lead in drinking water.

The basic message of a public education for reducing exposure to lead through drinking water should be three-fold:

- Awareness -- Learn about the possible health effects of lead. Check your home for the presence of lead pipes, including a lead service line.

- Testing -- If you think your water may contain high lead levels, have it tested by the District at a nominal cost.

- Action -- Replace any lead plumbing in your home, including a lead service line. Use only lead-free products when repairing or replacing plumbing. Run water from the tap if water has been sitting for an extended period. Use only the cold water tap for cooking and drinking purposes.

The public education program can be presented in many ways. Newspaper, television, and radio advertisements are an effective way to reach a large number of people. Envelope stuffers will

reach all customers of the water system, but customers often ignore extraneous material in a billing. Special programs can be directed at schools and hospitals which will have a higher percentage of persons at increased risk from exposure to lead. It is recommended that a good public education program be developed for implementation in the District.

One suggestion is to produce a videotape illustrating methods of identifying lead material in the plumbing system, along with ways to reduce exposure to lead in water. Such a videotape could be developed in conjunction with the Health Department, and could also include methods of dealing with other sources of lead such as paint. The videotape could be advertised and made available through schools and libraries. It could also be provided to neighborhood committees which would distribute it among the residents.

Option 2

Option 2 includes all of the recommendations of Option 1. It also calls for adjusting the pH at the treatment plant to be consistently greater than 8.0. The pH of water leaving each of the treatment plants is often less than 8.0. Raising the pH above 8.0 may not necessarily result in lower lead concentrations at the tap, as stated in Subsection 2.4.1.1. However, it may be necessary to take this action in order to meet the no-action levels established by EPA.

Raising the pH should not involve major changes in operation at either water treatment plant. The effectiveness of raising the pH should be examined by collecting water samples from addresses that have shown high lead concentrations in water from the tap. Homes sampled in previous water quality studies could be used for this purpose.

Option 3

Option 3 also includes the recommendations of Option 1. In addition, it calls for significant changes in water chemistry at the treatment plants to reduce lead solubility in the distribution system. Careful control of pH, along with the addition of orthophosphates, has been shown to be effective in reducing lead solubility. Pilot plant and/or pipe loop testing would be necessary to establish the exact parameters for such a plan.

This option would not be necessary if water quality studies done after adjusting the pH (Option 2) showed that pH was sufficient to lower lead solubilities in the distribution system. If orthophosphate addition did become necessary, a water quality sampling program would be necessary to verify its effectiveness in controlling lead at the tap.

SECTION 9

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be made about lead in drinking water in the District:

- A wealth of service line information is available to the District from a variety of sources. However, the data sources are scattered among a number of agencies and/or departments. Individual agencies/departments often are not aware of the information available from other sources.

- The District's Tap File, which contains information about services line installations, is incomplete and/or outdated in some cases.

- No proven technology is currently on the market that could be used to identify a lead service line without physical inspections.

- The raw water supply of the District contains low concentrations of lead, typically <5 ug/L.

- Lead concentrations in water in the distribution system are typically <5 ug/L.

- High concentrations of lead in tap water, more than 500 ug/L in one case, can be found in some homes in the District.

- High concentrations of lead in tap water may result from corrosion of lead in brass fixtures, lead-bearing solder, or the District- and homeowner-owned lead service lines.

- The presence of a lead service line does not necessarily result in elevated lead levels in water at the tap.

- There are approximately 28,000 lead service lines remaining in service in the District.

- The current cost incurred by the District to replace the District's portion of a single lead service line is approximately $2,900.

- Financing options available for replacement of the District's portion of lead service lines depend on whether the replacements are treated as part of the District's operating budget, or as a major infrastructure improvement financed as part of the District's Capital Improvement Program.

- Financial assistance to homeowners with incomes below the poverty level for replacing their portion of a lead service line may come from the District.

- The collection of water samples by homeowners is not an exact science. Each home has unique characteristics that make the development of a single set of simple sampling instructions almost impossible. This makes it difficult to positively identify a sample as originating in the service line, for example.

Based on these conclusions, a number of recommendations can be made to deal with the issue of lead in drinking water. Many of these recommendations are general in nature and should be acted on regardless of the content of the final EPA lead regulations. Those recommendations dealing with the District's specific actions to meet EPA guidelines may need to be modified based on the final content of the regulations. The recommendations are as follows:

- The Tap File Database should be installed on a computer(s) and used by District personnel to assist in the Lead Service Replacement Program. The Tap File Database User's Guide presented in Appendix H can be used to familiarize personnel with the database.

- Data from the Meter Relocation Program, Street Replacement Program, and Lead Service Replacement Program should be used to keep the Tap File Database current.

- The District should continue to maintain contact with remote sensing and metal detection companies in the event these technologies improve enough to provide a means to remotely detect lead service lines.

- A public education program should be instituted to teach customers how to reduce their exposure to lead in drinking water. One suggestion is to develop a videotape, in conjunction with the Health Department, pointing out the dangers of lead ingestion in general, and giving specifics on how to deal with lead paint, how to identify lead pipe, and ways to lessen possible exposure to lead in water at the tap. The District could distribute such a videotape through the neighborhood committees.

- The rate of lead service line replacements in the District should be increased by adding crews and following the prioritized lead service line replacement list given in Appendix E.

- Homeowners should be instructed to notify the District if they identify their service line as being lead. This

should be done in conjunction with the public education program.

- Treatment processes at the water treatment plants should be modified to increase the pH of water above 8.0 on a consistent basis. After the pH adjustment has been made, water quality samples should be taken at homes that had high lead levels (as identified by previous sampling studies) to determine the effectiveness of pH adjustment.

- If pH adjustment proves ineffective in reducing lead levels at the tap, orthophosphate addition at the water treatment plants to reduce the solubility of lead in water in the distribution system should be considered. Pipe loop studies should be conducted first to determine the optimum concentration of orthophosphates to be added. As with pH adjustment, water quality samples should be collected from homes to determine the effectiveness of orthophosphate addition.

- Homeowners willing to participate in an ongoing water quality sampling program should be located. These homes should be equally distributed throughout the District and consist of homes in different age categories and having different service line materials. The homeowners should be willing to have District personnel inspect their home plumbing systems so that water samples from specific locations can be identified. These homes would then be used for long-term monitoring to assess the effects of the different lead reduction strategies implemented at the water treatment plants, as well as for compliance monitoring for the EPA lead rule.

APPENDIX A

INTERVIEWS OF DISTRIBUTION SYSTEM MAINTENANCE PERSONNEL

DC LEAD PERSONNEL QUESTIONNAIRE

NAME : A. Cave
POSITION : Foreman
YRS. EXPERIENCE : 29- Years
INTERVIEWER : D. Nwabuin & S. Sarkar
DATE : 6-15-89

1. How often do your crews work on service lines(i.e., #/week) ?

   Everyday

2. How far in advance do you know where your upcoming jobs will be ?

   Scheduled by Health Department

3. Do you do any preparation for a service job ?

   Check
   - utility lines
   - No Parking signs & site clearing.
   - Contact/notify home owner if necessary.

4. Do you have access or ever call in to learn about previous history or maintenance at a location ?

   Not in service repair

5. How long have you been replacing defective lead services with copper instead of repairing them ?

   Since 1985

6. Have you ever put in a lead service line ? If so, when was the last time you did this?

   No

7. Do you have expectations as to the type of material you will find when you dig up a service ? If so, about how often do you find a nonlead service when you expected to find lead ?

   Sometimes, depending on whether or not it is indicated in the assignement card.

   Not very often.

8. Do you think lead is more prevalent in any particular geographic regions of the city ? If so, which sections ?

Yes, new areas in general.

9. How often is the customer service and the city side of the curb stop a different material ?

About 4 out of 7 times

10. Under what circumstances, if any, do city crews perform work on the customer side of the curb stop ?

Never.

11. What percent of the time do you see the customer's side of the service ?

Almost everytime.

12. What is the range of depth of service lines from the surface ?

3' +

13. Explain a 'typical' service replacement job :

a) How deep is the hole (feet) ? 3'-6' - 5'

b) How wide is the hole (feet) ? 2'-3'

c) Do city crews ever dig the hole by hand ? If so: Sometimes
   1. How many men are needed ? 4-men
   2. How long does it take ? up-to-3 days.

d) What other material (sidewalks, macadam) is removed ?
   Concrete

e) Who repairs the sidewalks, streets etc. ?
   Contractors.

DC LEAD PERSONNEL QUESTIONNAIRE

NAME : E. Miller
POSITION : Crew Chief.
YRS. EXPERIENCE : 8-yrs.
INTERVIEWER : David C. Nwabuisi & Sudipto Sarkar
DATE : 6-15-89

1. How often do your crews work on service lines(i.e., #/week) ?

   Everyday

2. How far in advance do you know where your upcoming jobs will be ?

   Scheduled on daily basis

3. Do you do any preparation for a service job ?

   (a) Utility checks through utility companies
   (b) Check location of water main etc.

4. Do you have access or ever call in to learn about previous history or maintenance at a location ?

   Sometimes; especially where there has been history of multiple connections..

5. How long have you been replacing defective lead services with copper instead of repairing them ?

   Five years (5 yrs)

6. Have you ever put in a lead service line ? If so, when was the last time you did this?

   No

7. Do you have expectations as to the type of material you will find when you dig up a service ? If so, about how often do you find a nonlead service when you expected to find lead ?

   (a) Known only when indicated on the assignment card
   (b) Not very often.

8. Do you think lead is more prevalent in any particular geographic regions of the city ? If so, which sections ?

Yes, S.E

9. How often is the customer service and the city side of the curb stop a different material ?

Fifty percent of the time

10. Under what circumstances, if any, do city crews perform work on the customer side of the curb stop ?

None

11. What percent of the time do you see the customer's side of the service ?

Nearly all the time

12. What is the range of depth of service lines from the surface ?

5' to 6'

13. Explain a 'typical' service replacement job :

a). How deep is the hole (feet) ? 5'

b) How wide is the hole (feet) ? 3'

c) Do city crews ever dig the hole by hand ? If so: Yes
   1. How many men are needed ? 3 men Crew
   2. How long does it take ? 2 - 3 days

d) What other material (sidewalks, macadam) is removed ?
   Brick walls, Concrete & Flowers.

e) Who repairs the sidewalks, streets etc. ?
   Hyw Department

DC LEAD PERSONNEL QUESTIONNAIRE

NAME : James D. Patterson
POSITION : Crew Chief.
YRS. EXPERIENCE : 12-yrs.
INTERVIEWER : S. Sarkar
DATE : 6-21-89

1. How often do your crews work on service lines(i.e., #/week) ?

   Everyday. Normally a job a day.

2. How far in advance do you know where your upcoming jobs will be ?

   Schedule is got in the morning of the same day.
   The supervisor makes the schedule.

3. Do you do any preparation for a service job ?

   Check on utility lines.

4. Do you have access or ever call in to learn about previous history or maintenance at a location ?

   Yes, most of the time

5. How long have you been replacing defective lead services with copper instead of repairing them ?

   It is mandatory for 3 years to replace. Before that worker may or may not replace.

6. Have you ever put in a lead service line ? If so, when was the last time you did this?

   No.
   Normally Cu lines are put in now.

7. Do you have expectations as to the type of material you will find when you dig up a service ? If so, about how often do you find a nonlead service when you expected to find lead ?

   Sometimes. By looking at the riser.
   Occasionally.

8. Do you think lead is more prevalent in any particular geographic regions of the city ? If so, which sections ?

About equal in all quandrants.

9. How often is the customer service and the city side of the curb stop a different material ?

Sometimes they are different. Normally they are same.

10. Under what circumstances, if any, do city crews perform work on the customer side of the curb stop ?

Very rarely. It is done only when the sewer Authority messes up

11. What percent of the time do you see the customer's side of the service ?

Everytime a service line is replaced.

12. What is the range of depth of service lines from the surface ?

5' - 6'

13. Explain a 'typical' service replacement job :

a) How deep is the hole (feet) ? 5'

b) How wide is the hole (feet) ? 3'-4'

c) Do city crews ever dig the hole by hand ? If so: Yes
   1. How many men are needed ? 3 men + Crew Chief
   2. How long does it take ? 2-days depending on the site

d) What other material (sidewalks, macadam) is removed ?

Brick, Asphalt roadway.

e) Who repairs the sidewalks, streets etc. ?

The Highway Dept / Contractors.

DC LEAD PERSONNEL QUESTIONNAIRE

NAME : H. Bast.
POSITION : Crew Chief.
YRS. EXPERIENCE : 22-years.
INTERVIEWER : David Nwabuisi & Sudipto Sarkar
DATE : 6-15-89

1. How often do your crews work on service lines(i.e., #/week) ?

Everydays.

2. How far in advance do you know where your upcoming jobs will be ?

Scheduled on daily basis

3. Do you do any preparation for a service job ?

- Call for utility check, • Note utility lines
- Check for type of service, if available on assignement card

4. Do you have access or ever call in to learn about previous history or maintenance at a location ?

No

5. How long have you been replacing defective lead services with copper instead of repairing them ?

2-years; Since 1987

6. Have you ever put in a lead service line ? If so, when was the last time you did this?

No

7. Do you have expectations as to the type of material you will find when you dig up a service ? If so, about how often do you find a nonlead service when you expected to find lead ?

- Never known until excavation is done unless information had been indicated in assignement card.
- About 4-5 times a month.

8. Do you think lead is more prevalent in any particular geographic regions of the city ? If so, which sections ?

Yes - N.W & particularly the old areas of D.C -

9. How often is the customer service and the city side of the curb stop a different material ?

Not frequently, only when customer has done previous renovation work.

10. Under what circumstances, if any, do city crews perform work on the customer side of the curb stop ?

Only when the backhoe mistakeenly pull the service on the customer side.

11. What percent of the time do you see the customer's side of the service ?

Almost every time excavation for repair is performed.

12. What is the range of depth of service lines from the surface ?

4'-5' in most cases, but could go up to 6'-7'

13. Explain a 'typical' service replacement job :

a) How deep is the hole (feet) ? 5'

b) How wide is the hole (feet) ? 4'

c) Do city crews ever dig the hole by hand ? If so: Yes
   1. How many men are needed ? 3-4 men crew
   2. How long does it take ? 2½ - 3 days

d) What other material (sidewalks, macadam) is removed ?
   Dirt.

e) Who repairs the sidewalks, streets etc. ?
   Hwy Department.

DC LEAD PERSONNEL QUESTIONNAIRE

NAME : A. McClain
POSITION : Crew Chief.
YRS. EXPERIENCE : 31-Years
INTERVIEWER : David Nwabuin & S. Sarkar
DATE : 6-15-89

1. How often do your crews work on service lines(i.e., #/week) ?

   3 to 4 times a week.

2. How far in advance do you know where your upcoming jobs will be ?

   Scheduled on daily basis

3. Do you do any preparation for a service job ?

   Check location of service line

4. Do you have access or ever call in to learn about previous history or maintenance at a location ?

   Yes

5. How long have you been replacing defective lead services with copper instead of repairing them ?

   Eleven years

6. Have you ever put in a lead service line ? If so, when was the last time you did this?

   No

7. Do you have expectations as to the type of material you will find when you dig up a service ? If so, about how often do you find a nonlead service when you expected to find lead ?

   No
   No

8. Do you think lead is more prevalent in any particular geographic regions of the city ? If so, which sections ?

N.W, particularly Georgetown areas.

9. How often is the customer service and the city side of the curb stop a different material ?

Fifty percent of the time.

10. Under what circumstances, if any, do city crews perform work on the customer side of the curb stop ?

Only when work in the public space interferes with customer's side.

11. What percent of the time do you see the customer's side of the service ?

Forty to fifty percent of the time.

12. What is the range of depth of service lines from the surface ?

3' - 5'

13. Explain a 'typical' service replacement job :

a) How deep is the hole (feet) ? 4'

b) How wide is the hole (feet) ? 5'

c) Do city crews ever dig the hole by hand ? If so:
   1. How many men are needed ? 3 - 4
   2. How long does it take ? 3 - 4 hrs depending on soil mat.

d) What other material (sidewalks, macadam) is removed ?
Concrete, Tree space, Brick walk.

e) Who repairs the sidewalks, streets etc. ?
Contractors.

DC LEAD PERSONNEL QUESTIONNAIRE

NAME : McKenzie
POSITION : Crew Chief.
YRS. EXPERIENCE : 14 - years
INTERVIEWER : David C. Nwabuisi & Sudipto Sarkar
DATE : 6 - 16 - 89

1. How often do your crews work on service lines(i.e., #/week) ?

   Everyday

2. How far in advance do you know where your upcoming jobs will be ?

   Scheduled on daily basis

3. Do you do any preparation for a service job ?

   Utility Checks

4. Do you have access or ever call in to learn about previous history or maintenance at a location ?

   Through other mantenance records.

5. How long have you been replacing defective lead services with copper instead of repairing them ?

   One year and 6 months. (1½ yrs)

6. Have you ever put in a lead service line ? If so, when was the last time you did this?

   No

7. Do you have expectations as to the type of material you will find when you dig up a service ? If so, about how often do you find a nonlead service when you expected to find lead ?

   Through assignment cards

   Oncace in a while.

8. Do you think lead is more prevalent in any particular geographic regions of the city ? If so, which sections ?

About the same in the whole city

9. How often is the customer service and the city side of the curb stop a different material ?

Very seldom

10. Under what circumstances, if any, do city crews perform work on the customer side of the curb stop ?

In cases where work had been previously done on the customer side by another DCDPW angency.

11. What percent of the time do you see the customer's side of the service ?

Almost everytime.

12. What is the range of depth of service lines from the surface ?

3' - 7'

13. Explain a 'typical' service replacement job :

a) How deep is the hole (feet) ? 4' - 5'

b) How wide is the hole (feet) ? 4'

c) Do city crews ever dig the hole by hand ? If so: Yes
   1. How many men are needed ? 3-men crew
   2. How long does it take ? Depending on materia encountered in so

d) What other material (sidewalks, macadam) is removed ?
   Concrete

e) Who repairs the sidewalks, streets etc. ?
   Hwy Department.

DC LEAD PERSONNEL QUESTIONNAIRE

NAME : John Peete
POSITION : Crew Chief.
YRS. EXPERIENCE : 14-YRS
INTERVIEWER : David C. Nwabuisi
DATE : 06-16-1989

1. How often do your crews work on service lines(i.e., #/week) ?

   Everyday

2. How far in advance do you know where your upcoming jobs will be ?

   Scheduled

3. Do you do any preparation for a service job ?

   (a) Consult Utility companies for utility check before excavation
   (b) Locate water mains etc

4. Do you have access or ever call in to learn about previous history or maintenance at a location ?

   Yes, Through the dispatchers

5. How long have you been replacing defective lead services with copper instead of repairing them ?

   2-years

6. Have you ever put in a lead service line ? If so, when was the last time you did this?

   No

7. Do you have expectations as to the type of material you will find when you dig up a service ? If so, about how often do you find a nonlead service when you expected to find lead ?

   Yes

   None

8. Do you think lead is more prevalent in any particular geographic regions of the city ? If so, which sections ?

About the same in all sections of the City.

9. How often is the customer service and the city side of the curb stop a different material ?

Not very often; only when there had been some repair work done previously.

10. Under what circumstances, if any, do city crews perform work on the customer side of the curb stop ?

None

11. What percent of the time do you see the customer's side of the service ?

About 9 out of 10 times

12. What is the range of depth of service lines from the surface ?

4' - 5'

13. Explain a 'typical' service replacement job :

a) How deep is the hole (feet) ? 4' - 5'

b) How wide is the hole (feet) ? 4'

c) Do city crews ever dig the hole by hand ? If so: Yes
   1. How many men are needed ? 3-men crew
   2. How long does it take ? 2-days

d) What other material (sidewalks, macadam) is removed ?
   Concrete r/w

e) Who repairs the sidewalks, streets etc. ?
   Hgw. Department.

DC LEAD PERSONNEL QUESTIONNAIRE

NAME : W. Wilkins
POSITION : Forman - Service repair / Tap removal
YRS. EXPERIENCE : 25 - Years
INTERVIEWER : D. Nwabuin / S. Sarkar
DATE : 6-16-89

1. How often do your crews work on service lines(i.e., #/week) ?

   Daily

2. How far in advance do you know where your upcoming jobs will be ?

   Scheduled on daily basis

3. Do you do any preparation for a service job ?

   Utility Check

4. Do you have access or ever call in to learn about previous history or maintenance at a location ?

   No

5. How long have you been replacing defective lead services with copper instead of repairing them ?

   3 - years

6. Have you ever put in a lead service line ? If so, when was the last time you did this?

   No

7. Do you have expectations as to the type of material you will find when you dig up a service ? If so, about how often do you find a nonlead service when you expected to find lead ?

   - No.
   - Once in a while

8. Do you think lead is more prevalent in any particular geographic regions of the city ? If so, which sections ?

Yes ; North West section

9. How often is the customer service and the city side of the curb stop a different material ?

Not often, unless customer has done some rehabilitation which entails change of service line.

10. Under what circumstances, if any, do city crews perform work on the customer side of the curb stop ?

Only when another agency of the District Government has done some damage on the Customer side

11. What percent of the time do you see the customer's side of the service ?

Nearly all the time work is performed

12. What is the range of depth of service lines from the surface ?

4' – 10'

13. Explain a 'typical' service replacement job :

a) How deep is the hole (feet) ? 4'

b) How wide is the hole (feet) ? 2'

c) Do city crews ever dig the hole by hand ? If so: Yes
   1. How many men are needed ? 4-men crew
   2. How long does it take ? 2 – 3 days

d) What other material (sidewalks, macadam) is removed ?
   Concrete

e) Who repairs the sidewalks, streets etc. ?

   Hwy – Contractors

APPENDIX B

MASTER PLUMBER INTERVIEWS

D.C. LEAD IN WATER STUDY
INTERVIEW WITH PRACTICING PLUMBERS

- Name of Respondent: Mr. Raleigh Hayward — Plumbing & Heating Inc.
- Position: Vice President
- Date of Interview: 7/18/89
- Type of Services: Plumbing installation & repair
- Age of Business: 17-years
- Interviewer: David C. Nwulbuion

1. What type of pipe materials have you been working on for the last 10 years?

   Cast iron, copper, black pipe, galvanized iron PVC with respect to installation.

   Lead, lead with copper in case of repair works.

2. Can you recollect the last time you installed/repaired a lead service and or used lead solder?

   1980

3. Are your plumbing works, sales, services, etc., evenly distributed/or concentrated to specific Section of D.C. ?

   Concentrated in N.W., N.E, and S.E; More so in N.W areas.

4. Other than your own practice, what can you say about the history of lead services in the District of Columbia?

   When a lead joint is not properly connected it becomes a weak point and subsequently creates problem.

5. Was use of lead services in the past due to the fact that there were more of them, ease of use, least expensive etc?

   They are easy to use; they come in rolled lengths.

6. Were there any problems associated with the use of lead pipes to the best of your knowledge? What type of problem were they?

   None

7. Do you have a knowledge of the following?

a. When was the use of lead pipes discontinued? Not aware of exactly when but none is in use today.

b. When was the use of lead pipes banned formally? 2-years ago or thereabout

c. When was the useof lead solder discontinued? 1985 August.

d. When was the use of lead solder banned? Completely banned at present.

Do not know

D.C. LEAD IN WATER STUDY
INTERVIEW WITH PRACTICING PLUMBERS

- Name of Respondent: Mr. J.C. Dorsey — John C. Dorsey Inc.
- Position: President
- Date of Interview: 7/5/89
- Type of Services: Installation, repair & replacement.
- Age of Business: 18 - years.
- Interviewer: David C. Nwabuzo

1. What type of pipe materials have you been working on for the last 10 years?

   Copper, cast iron, pvc, brass and alloys
   lead (in which case, they are usually replaced with other acceptable materials)

2. Can you recollect the last time you installed/repaired a lead service and or used lead solder?

   For this business, it is as far back as 40 years ago
   No installations or other work other than replacement has involved lead in that time. No body in the establishment at present knows how to work with lead pipes.

3. Are your plumbing works, sales, services, etc., evenly distributed/or concentrated to specific Section of D.C. ?

   Evenly distributed.

4. Other than your own practice, what can you say about the history of lead services in the District of Columbia?

   Being aware of the fact that lead services were very common in the years preceding 1940s or thereabout.

5. Was use of lead services in the past due to the fact that there were more of them, ease of use, least expensive etc?

   It could be due to any of the listed reasons or a combination of some of them.

6. Were there any problems associated with the use of lead pipes to the best of your knowledge? What type of problem were they?

   Cannot recall fail.

7. Do you have a knowledge of the following?

a. When was the use of lead pipes discontinued? Dont know exactly when. It has not been use recently since 40 yrs ago.

b. When was the use of lead pipes banned formally? Complete 9 year ago forme

c. When was the useof lead solder discontinued? Not completely except for water service lines.

d. When was the use of lead solder banned?

D.C. LEAD IN WATER STUDY
INTERVIEW WITH PRACTICING PLUMBERS

- Name of Respondent Ms. Cora William — Ideal Electronic Security Co.
- Position President
- Date of Interview 6/1/89
- Type of Services Wholesales/Distribution of security, electrical & plumbing supplies
- Age of Business 7-years.
- Interviewer

1. What type of pipe materials have you been working on for the last 10 years?

   Not applicable; business is only in supply and distribution

2. Can you recollect the last time you installed/repaired a lead service and or used lead solder?

   Not applicable because of nature of business.

3. Are your plumbing works, sales, services, etc., evenly distributed/or concentrated to specific Section of D.C. ?

   Other services like distribution of electrical & security supplies are evenly distributed. But plumbing supply has only been supplied to D.C. Dept. of Public Works - Blue Plains.

4. Other than your own practice, what can you say about the history of lead services in the District of Columbia?

   Not really

5. Was use of lead services in the past due to the fact that there were more of them, ease of use, least expensive etc?

   Not applicable due to nature of business

6. Were there any problems associated with the use of lead pipes to the best of your knowledge? What type of problem were they?

   Not applicable.

7. Do you have a knowledge of the following?

a. When was the use of lead pipes discontinued? N/A

b. When was the use of lead pipes banned formally? N/A

c. When was the useof lead solder discontinued? N/A

d. When was the use of lead solder banned? N/A

D.C. LEAD IN WATER STUDY
INTERVIEW WITH PRACTICING PLUMBERS

- Name of Respondent: Mr. H.D. Johnson – Plumbing & Heating
- Position: President H.D. Johnson, Inc.
- Date of Interview: 7/17/89
- Type of Services: Repair & replacement of existing services.
- Age of Business: 55 years
- Interviewer: David C. Hwabiri

1. What type of pipe materials have you been working on for the last 10 years?

   Galvanized iron, cast iron, lead, and copper.

2. Can you recollect the last time you installed/repaired a lead service and or used lead solder?

   About 1½ years ago

3. Are your plumbing works, sales, services, etc., evenly distributed/or concentrated to specific Section of D.C. ?

   Evenly distributed in the District of Columbia.

4. Other than your own practice, what can you say about the history of lead services in the District of Columbia?

   Between 1910 - 1946 lead pipes were the only material in use for water services. Good attributes of lead services are ① They came in rolled lengths, ② have larger (3) reduce the need for joining or coupling (4) easily installed

5. Was use of lead services in the past due to the fact that there were more of them, ease of use, least expensive etc?

   The use of lead service in the past was due many to the reasons listed – more prevalent, easy to work on and inexpensive.

6. Were there any problems associated with the use of lead pipes to the best of your knowledge? What type of problem were they?

   None whatsoever.

7. Do you have a knowledge of the following? Yes

a. When was the use of lead pipes discontinued? In 1940's there about

b. When was the use of lead pipes banned formally? Two to three years ago

c. When was the useof lead solder discontinued? Two years ago

d. When was the use of lead solder banned? Not until two years ago

D.C. LEAD IN WATER STUDY
INTERVIEW WITH PRACTICING PLUMBERS

- Name of Respondent: Mr. Edward Neddle — Atlantic Plumbing Supply Co. In
- Position: President
- Date of Interview: 7/17/89
- Type of Services: Plumbing supplies
- Age of Business: 32-years
- Interviewer: David C. Nwabuzo

1. What type of pipe materials have you been working on for the last 10 years?

   Copper, Cast iron, Brass, and some other alloys

2. Can you recollect the last time you installed/repaired a lead service and or used lead solder?

   Not applicable; do not install, replace or repair water service lines.

3. Are your plumbing works, sales, services, etc., evenly distributed/or concentrated to specific Section of D.C. ?

   Evenly distributed around the District of Columbia; plumbers come from every part to purchase materials.

4. Other than your own practice, what can you say about the history of lead services in the District of Columbia?

   The lead service has long been discontinued.

5. Was use of lead services in the past due to the fact that there were more of them, ease of use, least expensive etc?

   Easier to work on, and also cheaper than brass at the period they were used.

6. Were there any problems associated with the use of lead pipes to the best of your knowledge? What type of problem were they?

   Not applicable, have never worked on lead pipes.

7. Do you have a knowledge of the following?

a. When was the use of lead pipes discontinued? – About 15 yrs ago

b. When was the use of lead pipes banned formally? A couple of years ago

c. When was the useof lead solder discontinued? – Lead solder or alloy of lead solder is still in use for drainage, wastes & vents but not for water lines

d. When was the use of lead solder banned?
A couple of years ago for water lines only.

Additional Comments:

Alloys such as 50% lead and 50% Tin
Alloys " " 95% Tin and 5% Antimony
} still used for drainage, waste and vents

Alloy – 95% Tin, 4.5% Copper and 0.5% Silver which is considered lead-free is used for water service lines.

APPENDIX C

WATER QUALITY DATA

WASHINGTON AQUEDUCT DIVISION

U.S. ARMY ENGINEER DISTRICT, BALTIMORE

COMPOSITE ANALYSIS OF WATER BY DALECARLIA LABORATORY

POTOMAC RIVER RAW WATER SUPPLY

1984	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphorous	Dissolved Silica	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	8.0	71	14	39	217	123	-	16.2	.22	.048	8.9	33.2	3.44	.059	.095	.46	.001	.058	.0001	35	.002	.003	.80	.0023	9	.050	.0000	.002	2.6	.001	.0001	8.4	.17	.004
February	7.7	48	66	46	168	92		13.7	.20	.107	9.1	24.3	2.86	.178	.180	2.66	.002	.059	.0000	25	.004	.025	1.20	.0016	7	.092	.0000	.003	2.9	.002	.0001	7.8	.16	.010
March	7.9	53	38	48	158	96	-	12.8	.18	.068	7.9	25.5	3.06	.130	.052	3.27	.001	.051	.0000	27	.004	.005	.95	.0012	7	.061	.0000	.003	2.1	.001	.0000	5.4	.11	.004
April	7.8	54	43	57	207	88	-	8.1	.14	.033	8.3	22.7	1.87	.097	.041	6.4	.001	.063	.0000	25	.005	.007	3.67	.0027	6	.071	.0000	.003	2.0	.002	.0000	4.1	.11	.016
May	8.1	66	28	71	206	109	-	10.3	.16	.0[illegible]3	9.1	22.4	2.02	.017	.024	2.8	.001	.059	.0003	31	.003	.005	1.04	.0016	7	.110	.0002	.003	1.9	.000	.0001	5.3	.12	.006
June	8.3	93	14	81	242	139	-	24.6	.19	.027	4.1	31.7	1.42	.024	.034	2.04	.001	.071	.0001	41	.002	.004	1.02	.0009	9	.068	.0001	.004	2.2	.001	.0001	8.2	.20	.004
July	8.2	89	13	83	237	149	-	14.6	.17	.060	4.0	27.4	2.06	.032	.025	17.2	.001	.050	.0000	42	.004	.011	7.40	.0035	11	.179	.0000	.003	4.4	.001	.0000	6.4	.14	.010
August	7.8	76	27	83	209	120	-	12.3	.17	.049	3.9	27.2	1.11	.027	.046	3.46	.001	.042	.0000	36	.005	.014	1.57	.0020	7	.111	.0001	.002	2.7	.000	.0000	10.7	.18	.008
September	8.1	99	13	76	234	161	-	16.5	.20	.034	3.2	39.1	1.46	.017	.033	2.36	.000	.057	.0000	46	.003	.008	1.55	.0016	11	.079	.0000	.002	2.8	.000	.0001	11.6	.23	.005
October	8.2	109	11	67	284	177	-	19.6	.19	.034	1.7	51.1	2.09	.012	.032	2.91	.001	.055	.0001	53	.002	.008	1.26	.0037	11	.067	.0000	.003	2.9	.000	.0001	13.7	.24	.004
November	8.2	96	10	55	215	158	-	21.2	.19	.102	2.4	48.0	2.41	.018	.066	1.54	.001	.049	.0000	49	.003	.008	.81	.0015	9	.058	.0000	.004	3.5	.000	.0001	13.4	.23	.005
December	8.0	65	15	50	197	118	-	13.5	.11	.085	4.1	26.0	2.37	.021	.065	.51	.001	.033	.0001	32	.006	.008	2.20	.0021	8	.092	.0000	.004	2.7	.001	.0000	7.0	.13	.004
Average	8.0	77	24	63	214	127	-	15.3	.18	.059	5.5	31.5	2.18	.053	.058	3.80	.001	.054	.0001	37	.004	.009	1.89	.0020	8	.087	.0000	.003	2.7	.001	.0001	8.5	.17	.007
Maximum	8.3	109	66	85	284	177	-	24.6	.22	.102	9.1	51.1	3.44	.178	.180	17.2	.002	.071	.0003	53	.006	.025	7.40	.0037	11	.050	.0002	.004	4.4	.002	.0001	13.7	.25	.016
Minimum	7.7	48	10	39	158	88	-	8.1	.11	.027	1.7	22.4	1.11	.012	.024	.46	.000	.033	.0000	25	.002	.003	.81	.0009	6	.179	.0000	.002	1.9	.000	.0000	4.1	.11	.004

DALECARLIA WATER TREATMENT PLANT FINISHED WATER

1984	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphorous	Dissolved Silica	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	7.6	65	1.18	38	226	130	2.1	21.9	1.04	.022	9.0	37.2	3.87	.004	.016	.76	.001	.058	.0000	38	.001	.013	.187	.0002	9	.014	.0002	.002	2.5	.001	.0001	8.4	.15	.002
February	7.6	46	.43	45	191	108	2.3	19.4	1.14	.009	8.2	32.0	4.08	.002	.027	.14	.001	.054	.0001	32	.001	.006	.032	.0003	7	.004	.0002	.003	2.9	.002	.0001	8.0	.16	.003
March	7.7	50	.22	47	162	106	2.3	18.6	1.00	.016	6.8	29.7	3.63	.007	.012	.05	.001	.037	.0000	31	.000	.005	.008	.0003	7	.002	.0001	.001	2.1	.001	.0000	7.8	.12	.001
April	7.7	52	.24	56	158	106	2.2	12.1	.95	.001	7.3	35.6	2.82	.011	.011	.05	.001	.054	.0000	31	.000	.005	.015	.0002	7	.002	.0000	.001	1.9	.001	.0000	4.2	.10	.002
May	7.8	62	.17	67	182	120	2.2	14.7	1.00	.010	7.6	29.7	2.03	.001	.016	.05	.001	.067	.0002	36	.001	.012	.026	.0002	7	.011	.0000	.002	1.9	.001	.0000	5.3	.14	.001
June	7.7	88	.48	78	243	146	2.5	31.6	1.01	.007	3.1	38.7	1.60	.003	.011	.40	.001	.069	.0001	43	.001	.013	.015	.0005	9	.005	.0002	.001	2.2	.001	.0000	8.1	.19	.001
July	7.8	91	.34	81	254	158	2.0	17.8	.87	.004	3.4	34.3	2.24	.005	.009	.07	.001	.047	.0000	47	.001	.010	.014	.0000	10	.004	.0000	.002	3.8	.001	.0001	9.0	.18	.001
August	7.7	75	.28	81	221	135	2.3	18.0	1.03	.022	3.2	35.0	1.21	.006	.007	.15	.000	.047	.0000	41	.001	.005	.009	.0004	8	.003	.0001	.001	2.7	.000	.0001	10.3	.19	.001
September	7.7	96	.22	74	219	162	2.3	22.4	1.09	.007	4.3	44.4	1.80	.002	.009	.09	.000	.050	.0000	51	.001	.005	.009	.0003	10	.004	.0000	.001	2.7	.000	.0001	11.7	.25	.001
October	7.7	99	.19	67	262	181	2.2	25.8	.98	.016	1.8	55.5	2.35	.001	.013	.15	.000	.043	.0001	54	.001	.004	.011	.0001	11	.004	.0000	.002	2.9	.000	.0001	16.1	.21	.001
November	7.7	94	.30	55	267	169	2.5	28.4	.94	.031	2.3	54.6	2.69	.001	.028	.15	.001	.050	.0000	52	.001	.005	.024	.0003	9	.004	.0001	.004	3.1	.001	.0001	13.4	.24	.001
December	7.6	62	.44	50	199	123	2.2	19.4	.96	.017	3.8	31.1	2.69	.001	.011	.08	.001	.029	.0000	37	.001	.003	.025	.0018	7	.003	.0000	.002	2.6	.001	.0002	6.1	.14	.002
Average	7.7	73	.37	62	215	136	2.3	20.8	1.00	.014	5.1	38.1	2.58	.004	.014	.18	.001	.051	.0000	41	.001	.007	.031	.0004	8	.005	.0001	.002	2.6	.001	.0001	9.0	.16	.001
Maximum	7.8	99	1.18	81	267	181	2.5	31.6	1.14	.031	9.0	55.5	4.08	.011	.028	.76	.001	.069	.0002	54	.001	.013	.187	.0018	11	.014	.0002	.004	3.8	.002	.0002	16.1	.25	.002
Minimum	7.6	46	.17	38	158	106	2.0	12.1	.87	.001	1.8	29.7	1.21	.001	.007	.05	.000	.029	.0000	31	.000	.003	.008	.0000	7	.002	.0000	.001	1.9	.000	.0000	4.2	.10	.001

McMILLAN WATER TREATMENT PLANT FINISHED WATER

1984	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphorous	Dissolved Silica	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	7.6	59	.42	37	221	125	2.5	21.0	1.05	.019	8.9	38.1	2.44	.006	.008	.11	.001	.059	.0000	37	.001	.069	.0[illegible]	.0003	9	.011	.0003	.003	2.8	.002	.0001	8.8	.15	.003
February	7.6	48	.30	42	208	114	2.0	18.9	1.05	.010	8.0	35.0	3.95	.002	.023	.05	.001	.059	.0000	33	.001	.042	.034	.0006	8	.004	.0001	.003	2.9	.002	.0001	9.1	.19	.003
March	7.7	41	.29	46	157	104	2.0	18.8	1.22	.019	7.4	33.6	3.36	.004	.008	.10	.001	.040	.0001	31	.000	.031	.007	.0003	7	.003	.0000	.001	2.2	.001	.0000	5.4	.13	.002
April	7.8	39	.17	53	156	98	2.0	14.0	1.05	.001	7.2	37.4	2.01	.004	.011	.03	.001	.060	.0000	29	.001	.019	.004	.0002	6	.019	.0000	.001	1.7	.001	.0000	5.7	.12	.003
May	7.8	50	.19	65	191	114	2.0	15.5	1.10	.020	6.5	35.6	1.74	.001	.02	.03	.001	.054	.0001	33	.000	.020	.008	.0006	8	.001	.0000	.002	1.7	.000	.000	4.8	.14	.001
June	7.7	78	.13	77	220	141	2.1	33.0	1.12	.007	3.0	40.3	1.44	.003	.008	.05	.001	.073	.0001	42	.000	.026	.009	.0004	9	.006	.0003	.001	2.4	.001	.0000	7.2	.22	.001
July	7.8	82	.28	79	236	161	2.2	18.4	1.09	.001	4.4	44.0	1.77	.005	.008	.05	.001	.049	.0002	49	.001	.032	.005	.0010	10	.002	.0000	.100	2.9	.001	.0001	11.1	.26	.428
August	7.9	69	.33	81	221	135	2.3	21.1	1.00	.019	2.4	41.9	1.39	.007	.007	.05	.000	.044	.0000	41	.001	.022	.004	.0000	8	.002	.0000	.001	2.6	.000	.0001	11.3	.21	.001
September	7.8	82	.33	76	185	157	2.2	21.5	1.29	.009	4.1	41.7	1.37	.001	.006	.14	.001	.055	.0000	47	.001	.077	.078	.0009	10	.002	.0000	.002	2.6	.000	.0000	9.6	.19	.018
October	7.7	97	.15	67	268	184	2.1	27.7	1.12	.009	1.7	57.3	1.93	.001	.007	.05	.000	.058	.0001	54	.001	.043	.014	.0001	12	.001	.0000	.004	2.9	.000	.0001	14.3	.25	.002
November	7.7	89	.20	57	269	172	2.2	29.8	1.12	.016	2.2	57.4	2.48	.001	.028	.05	.007	.047	.0000	52	.001	.045	.014	.0006	10	.001	.0001	.004	3.5	.000	.0001	15.9	.25	.001
December	7.6	63	.21	47	184	138	2.3	22.4	.96	.019	2.9	40.6	2.34	.001	.026	.05	.001	.040	.0000	40	.001	.051	.020	.0005	9	.002	.0000	.004	3.0	.002	.0002	9.2	.19	.005
Average	7.7	66	.25	60	210	137	2.2	21.8	1.10	.012	4.9	41.9	2.18	.003	.013	.06	.001	.057	.0001	41	.001	.040	.017	.0005	9	.005	.0001	.011	2.6	.001	.0000	9.4	.19	.039
Maximum	7.9	97	.42	81	269	184	2.5	33.0	1.29	.020	8.9	57.3	3.95	.007	.028	.14	.007	.073	.0002		.001	.077	.078	.0010	12	.019	.0003	.100	3.5	.002	.0002	15.9	.26	.428
Minimum	7.6	39	.13	37	156	98	2.0	14.0	.96	.001	1.7	33.6	1.37	.001	.006	.03	.000	.040	.0000	2.	.000	.019	.003	.0000	6	.001	.0000	.001	1.7	.000	.0000	4.8	.12	.001

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WASHINGTON AQUEDUCT DIVISION

U.S. ARMY ENGINEER DISTRICT, BALTIMORE

COMPOSITE ANALYSIS OF WATER BY DALECARLIA LABORATORY

POTOMAC RIVER RAW WATER SUPPLY

1984	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohms/cm	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226-228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l	Total Coliform MPN	Fecal Coliform MPN	Fecal Strep MPN	Fecal Strep MF Org./ml	Salmonella MPN/10L	Staphylococcus aureus Org/ml	Pseudomonas Aeruginosa MPN	Algae Count Org/ml	Bacterial Endotoxin ng/ml
January	-	-	-	-	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.26	8	13	347						97950	290	15		0	0	7		
February	-	-	-	-	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.11	18	13	270						89070	3820	150		0	0	7		
March	-	-	-	-	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.14	15	13	283						17780	340	80		4	0	22400		
April	-	-	-	-	<.1	<.2	<1.0	2.0	<1.0	<1.0	.05	6	13	226						32630	2290	1920		23	0	0		
May	-	-	-	-	NR	NR	NR	NR	NR	NR	.14	17	10	230						39110	4070	110		4	0	9		
June	-	-	-	-	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.13	14	8	324						11570	1570	90		9	0	5	7360	
July	-	-	-	-	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.09	14	8	357						1630	260	160		4	0	20		
August	-	-	-	-	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.14	23	7	316						2380	790	420		9	0	-		
September	-	-	-	-	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.03	15	8	421						470	90	60		0	0	21		
October	-	-	-	-	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.04	17	8	474						2060	450	160		0	0	0		
November	-	-	-	-	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.04	8	8	375						1470	350	70		0	0	21		
December	-	-	-	-	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.02	9	8	300						12440	2070	290		0	1	21		
Average	-	-	-	-	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.10	14	10	327						20711	1366	294		4	.08	208	7360	
Maximum	-	-	-	-	-	-	-	-	-	-	.26	23	13	474						89070	3820	1920		23	1	>2400	7360	
Minimum	-	-	-	-	-	-	-	-	-	-	.02	6	7	226						470	90	60		0	0	0	7360	

DALECARLIA WATER TREATMENT PLANT FINISHED WATER

1984	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohms/cm	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226-228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l	Total Coliform MPN	Fecal Coliform MPN	Fecal Strep MPN	Fecal Strep MF Org./ml	Salmonella MPN/10L	Staphylococcus aureus Org/ml	Pseudomonas Aeruginosa MPN	Algae Count Org/ml	Bacterial Endotoxin ng/ml
January	15	5.5	1.5	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.10	6	13	388	<2.2	<3.7		<3.1	<343	0					0.2	0		
February	32	6.2	0.9	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.08	7	12	320						0					0	0		
March	22	5.9	1.1	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.03	5	13	318						0					0	0		
April	30	5.1	.7	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.04	8	13	271	<3.0	<3.4		<2.9	<580	0					0	0		
May	45	8.2	1.5	0	NR	NR	NR	NR	NR	NR	.10	3	10	306						0					0	0		
June	78	13.9	2	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.06	3	9	384						0.04					0	0		
July	80	13.7	1.4	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.07	7	9	396	<2.3	<6.7		<5.6	<353	0					0	0		
August	77	12.7	1.3	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.07	11	9	355						0.04					0			
September	66	14.0	2.0	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.03	5	9	419						0.03					0	0		
October	65	11.7	1.1	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.02	4	10	506	<1.0	<3.6		<1.2	<320	0.09					0	23		
November	52	9.9	1.9	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.01	4	8	395						0					0	0		
December	39	5.9	.8	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.01	3	8	338						0.17					0	0		
Average	50	9.4	1.3	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.05	6	10	366	<2.1	<4.4		<3.2	<449	0.03					0.016	2		
Maximum	80	14.0	2.0	0	-	-	-	-	-	-	.10	11	13	506	<3.0	<6.7		<5.6	<580	0.09					0.2	23		
Minimum	15	5.1	.7	0	-	-	-	-	-	-	.01	3	8	271	<1.0	<3.4		<1.2	<343	0					0	0		

McMILLAN WATER TREATMENT PLANT FINISHED WATER

1984	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohms/cm	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226-228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l	Total Coliform MPN	Fecal Coliform MPN	Fecal Strep MPN	Fecal Strep MF Org./ml	Salmonella MPN/10L	Staphylococcus aureus Org/ml	Pseudomonas Aeruginosa MPN	Algae Count Org/ml	Bacterial Endotoxin ng/ml
January	41	7.6	0.9	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.14	6	-	366	<2.1	<2.9		<2.5	<714	0					0	0		
February	48	8.7	1.9	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.06	8	-	330						0					0	0		
March	34	6.2	1.2	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.03	4	-	305						0.018					0	0		
April	37	5.6	1.3	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.04	2	-	258	<1.3	<2.9		<2.4	<610	0					0	0		
May	32	7.5	2	0	NR	NR	NR	NR	NR	NR	.12	5	-	297						0					0	0		
June	49	9.9	2.1	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.06	5	-	331						0					0	0		
July	59	12.9	1.7	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.06	4	-	402	<2.9	<5.2		<4.4	<292	0.04					0	0		
August	69	12.9	1.9	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.05	6	-	369						0.04					0	0		
September	64	14.7	3.0	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.03	3	-	402						0.22					0	0		
October	61	13.2	2.6	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.02	4	-	498	<1.0	<3.5		<0.5	<520	0					0	0		
November	59	10.2	2.0	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.01	3	-	420						0.04					0	0		
December	55	8.9	1.8	0	<.1	<.2	<1.0	<2.0	NS	NS	.01	0	-	373						0					0	0		
Average	51	9.9	1.9	0	<.1	<.2	<1.0	<2.0	<1.0	<1.0	.05	4		362	<1.8	<3.6		<2.4	<534	0.03					0	0		
Maximum	69	14.7	3.0	0	-	-	-	-	-	-	.14	8		498	<2.9	<5.2		<4.4	<714	0.22					0	0		
Minimum	32	5.6	.9	0	-	-	-	-	-	-	.01	0		258	<1.0	<2.9		<0.5	<292	0					0	0		

NAB Form 648 rev. JAN "81"

W. A. Dwg. No. 100.1-4.14-4

WASHINGTON AQUEDUCT DIVISION

U.S. ARMY ENGINEER DISTRICT, BALTIMORE

COMPOSITE ANALYSIS OF WATER BY DALECARLIA LABORATORY

POTOMAC RIVER RAW WATER SUPPLY

1985	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphorous	Silica	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	8.2	75	7.4	43	374	119	—	14.0	0.16	0.054	3.2	31.8	3.08	0.027	0.014	1.23	0.001	0.042	0.0001	35	0.003	0.006	0.970	0.0012	8	0.067	0.0002	0.003	2.00	0.001	0.00[illegible]	6.90	0.190	0.000
February	7.8	91	30.1	43	406	107	—	16.3	0.18	0.040	6.6	32.2	1.80	0.028	0.006	12.17	0.005	0.089	0.0001	30	0.012	0.014	4.80	0.0050	8	0.141	0.0000	0.011	3.30	0.001	0.0000	12.00	0.100	0.002
March	7.9	57	12.6	54	355	100	—	10.7	0.14	0.039	6.6	43.5	3.44	0.023	0.049	1.34	0.001	0.081	0.0000	29	0.003	0.006	0.840	0.0012	6	0.113	0.0001	0.003	1.73	0.001	0.0000	6.40	0.140	0.009
April	8.0	81	12.0	66	320	99	—	11.2	0.13	0.044	3.0	28.3	1.76	0.032	0.037	5.88	0.001	0.080	0.0001	30	0.003	0.005	3.74	0.0019	6	0.081	0.0000	0.003	1.80	0.002	0.0001	5.80	0.11	0.01
May	7.6	69	10.0	73	400	107	—	11.4	0.13	0.040	1.8	45.6	1.82	0.037	0.020	1.67	0.001	0.060	0.0000	32	0.002	0.008	1.05	0.0014	7	0.115	0.0003	0.002	2.21	0.000	0.0000	5.96	0.196	0.004
June	7.7	87	23.9	77	438	112	—	11.4	0.14	0.040	3.2	32.0	1.36	0.048	0.064	14.47	0.002	0.054	0.0000	33	0.016	0.014	0.840	0.0036	9	0.112	0.0003	0.007	2.28	0.002	0.0000	7.86	0.148	0.010
July	7.6	66	22.4	84	430	[illegible]	—	13.5	0.20	0.041	1.6	46.5	0.80	0.034	0.052	0.754	0.000	[illegible]	0.0000	33	0.001	0.003	0.800	0.0018	8	0.127	0.0001	0.003	2.80	0.001	0.0000	11.20	0.311	0.009
August	7.6	75	11.0	84	343	131	—	23.3	0.16	0.083	2.0	67.1	1.38	0.053	0.037	0.303	0.001	0.090	0.0000	36	0.002	0.003	0.487	0.0007	9	0.097	0.0010	0.002	3.20	0.000	0.0000	15.20	0.398	0.003
September	7.9	86	7.8	79	506	150	—	23.0	0.17	0.078	2.8	52.0	2.18	0.036	0.020	0.280	0.002	0.063	0.0000	43	0.001	0.003	0.248	0.0007	10	0.041	0.0000	0.001	3.08	0.000	0.0000	19.90	0.292	0.002
October	7.9	91	7.3	88	412	181	—	30.6	0.18	0.081	1.8	56.4	1.04	0.052	0.034	0.440	0.001	0.085	0.0000	48	0.001	0.003	0.473	0.0007	12	0.043	0.0002	0.002	3.75	0.000	0.0000	14.20	0.256	0.004
November	7.8	56	125	59	336	111	—	8.2	0.14	0.045	6.2	33.6	1.67	0.066	0.207	1.59	0.001	0.066	0.0001	32	0.007	0.003	1.59	0.0034	22	0.107	0.0000	0.003	3.06	0.000	0.0000	7.15	0.180	0.013
December	7.7	56	14.6	45	282	120	—	10.2	0.16	0.000	4.2	39.0	1.80	0.040	0.044	0.380	0.001	0.070	0.0000	34	0.001	0.004	0.540	0.0014	9	0.065	0.0000	0.003	2.37	0.001	0.0000	4.86	0.130	0.012
Average	7.8	69	23.7	64	424	120	—	15.6	0.15	0.047	3.6	42.5	1.83	0.048	0.054	3.36	0.001	0.068	0.0000	34	0.004	0.006	1.35	0.0019	9	0.092	0.0006	0.004	2.61	0.001	0.0000	10.14	0.187	0.009
Maximum	8.2	91	125	84	612	181	—	30.6	0.20	0.083	6.8	67.1	3.44	0.066	0.207	14.47	0.005	0.089	0.0001	48	0.016	0.014	4.80	0.0050	22	0.141	0.0010	0.011	3.75	0.002	0.0000	19.90	0.392	0.002
Minimum	7.6	56	7.3	43	282	99	—	8.2	0.13	0.000	1.6	28.3	0.80	0.023	0.014	0.280	0.000	0.042	0.0000	29	0.001	0.003	0.248	0.0007	6	0.041	0.0000	0.001	1.73	0.000	0.0000	4.86	0.16	0.002

DALECARLIA WATER TREATMENT PLANT FINISHED WATER

1985	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphorous	Silica	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	7.6	69	0.41	42	346	127	2.18	17.0	1.01	0.018	3.3	38.6	2.59	0.001	0.000	0.072	0.001	0.034	0.0000	38	0.001	0.004	0.009	0.0013	8	0.002	0.0001	0.002	1.90	0.001	0.0001	8.80	0.160	0.001
February	7.8	63	0.45	42	437	126	2.05	24.3	1.00	0.016	6.0	39.8	2.11	0.004	0.018	0.146	0.001	0.040	0.0000	37	0.001	0.003	0.073	0.0002	8	0.004	0.0001	0.003	3.00	0.001	0.0000	13.60	0.184	0.002
March	8.1	56	0.28	53	325	113	2.04	13.9	0.96	0.005	6.3	48.5	3.12	0.001	0.000	0.083	0.001	0.048	0.0000	35	0.001	0.005	0.023	0.0002	6	0.007	0.0000	0.003	1.67	0.001	0.0000	6.10	0.131	0.004
April	8.1	58	0.41	64	353	109	2.06	20.5	1.03	0.001	2.8	38.5	2.25	0.006	0.015	0.090	0.001	0.048	0.0001	34	0.001	0.004	0.058	0.0005	8	0.008	0.0000	0.002	1.90	0.001	0.0001	5.80	0.119	0.002
May	7.8	69	0.[illegible]	73	379	121	2.10	17.8	1.03	0.007	1.9	56.3	1.78	0.001	0.014	0.347	0.001	0.062	0.0000	38	0.001	0.004	0.062	0.0006	7	0.011	0.0000	0.002	2.17	0.001	0.0000	10.70	0.212	0.001
June	7.8	66	0.38	77	371	125	2.11	15.6	1.03	0.004	3.2	46.8	1.31	0.004	0.007	0.081	0.001	0.067	0.0000	38	0.001	0.007	0.040	0.0003	7	0.003	0.0003	0.002	2.32	0.000	0.0000	8.00	0.158	0.001
July	7.7	69	0.38	83	475	129	2.18	21.6	0.88	0.000	2.2	53.4	0.62	0.002	0.001	0.198	0.001	0.047	0.0000	39	0.001	0.006	0.013	0.0001	7	0.009	0.0002	0.002	2.45	0.001	0.0001	11.15	0.223	0.001
August	7.7	73	0.20	83	562	144	2.52	28.4	0.86	0.006	1.8	66.8	1.38	0.007	0.001	0.130	0.001	0.055	0.0000	42	0.000	0.009	0.012	0.0001	10	0.006	0.0004	0.002	3.10	0.000	0.0000	14.75	0.250	0.001
September	7.8	81	0.28	79	462	157	2.45	27.5	0.95	0.003	2.6	56.5	2.18	0.009	0.001	0.183	0.001	0.066	0.0000	47	0.001	0.008	0.099	0.0002	10	0.002	0.0004	0.001	3.26	0.000	0.0000	18.75	0.298	0.003
October	7.7	87	0.23	69	586	172	2.54	33.9	0.90	0.005	1.6	62.6	1.33	0.028	0.004	0.171	0.001	0.062	0.0000	51	0.001	0.015	0.022	0.0004	11	0.004	0.0008	0.002	3.70	0.000	0.0000	14.45	0.253	0.002
November	7.7	55	0.50	61	390	129	2.72	17.1	0.94	0.000	4.8	46.7	1.78	0.022	0.002	0.199	0.001	0.090	0.0000	39	0.001	0.004	0.038	0.0000	8	0.007	0.0007	0.002	2.86	0.000	0.0000	8.17	0.178	0.001
December	7.7	60	0.36	48	325	125	2.63	12.3	1.05	0.000	4.4	45.0	1.80	0.000	0.008	0.064	0.001	0.065	0.0000	37	0.000	0.005	0.014	0.0005	7	0.002	0.0000	0.002	2.36	0.001	0.0000	4.56	0.133	0.001
Average	7.8	67	0.34	64	421	131	2.30	20.8	0.97	0.006	3.4	49.5	1.85	0.007	0.006	0.181	0.001	0.061	0.0000	40	0.001	0.007	0.038	0.0004	8	0.006	0.0002	0.002	2.81	0.001	0.0000	11.07	0.211	0.002
Maximum	8.1	87	0.50	83	586	172	2.72	33.9	1.05	0.018	6.3	66.8	3.12	0.028	0.018	0.347	0.001	0.090	0.0001	51	0.001	0.015	0.099	0.0013	11	0.011	0.0007	0.003	3.70	0.001	0.0001	18.75	0.298	0.004
Minimum	7.6	55	0.20	42	325	108	2.04	12.3	0.88	0.000	1.6	38.3	0.82	0.000	0.000	0.064	0.001	0.034	0.0000	34	0.000	0.003	0.009	0.0000	6	0.002	0.0000	0.001	1.88	0.000	0.0000	4.36	0.119	0.001

McMILLAN WATER TREATMENT PLANT FINISHED WATER

1985	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphorous	Silica	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	7.6	57	0.21	42	305	123	2.25	18.7	1.10	0.018	3.4	41.4	2.74	0.001	0.007	0.045	0.001	0.040	0.0000	36	0.001	0.060	0.007	0.0008	8	0.001	0.0001	0.002	2.40	0.002	0.0002	7.80	0.180	0.002
February	7.7	66	0.32	40	452	137	2.23	23.8	1.03	0.015	4.5	51.4	2.36	0.004	0.018	0.095	0.001	0.050	0.0001	43	0.001	0.088	0.010	0.0001	7	0.002	0.0001	0.003	2.60	0.002	0.0000	15.40	0.208	0.004
March	8.0	45	0.29	50	351	110	2.18	19.8	1.20	0.006	7.1	55.8	2.56	0.004	0.003	0.064	0.001	0.043	0.0000	34	0.001	0.037	0.007	0.0001	6	0.001	0.0000	0.003	2.05	0.002	0.0000	6.85	0.120	0.008
April	7.7	48	0.24	60	361	105	2.21	20.4	1.16	0.001	2.7	43.0	2.22	0.007	0.011	0.033	0.001	0.042	0.0000	31	0.001	0.038	0.006	0.0009	6	0.002	0.0000	0.002	1.90	0.001	0.0001	6.90	0.139	0.008
May	7.8	60	0.33	71	386	115	2.27	19.6	1.05	0.000	1.6	54.4	1.50	0.003	0.014	0.173	0.000	0.047	0.0000	35	0.001	0.098	0.247	0.0124	7	0.009	0.0001	0.001	2.02	0.000	0.0000	9.20	0.195	0.014
June	7.8	53	0.40	76	448	116	2.27	19.4	1.03	0.003	2.9	53.7	1.52	0.004	0.007	0.101	0.002	0.041	0.0004	35	0.001	0.029	0.170	0.0134	7	0.012	0.0003	0.002	2.48	0.002	0.0000	8.90	0.197	0.008
July	7.7	62	0.47	81	454	128	2.32	20.5	0.95	0.003	2.5	53.9	0.49	0.002	0.003	0.047	0.000	0.048	0.0000	38	0.001	0.038	0.003	0.0003	8	0.001	0.0000	0.002	2.67	0.001	0.0001	12.10	0.208	0.004
August	7.8	58	0.44	83	487	131	2.37	24.9	0.98	0.006	13.5	68.2	1.12	0.006	0.001	0.028	0.001	0.045	0.0000	38	0.000	0.041	0.007	0.0001	9	0.003	0.0001	0.002	3.10	0.001	0.0000	14.15	0.196	0.003
September	7.8	71	0.30	79	510	151	2.37	28.2	1.07	0.001	2.8	58.9	2.06	0.012	0.001	0.058	0.001	0.055	0.0000	44	0.001	0.035	0.005	0.0001	10	0.001	0.0001	0.001	3.15	0.000	0.0001	16.20	0.236	0.003
October	7.8	85	0.31	68	508	173	2.39	31.8	1.03	0.003	1.8	68.3	1.01	0.020	0.004	0.127	0.000	0.066	0.0000	49	0.001	0.031	0.013	0.0002	12	0.001	0.0000	0.001	3.30	0.000	0.0000	21.15	0.290	0.002
November	7.8	58	0.34	62	447	143	2.48	16.8	0.93	0.000	4.1	66.4	1.56	0.018	0.002	0.055	0.001	0.061	0.0000	42	0.001	0.035	0.002	0.0001	10	0.001	0.0026	0.002	2.96	0.001	0.0000	9.83	0.283	0.002
December	7.8	43	0.27	48	307	122	2.29	15.0	1.10	0.000	4.5	50.0	1.74	0.000	0.008	0.071	0.001	0.062	0.0000	35	0.000	0.034	0.012	0.0002	9	0.003	0.0003	0.002	2.43	0.001	0.0000	2.56	0.138	0.003
Average	7.7	59	0.33	63	418	130	2.30	21.6	1.05	0.005	4.3	55.4	1.74	0.007	0.007	0.082	0.001	0.055	0.0000	38	0.001	0.051	0.044	0.0026	8	0.003	0.0003	0.002	2.82	0.001	0.0000	12.20	0.217	0.005
Maximum	8.0	85	0.47	83	510	173	2.48	31.8	1.20	0.018	13.5	68.3	2.74	0.018	0.18	0.173	0.002	0.066	0.0004	49	0.001	0.098	0.247	0.0134	12	0.012	0.0026	0.003	3.30	0.002	0.0008	21.15	0.283	0.014
Minimum	7.6	43	0.21	40	305	105	2.19	15.0	0.93	0.000	1.6	41.4	0.49	0.000	0.001	0.028	0.000	0.040	0.0000	31	0.000	0.028	0.002	0.0001	6	0.001	0.0000	0.001	1.90	0.000	0.0000	5.80	0.120	0.002

NAB Form 648 rev. JUNE "86"

W.A. Dwg. No. 100.1-4.14-5

WASHINGTON AQUEDUCT DIVISION

U.S. ARMY ENGINEER DISTRICT, BALTIMORE

COMPOSITE ANALYSIS OF WATER BY DALECARLIA LABORATORY

POTOMAC RIVER RAW WATER SUPPLY

1985	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Total Trihalomethanes ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohoms/cm	Total Coliform MPN	Fecal Coliform MPN	Fecal Strep MPN	Algae Count Org/ml	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226 - 228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l
January	—	—	—	—	—	0J	0.2	1.0	2.0	1.0	1.0	0.023	12.4	8.6	345	1462	80	10	—					
February	—	—	—	—	—	0J	0.2	1.0	2.0	1.0	1.0	0.030	13.0	9.3	314	71389	660	1256	—					
March	8.8	0.3	0.0	0.0	9.3	0J	0.2	1.0	2.0	1.0	1.0	0.042	14.2	9.8	279	2953	124	1	—					
April	8.7	0.3	0.0	0.0	9.0	0J	0.2	1.0	2.0	1.0	1.0	0.025	30J	9.8	268	3893	1162	15	—					
May	8.0	0.4	0J	0.0	8.5	0J	0.2	1.0	2.0	1.0	1.0	0.034	15.0	8.0	290	12248	907	198	421					
June	1.3	0.3	0.0	0.0	6.6	0J	0.2	1.0	2.0	1.0	1.0	0.027	13.8	7.4	297	12781	846	175	327					
July	1.3	0.6	0.0	0.0	8J	0J	0.2	1.0	2.0	1.0	1.0	0.039	30.4	8J	350	9835	1729	641	374					
August	8.4	0.3	0.0	0.0	8.6	0J	0.2	1.0	2.0	1.0	1.0	0.109	17.4	8.5	390	1394	135	98	373					
September	8.6	0.3	0.0	0.0	8.9	0J	0.2	1.0	2.0	1.0	1.0	0.063	11.8	8.5	415	286	873	40	—					
October	6.5	0.4	0J	0.0	7.0	0J	0.2	1.0	2.0	1.0	1.0	0.049	14.0	7.5	453	1899	2357	196	—					
November	5.7	0.2	0.	0.0	5.9	0J	0.2	1.0	2.0	1.0	1.0	0.030	15.8	8.5	266	13023	3970	1799	—					
December	2.0	0J	0J	0.2	2.3	0J	0.2	1.0	2.0	1.0	1.0	0.028	12.8	8J	281	29059	2777	374	—					
Average	7.2	0.3	0.0	0.0	7.6	0J	0.2	1.0	2.0	1.0	1.0	0.042	16.7	8.6	330	13811	1285	400	374					
Maximum	9.3	0.6	0.1	0.2	9.6	0J	0.2	1.0	2.0	1.0	1.0	0.109	30.4	9.8	453	71389	3970	1799	421					
Minimum	2.0	0J	0.0	0.0	2.3	0J	0.2	1.0	2.0	1.0	1.0	0.023	11.8	7.4	266	1394	80	1	327					

DALECARLIA WATER TREATMENT PLANT FINISHED WATER

1985	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Total Trihalomethanes ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohoms/cm	Total Coliform MPN	Fecal Coliform MPN	Fecal Strep MPN	Algae Count Org/ml	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226 - 228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l
January	24.6	8.5	1.4	0.0	32.7	0J	0.2	1.0	2.0	1.0	1.0	0.009	2.7	9.5		0								
February	37.8	6.9	0.9	0.0	45.6	0J	0.2	1.0	2.0	1.0	1.0	0.028	6.6	9.4		0								
March	39.4	7.6	1J	0.0	48.0	0J	0.2	1.0	2.0	1.0	1.0	0.032	3.2	9.8		0				• 0.8	2.2		• 0.37	• 590
April	55.6	9.7	1.7	0.0	67.0	0J	0.2	1.0	2.0	1.0	1.0	0.025	5J	9.7	299	0								
May	73.0	10.8	1.0	0.0	86.8	0J	0.2	1.0	2.0	1.0	1.0	0.018	8.3	8.8	322	0								
June	70.0	13.8	1.8	0.0	85.3	0J	0.3	1.0	2.0	1.0	1.0	0.007	6.8	7.7	327	0								
July	84.4	15.8	2.2	0.0	103.4	0.1	0.2	1.0	2.0	1.0	1.0	0.024	9.7	8.4	384	0								
August	68J	15.3	1.9	0.0	85.3	0.1	0.2	1.0	2.0	1.0	1.0	0.054	7.7	8.8	417	0								
September	56.2	13.2	1.6	0.0	71J	0J	0.2	1.0	2.0	1.0	1.0	0.026	1.3	8.2	447	0				• 1.0	2.8		• 0.5	• 440
October	62.4	11.4	1.1	0.0	74.9	0.1	0.2	1.0	2.0	1.0	1.0	0.032	3.3	8.1	466	0								
November	34.7	5.0	0.5	0.0	40.2	0J	0.2	1.0	2.0	1.0	1.0	0.030	3.8	8.9	318	0								
December	17.8	4.7	1.2	0.2	23.9	0J	0.2	1.0	2.0	1.0	1.0	0.026	4.5	9.5	318	0				• 1.5	3.0		• 0.7	• 460
Average	52.2	10J	1.4	0.0	63.7	0J	0.2	1.0	2.0	1.0	1.0	0.026	5.2	8.9	362	0				• 1J	2.8		• 0.39	• 463
Maximum	84.4	16.8	2.2	0.2	103.4	0J	0.2	1.0	2.0	1.0	1.0	0.054	9.7	9.8	465	0				• 1.5	3.0		• 0.7	• 590
Minimum	17.8	4.7	0.5	0.0	23.9	0J	0.2	1.0	2.0	1.0	1.0	0.007	1.3	7.7	298	0				• 0.8	2.2		• 0.5	• 440

McMILLAN WATER TREATMENT PLANT FINISHED WATER

1985	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Total Trihalomethanes ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohoms/cm	Total Coliform MPN	Fecal Coliform MPN	Fecal Strep MPN	Algae Count Org/ml	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226 - 228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l
January	40.2	9.0	1.6	0.0	50.8	0J	0.2	1.0	2.0	1.0	1.0	0.009	2J	—	358	0								
February	48.9	9.4	1.2	0.0	60.5	0J	0.2	1.0	2.0	1.0	1.0	0.024	4.6	—	378	0								
March	42.3	6.5	1.2	0.0	50.0	0J	0.2	1.0	2.0	1.0	1.0	0.032	3.4	—	314	0				• 0.8	1.8		• 0.36	• 590
April	50.8	8J	1.9	0.0	60.7	0J	0.2	1.0	2.0	1.0	1.0	0.025	4.8	—	292	0								
May	51.5	8.8	1.9	0.0	62.2	0J	0.2	1.0	2.0	1.0	1.0	0.015	8.3	—	319	0								
June	44.9	8.5	2.1	0.0	55.8	0J	0.2	1.0	2.0	1.0	1.0	0.007	4.9	—	311	0								
July	50.9	10.4	2.9	0.0	64.2	0J	0.2	1.0	2.0	1.0	1.0	0.024	9.9	—	362	0								
August	52.7	12.5	2.5	0.0	67.7	0J	0.2	1.0	2.0	1.0	1.0	0.060	3.5	—	378	0								
September	59.6	15.0	3.2	0.0	77.8	0J	0.2	1.0	2.0	1.0	1.0	0.026	3.7	—	420	0				• 1.0	2.5		• 0.5	• 440
October	56.0	11.7	1.9	0.0	69.6	0J	0.2	1.0	2.0	1.0	1.0	0.032	6.3	—	467	0								
November	62.9	6.5	0.8	0.0	70.2	0J	0.2	1.0	2.0	1.0	1.0	0.030	5.3	—	372	0								
December	36.4	5J	1.0	0.2	42.7	0J	0.2	1.0	2.0	1.0	1.0	0.026	4.4	—	310	0				• 1.8	4.3		• 0.6	• 460
Average	49.9	9.3	1.8	0.0	61.0	0J	0.2	1.0	2.0	1.0	1.0	0.026	5J	—	358	0				• 0.8	2.9		• 0.36	• 463
Maximum	62.9	15.0	3.2	0.2	77.8	0J	0.2	1.0	2.0	1.0	1.0	0.060	9.9	—	467	0				• 1.8	4.3		• 0.6	• 590
Minimum	36.4	5J	0.8	0.0	42.7	0J	0.2	1.0	2.0	1.0	1.0	0.007	2J	—	292	0				• 0.8	1.8		• 0.5	• 440

NAB Form 648 rev. JUNE "86"

W.A. Dwg No 100.1-4 14-4

WASHINGTON AQUEDUCT DIVISION

U.S. ARMY ENGINEER DISTRICT, BALTIMORE

COMPOSITE ANALYSIS OF WATER
BY DALECARLIA LABORATORY

POTOMAC RIVER RAW WATER SUPPLY

1986	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphorous	Silicates	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	8.0	83	7.9	42	206	151	—	16.8	0.21	—	2.4	49.3	2.32	0.02	0.04	0.31	.001	.038	.0000	44	.002	.001	.29	.0000	9	.048	.0001	.004	2.01	.001	.0000	9.8	.234	.006
February	7.7	54	20.6	43	206	115	—	22.0	0.16	—	3.8	29.9	2.10	0.03	0.06	0.30	.001	.054	.0001	30	.001	.002	.29	.0006	9	.049	.0000	.003	2.10	.000	.0000	11.8	.188	.004
March	7.7	57	48.1	51	276	108	—	14.0	0.19	—	3.4	28.2	3.21	0.00	0.00	0.80	.001	.040	.0000	31	.001	.003	.28	.0004	7	.053	.0003	.002	1.79	.001	.0000	8.8	.156	.003
April	8.2	81	15.6	61	175	114	—	12.6	0.16	—	3.5	27.3	1.26	0.00	0.03	3.38	.001	.050	.0000	31	.003	.004	.59	.0005	8	.166	.0000	.003	2.11	.000	.0000	9.4	.196	.005
May	8.0	76	12.8	73	248	124	—	12.7	0.16	—	3.7	30.5	1.02	0.01	0.02	0.54	.001	.053	.0001	36	.001	.002	.93	.0004	8	.093	.0000	.002	1.30	.000	.0001	7.5	.187	.013
June	7.8	76	12.6	82	252	121	—	14.8	0.16	—	2.2	34.4	0.96	0.00	0.02	0.31	.001	.050	.0001	35	.001	.002	.48	.0013	8	.153	.0001	.002	2.25	.001	.0000	8.1	.187	.004
July	7.4	68	15.4	85	236	129	—	20.8	0.21	—	1.9	49.2	0.81	0.02	0.02	0.31	.002	.074	.0000	36	.001	.002	.48	.0007	9	.085	.0000	.003	3.02	.000	.0001	19.0	.222	.002
August	7.4	68	12.6	81	276	129	—	26.8	0.25	0.09	1.4	67.3	0.29	0.05	0.07	0.87	.000	.058	.0001	33	.001	.005	.70	.0006	11	.160	.0000	.005	3.14	.001	.0000	22.3	.182	.006
September	7.8	90	9.5	74	319	166	—	28.0	0.21	0.07	2.4	98.2	0.83	0.03	0.10	0.64	.002	.074	.0000	48	.001	.002	.50	.0010	10	.069	.0000	.002	3.45	.002	.0000	24.4	.234	.003
October	7.9	99	6.9	65	318	184	—	28.8	0.25	0.05	2.7	113.5	0.84	0.00	0.04	0.74	.024	.095	.0003	54	.001	.003	.84	.0016	12	.096	.0000	.004	3.39	.001	.0001	28.2	.371	.003
November	7.8	89	8.6	52	298	171	—	22.4	0.18	0.03	0.7	77.2	1.13	0.00	0.03	0.11	.001	.079	.0002	51	.000	.002	.43	.0095	10	.038	.0000	.003	3.21	.000	.0001	28.0	.278	.006
December	7.7	63	24.1	46	172	115	—	16.5	0.14	0.07	1.6	40.8	1.98	0.00	0.06	0.15	.000	.051	.0002	34	.000	.003	.81	.0018	7	.052	.0000	.003	3.25	.000	.0000	12.3	.183	.006
Average	7.8	74	16.2	63	247	136	—	19.5	0.19	0.06	2.5	53.3	1.36	0.01	0.04	0.69	.003	.061	.0001	39	.001	.002	.55	.0015	9	.069	.0000	.003	2.59	.001	.0000	15.9	.218	.006
Maximum	8.2	99	48.1	85	318	187	—	28.8	0.25	0.09	3.7	113.5	3.21	0.05	0.10	3.38	.024	.095	.0003	54	.005	.005	.93	.0095	12	.166	.0003	.005	3.45	.002	.0001	28.2	.371	.013
Minimum	7.4	54	6.9	42	172	109	—	12.6	0.14	0.03	0.7	27.3	0.29	0.00	0.00	0.11	.000	.040	.0000	30	.000	.001	.28	.0000	7	.038	.0000	.002	1.30	.000	.0000	7.5	.158	.002

DALECARLIA WATER TREATMENT PLANT FINISHED WATER

1986	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphorous	Silicates	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	7.8	64	0.31	44	233	156	2.02	18.8	1.12	—	2.7	55.3	2.30	0.00	0.01	0.09	.001	.063	.0000	47	.001	.003	.014	.0000	9	.003	.0001	.003	2.01	.001	.0000	9.8	.206	.001
February	8.1	56	0.23	46	212	129	1.90	24.6	1.08	—	3.6	38.7	2.11	0.00	0.01	0.11	.000	.046	.000	36	.001	.002	.016	.0001	9	.003	.0000	.002	2.14	.001	.0001	12.3	.182	.001
March	8.2	59	0.19	53	194	122	1.87	16.8	0.99	—	3.2	35.8	3.21	0.00	0.00	0.10	.001	.043	.0000	36	.001	.001	.013	.0002	7	.002	.0000	.001	1.83	.001	.0000	8.8	.154	.001
April	8.1	61	0.43	64	150	123	1.95	18.0	0.89	—	3.5	35.6	1.37	0.00	0.00	0.31	.000	.049	.0000	35	.001	.002	.018	.0000	10	.004	.0000	.001	2.20	.000	.0001	9.2	.180	.005
May	7.8	74	0.62	71	234	131	2.00	17.8	0.84	—	2.8	37.6	1.01	0.00	0.00	0.83	.001	.057	.0001	37	.000	.003	.020	.0004	8	.005	.0000	.001	1.88	.000	.0001	7.6	.218	.017
June	7.7	75	0.67	80	246	136	2.20	20.5	0.82	—	1.7	42.8	0.93	0.00	0.00	0.19	.000	.043	.0001	38	.001	.004	.036	.0005	9	.007	.0000	.001	2.22	.001	.0000	8.9	.186	.002
July	7.7	70	0.71	83	222	147	2.26	27.9	0.95	—	1.7	59.0	0.36	0.00	0.00	0.42	.001	.061	.0000	43	.001	.006	.033	.0006	9	.018	.0000	.001	3.00	.000	.0000	18.8	.218	.001
August	7.7	71	0.40	80	235	144	2.36	31.5	0.92	0.00	1.3	74.9	0.31	0.00	0.03	0.27	.001	.058	.0001	39	.001	.005	.033	.0002	10	.027	.0000	.002	3.10	.001	.0000	22.7	.298	.003
September	7.8	97	0.38	74	306	167	2.15	29.7	0.89	0.00	2.1	99.4	0.62	0.00	0.04	0.36	.001	.071	.0000	51	.001	.003	.010	.0010	11	.006	.0000	.001	3.44	.002	.0000	23.[illegible]	.305	.007
October	7.9	96	0.22	65	330	196	2.14	30.9	0.83	0.00	2.7	119.0	0.69	0.00	0.01	0.06	.000	.101	.0003	58	.000	.006	.009	.0014	12	.007	.0000	.004	3.45	.000	.0001	28.9	.302	.002
November	7.8	87	0.28	54	329	181	2.22	27.8	0.95	0.01	0.5	88.2	1.21	0.00	0.00	0.06	.000	.058	.0003	55	.000	.003	.010	.0011	10	.002	.0000	.002	3.20	.000	.0001	22.0	.303	.017
December	7.8	82	0.26	49	190	130	2.27	20.1	0.99	0.00	1.4	51.8	2.19	0.00	0.00	0.10	.000	.069	.0001	39	.001	.004	.011	.0011	9	.002	.0000	.002	3.32	.000	.0001	12.0	.179	.004
Average	7.8	74	0.40	64	238	147	2.12	23.6	0.96	0.00	2.5	81.4	1.36	0.00	0.01	0.28	.001	.058	.0001	43	.001	.004	.019	.0006	10	.007	.0000	.002	2.85	.001	.0001	15.4	.223	.006
Maximum	8.2	98	0.71	83	330	196	2.36	31.5	1.12	0.01	4.8	119.0	3.21	0.00	0.04	0.83	.001	.101	.0003	58	.001	.006	.036	.0014	12	.027	.0001	.004	3.45	.002	.0001	28.9	.305	.017
Minimum	7.8	56	0.19	44	150	122	1.87	16.0	0.84	0.00	1.3	35.8	0.31	0.00	0.00	0.06	.000	.043	.0000	35	.000	.001	.009	.0000	7	.002	.0000	.001	1.83	.000	.0000	7.8	.154	.001

McMILLAN WATER TREATMENT PLANT FINISHED WATER

1986	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphorous	Silicates	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	7.7	70	0.21	41	202	150	1.93	20.8	1.14	—	3.6	64.8	2.23	0.00	0.01	0.05	.001	.048	.0000	43	.001	.011	.007	.0007	10	.002	.0000	.003	1.71	.000	.0000	8.0	.217	.003
February	7.8	52	0.17	43	206	130	1.71	23.9	0.86	—	2.9	44.8	2.09	0.00	0.01	0.06	.000	.045	.0000	37	.000	.012	.016	.0005	9	.001	.0000	.002	1.88	.000	.0001	8.7	.184	.003
March	7.7	43	0.15	42	269	109	1.90	18.5	0.90	—	3.3	36.6	3.21	0.00	0.00	0.40	.001	.042	.0000	32	.001	.004	.011	.0001	6	.002	.0006	.002	1.98	.001	.0000	8.8	.146	.003
April	7.8	57	0.49	50	145	120	1.94	17.4	0.86	—	2.6	36.0	1.58	0.00	0.00	0.15	.000	.045	.0000	35	.001	.012	.011	.0002	10	.003	.0001	.001	2.06	.000	.0001	7.7	.177	.003
May	7.7	67	0.47	59	234	129	1.95	17.1	0.87	—	2.4	38.2	0.99	0.01	0.00	0.06	.000	.058	.0001	36	.001	.010	.023	.0009	9	.002	.0003	.002	1.97	.000	.0001	7.3	.189	.001
June	7.7	70	0.77	68	240	130	2.11	19.8	0.95	—	1.3	42.7	3.48	0.00	0.00	0.12	.001	.061	.0001	38	.000	.013	.018	.0010	7	.009	.0001	.002	2.39	.001	.0000	8.9	.208	.003
July	7.9	65	0.91	73	239	141	2.23	29.8	1.20	—	1.4	60.6	0.48	0.00	0.00	0.30	.000	.067	.0000	40	.001	.023	.038	.0002	9	.011	.0000	.002	2.97	.000	.0000	16.1	.220	.001
August	7.8	67	0.47	74	306	143	2.24	33.5	0.95	0.00	2.4	71.8	0.37	0.00	0.03	0.15	.000	.061	.0001	39	.001	.019	.024	.0004	10	.010	.0001	.002	3.12	.001	.0000	19.1	.328	.003
September	7.9	88	0.84	70	314	175	2.31	30.2	0.94	0.00	2.1	99.6	0.62	0.00	0.05	0.49	.001	.066	.0000	51	.001	.049	.020	.0010	11	.006	.0000	.002	3.37	.002	.0000	24.4	.227	.002
October	7.8	91	0.33	67	328	189	2.29	32.0	0.92	0.00	2.7	113.0	0.72	0.00	0.01	0.09	.000	.061	.0006	55	.000	.043	.014	.0013	12	.014	.0000	.003	3.30	.000	.0000	27.3	.285	.010
November	7.7	89	0.27	60	293	184	2.24	30.2	0.82	0.00	0.7	99.1	0.95	0.00	0.00	0.08	.000	.069	.0003	56	.000	.060	.018	.0022	10	.002	.0000	.003	3.33	.000	.0001	28.0	.299	.081
December	7.7	61	0.33	51	172	128	2.18	19.7	0.88	0.00	1.7	58.8	1.79	0.00	0.00	0.04	.000	.029	.0002	39	.001	.016	.010	.0022	6	.001	.0000	.002	3.19	.000	.0001	12.5	.239	.012
Average	7.8	69	0.44	59	247	144	2.10	24.4	0.95	0.00	2.2	63.8	1.54	0.00	0.01	0.18	.000	.054	.0001	42	.001	.023	.017	.0009	10	.005	.0001	.002	2.58	.000	.0000	14.9	.220	.006
Maximum	7.9	91	0.91	74	329	189	2.34	33.5	1.20	0.00	3.6	113.0	3.48	0.01	0.05	0.49	.001	.069	.0006	56	.001	.060	.038	.0022	12	.014	.0006	.003	3.37	.002	.0001	28.0	.328	.081
Minimum	7.6	43	0.15	41	145	109	1.71	17.1	0.82	0.00	0.7	36.0	0.37	0.00	0.00	0.04	.000	.029	.0000	32	.000	.004	.007	.0001	6	.001	.0000	.001	1.81	.000	.0000	7.3	.126	.001

NAB Form 648 rev. JUNE "86"

W.A. Dwg. No. 100.1-4.14-5

WASHINGTON AQUEDUCT DIVISION

U.S. ARMY ENGINEER DISTRICT, BALTIMORE

COMPOSITE ANALYSIS OF WATER
BY DALECARLIA LABORATORY

POTOMAC RIVER RAW WATER SUPPLY

1986	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Total Trihalomethanes ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohms/cm	Total Coliform MPN	Fecal Coliform MPN	Fecal Strep MPN	Algae Count Org/ml	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226-228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l
January	1.3	0.4	0.0	0.0	1.7	0J	0.2	1.0	2.0	1.0	1.0	0.19	5	7.5	404	2012	182	351	-					
February	0.4	0.0	0.0	0.0	0.4	0J	0.2	1.0	2.0	1.0	1.0	0.04	5	7.7	314	30604	862	310	-					
March	1.2	0.3	0J	0.0	1.6	0J	0.2	1.0	2.0	1.0	1.0	0.02	10	7.8	285	7375	76	150	-					
April	1.4	0J	0.0	0.0	1.5	0J	0.2	1.0	2.0	1.0	1.0	0.02	13	8.3	290	10059	42	[illegible]	-					
May	2.7	0.2	0.0	0.0	2.9	0J	0.2	1.0	2.0	1.0	1.0	0.02	17	7.5	298	2823	78	171	288					
June	1.3	0.3	0J	0.0	1.7	0J	0.2	1.0	2.0	1.0	1.0	0.03	13	6.2	345	12582	155	84	474					
July	1.2	0.3	0J	0.0	1.8	0J	0.2	1.0	2.0	1.0	1.0	0.00	26	4.6	381	2824	1478	12	279					
August	1.5	0.5	0J	0.0	2J	0J	0.2	1.0	2.0	1.0	1.0	0.00	8	5.8	430	2576	80	82	298					
September	1.3	0J	0.0	0.0	1.4	0J	0.2	1.0	2.0	1.0	1.0	0.05	14	7J	515	1163	39	9	0					
October	1.4	0.3	0.0	0.0	1.7	0J	0.2	1.0	2.0	1.0	1.0	0.06	17	7.4	568	4285	364	82	-					
November	2.7	0.0	0.0	0.0	2.7	0J	0.2	1.0	2.0	1.0	1.0	0.03	15	7.5	490	4931	847	1047	-					
December	1.3	0.3	0.0	0.0	1.6	0J	0.2	1.0	2.0	1.0	1.0	0.04	3	8.5	326	74104	1470	482	-					
Average	1.5	0.2	0.0	0.0	1.7	0J	0.2	1.0	2.0	1.0	1.0	0.04	12	7.2	388	12993	473	230	262					
Maximum	2.7	0.5	0J	0.0	2.9	0J	0.2	1.0	2.0	1.0	1.0	0.19	26	8.5	568	74104	1478	1047	474					
Minimum	0.4	0.0	0.0	0.0	0.4	0J	0.2	1.0	2.0	1.0	1.0	0.00	3	4.6	285	1163	39	9	0					

DALECARLIA WATER TREATMENT PLANT FINISHED WATER

1986	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Total Trihalomethanes ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohms/cm	Total Coliform MPN	Fecal Coliform MPN	Fecal Strep MPN	Algae Count Org/ml	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226-228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l
January	18.6	8.0	1.4	0.0	28	0J	0.2	1.0	2.0	1.0	1.0	0.07	2	9.0	411	0.0				4.0	2.3		-0.7	-440
February	26.6	5.6	0.8	0.0	33	0J	0.2	1.0	2.0	1.0	1.0	0.02	2	9.0	341	0.2								
March	25.3	7.3	1.4	0.0	34	0J	0.2	1.0	2.0	1.0	1.0	0.01	4	9.0	322	0.8								
April	49.0	11.3	1.8	0.0	63	0J	0.2	1.0	2.0	1.0	1.0	0.00	3	9.6	332	0.8				4.0	2.9		4.8	-440
May	64.5	11.8	1.2	0.0	78	0J	0.2	1.0	2.0	1.0	1.0	0.00	6	8.2	332	0.0								
June	74.1	14.7	1.9	0.0	91	0J	0.2	1.0	2.0	1.0	1.0	0.01	6	8.0	379	0.0								
July	85.7	15.8	2.4	0.0	104	0J	0.2	1.0	2.0	1.0	1.0	0.00	13	7.0	428	0.2				<1.5	4.8		-0.8	-440
August	86.9	15.4	1.3	0J	84	0J	0.2	1.0	2.0	1.0	1.0	0.00	8	8.0	455	2.5								
September	56.5	15.3	2.3	0.0	74	0J	0.2	1.0	2.0	1.0	1.0	0.00	7	7.7	534	0.4								
October	49.2	12.4	1.8	0.0	63	0J	0.2	1.0	2.0	1.0	1.0	0.03	8	8J	599	0.0				4.8	3.5		-0.8	-440
November	59.5	14.0	2.0	0.0	76	0J	0.2	1.0	2.0	1.0	1.0	0.02	9	8.6	513	0J								
December	19J	4J	0.7	0.0	24	0J	0.2	1.0	2.0	1.0	1.0	0.00	4	9.7	34[illegible]	0.3								
Average	49.8	11.3	1.6	0.0	63	0J	0.2	1.0	2.0	1.0	1.0	0.01	6	8.6	417	0.4				4.3	2.3		-0.8	-440
Maximum	85.7	15.8	2.4	0J	104	0J	0.2	1.0	2.0	1.0	1.0	0.07	13	9.7	599	2.5				4.8	4.8		4.8	-440
Minimum	18.6	4J	0.7	0.0	24	0J	0.2	1.0	2.0	1.0	1.0	0.00	2	7.0	322	0.0				4.0	2.3		-0.8	-440

McMILLAN WATER TREATMENT PLANT FINISHED WATER

1986	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Total Trihalomethanes ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohms/cm	Total Coliform MPN	Fecal Coliform MPN	Fecal Strep MPN	Algae Count Org/ml	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226-228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l
January	30.2	9.5	2.4	0.0	42	0J	0.2	1.0	2.0	1.0	1.0	0.10	3	-	392	0.0				4.1	1.8		-0.7	-440
February	44.2	10.4	1.9	0.0	57	0J	0.2	1.0	2.0	1.0	1.0	0.02	2	-	348	0.0								
March	37J	7.4	1.2	0.0	46	0J	0.2	1.0	2.0	1.0	1.0	0.00	4	-	306	0.0								
April	50.8	10.0	1.6	0.0	62	0J	0.2	1.0	2.0	1.0	1.0	0.00	2	-	319	0.0				4.0	2.3		4.8	-440
May	61.0	12.8	2.0	0.0	76	0J	0.2	1.0	2.0	1.0	1.0	0.00	8	-	317	0.2								
June	70.6	14.5	2.5	0.0	86	0J	0.2	1.0	2.0	1.0	1.0	0.00	9	-	356	0.0								
July	78.4	15.8	2.9	0.0	97	0J	0.2	1.0	2.0	1.0	1.0	0.00	12	-	418	0.0				<1.2	3.8		-0.8	-440
August	72.6	14.2	1.6	0.0	89	0J	0.2	1.0	2.0	1.0	1.0	0.00	5	-	455	0.0								
September	60.2	15.9	2.6	0.0	79	0J	0.2	1.0	2.0	1.0	1.0	0.00	6	-	523	0.0								
October	55.6	13J	1.7	0.0	70	0J	0.2	1.0	2.0	1.0	1.0	0.03	7	-	579	0.0				<1.8	3.7		-0.6	-440
November	45.8	12J	1.9	0.0	60	0J	0.2	1.0	2.0	1.0	1.0	0.01	8	-	533	0.0								
December	21.9	4.5	0.8	0.0	27	0J	0.2	1.0	2.0	1.0	1.0	0.01	6	-	364	0.0								
Average	52.4	11.7	1.9	0.0	66	0J	0.2	1.0	2.0	1.0	1.0	0.01	6	-	409	0.0				<1.2	2.9		-0.8	-440
Maximum	78.4	15.9	2.9	0.0	97	0J	0.2	1.0	2.0	1.0	1.0	0.10	12	-	579	0.2				<1.2	3.8		<1.8	-440
Minimum	21.9	4.5	0.8	0.0	27	0J	0.2	1.0	2.0	1.0	1.0	0.00	2	-	306	0.0				<1.0	1.8		-0.8	-440

NAB Form 648 rev. JUNE "86"

W.A. Dwg. No 100.1-4 14-4

WASHINGTON AQUEDUCT DIVISION

U.S. ARMY ENGINEER DISTRICT, BALTIMORE

COMPOSITE ANALYSIS OF WATER
BY DALECARLIA LABORATORY

POTOMAC RIVER RAW WATER SUPPLY

1987	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphorous	Silicates	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	[illegible]	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	7.8	82	30.0	38	238	108	-	18.9	.24	.02	3.8	37.8	2.41	0.00	.05	4.500	.000	.029	.0001	30	.002	.003	.844	.0024	8	.043	.0000	.001	2.18	.001	.0001	7.0	197	.008
February	7.8	86	8.9	44	178	114	-	20.8	.18	.02	2.9	38.2	2.47	0.00	.04	0.834	.000	.028	.0002	38	.003	.004	.365	.0004	7	.032	.0001	.001	2.41	.002	.0001	22.3	172	.008
March	7.8	80	15.8	58	184	102	-	14.8	.17	.08	2.3	33.8	1.82	0.01	.04	0.810	.000	.033	.0002	30	.002	.003	.400	.0014	8	.002	.0000	.002	2.48	.000	.0033	5.6	100	.017
April	7.8	81	34.3	68	208	87	-	10.2	.14	.14	3.2	25.7	1.40	0.01	.05	0.505	.001	.038	.0001	26	.001	.004	.410	.0065	5	.082	.0000	.002	2.07	.001	.00[illegible]	[illegible]	.033	.000
May	7.8	81	12.2	80	188	100	-	10.1	.11	.06	4.4	25.8	1.32	0.01	.03	0.478	.000	.042	.0001	28	.001	.003	.206	.0007	6	.080	.000[illegible]	.000	1.9[illegible]	.001	.0002	[illegible]	170	.002
June	7.7	81	9.4	80	181	126	-	14.5	.20	.08	3.8	30.1	1.40	0.00	.07	0.204	.000	.041	.0000	36	.001	.002	.296	.0008	8	.058	.0000	.002	2.20	.000	.0000	7.4	148	.002
July	7.8	79	30.8	83	228	129	-	18.5	.19	.11	4.2	38.8	1.81	0.00	.04	0.440	.001	.040	.0000	37	.001	.004	.580	.0013	7	.104	.0000	.002	4.78	.001	.0000	8.0	127	.004
August	7.7	86	7.5	80	210	136	-	26.5	.23	.14	2.5	62.8	1.01	0.00	.00	0.100	.001	.043	.0000	43	.001	.003	.295	.0002	11	.018	.0000	.002	3.40	.001	.0000	15.1	.239	.002
September	7.7	81	23.7	72	220	144	-	24.3	.18	.13	2.9	54.1	1.44	0.00	.00	0.365	.001	.073	.0001	41	.001	.004	.200	.0010	9	.004	.0000	.001	3.42	.001	.0000	30.0	.217	.002
October	8.1	83	8.9	58	238	150	-	19.5	.16	.08	3.4	43.5	1.30	0.00	.04	0.154	.001	.043	.0000	43	.001	.004	.316	.0008	10	.031	.0000	.003	3.03	.002	.0000	14.7	.256	.004
November	7.8	82	8.7	50	246	142	-	23.0	.15	.17	5.0	38.0	1.42	0.00	.06	0.080	.000	.033	.0001	41	.001	.007	.970	.0002	8	.069	.0000	.002	3.44	.000	.0001	13.1	.169	.002
December	7.8	58	17.7	46	180	106	-	12.1	.12	.02	4.2	23.6	2.4	0.00	.06	0.139	.000	.032	.0000	30	.001	.004	.907	.0005	7	.044	.0000	.001	2.82	.000	.0000	7.7	132	.002
Average	7.8	72.4	17.2	63	215	122	-	17.9	.17	.08	3.6	37.2	1.03	0.00	.04	0.649	.000	.040	.0001	35	.001	.004	.474	.0010	8	.049	.0000	.002	2.83	.001	.0000	12.6	170	.004
Maximum	8.1	86	34.3	83	310	156	-	26.5	.24	.17	5.0	62.6	2.47	0.01	.07	4.500	.001	.073	.0002	43	.003	.007	.970	.0025	8	.104	.0001	.003	4.78	.002	.0001	30.0	.317	017
Minimum	7.5	51	6.8	38	181	80	-	10.1	.11	.02	2.3	23.6	1.01	0.00	.00	0.080	.000	.028	.0000	26	.001	.002	.200	.0002	11	.018	.0000	.000	1.90	.000	.0000	5.2	.098	.000

DALECARLIA WATER TREATMENT PLANT FINISHED WATER

1987	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphorous	Silicates	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	8.0	84	0.34	38	214	118	1.7	22.8	.96	.00	2.1	47.2	2.80	0.00	.00	0.198	.000	.030	.0002	35	.002	.003	.027	.0019	7	.003	.0000	.001	2.23	.001	.0000	6.3	110	.003
February	7.9	86	0.42	46	188	124	2.1	26.3	1.07	.00	1.8	38.4	2.37	0.00	.00	0.466	.000	.022	.0001	36	.002	.001	.022	.0000	7	.003	.0001	.001	2.20	.002	.0001	16.0	153	.004
March	8.1	80	0.37	58	154	115	2.1	15.7	1.01	.02	2.8	37.0	1.96	0.00	.00	0.068	.000	.033	.0001	36	.001	.003	.015	.0009	6	.007	.0000	.002	2.16	.000	.0000	6.3	100	.017
April	8.1	54	0.30	68	138	107	2.1	13.4	1.06	.04	2.5	34.8	1.48	0.00	.00	0.086	.001	.033	.0001	33	.001	.002	.012	.0014	5	.014	.0000	.001	2.08	.001	.0000	5.3	.082	.006
May	8.0	81	0.46	80	156	114	2.0	12.7	.96	.03	4.1	32.4	1.30	0.00	.00	0.046	.000	.036	.0000	35	.001	.003	.011	.0002	6	.003	.0002	.001	1.90	.000	.0000	6.5	171	.001
June	7.7	80	0.50	79	180	141	2.2	19.0	.98	.02	3.3	36.1	1.46	0.00	.01	0.112	.000	.042	.0000	45	.000	.005	.009	.0007	7	.003	.0000	.002	2.30	.000	.0000	7.3	174	[illegible]
July	7.9	81	0.37	83	230	146	2.3	23.4	.77	.01	3.5	46.3	1.85	0.00	.01	0.117	.000	.036	.0000	45	.001	.005	.031	.0000	9	.004	.0000	.002	4.40	.001	.0000	9.8	118	.001
August	7.7	81	0.43	80	264	171	2.3	32.3	.84	.02	2.5	67.3	.96	0.00	.00	0.152	.001	.054	.0000	48	.000	.008	.014	.0003	12	.003	.0000	.002	3.40	.001	.0000	11.0	.222	.002
September	7.9	80	0.48	72	229	157	2.2	27.4	.80	.02	4.1	54.6	1.26	0.00	.00	0.242	.001	.071	.0001	47	.001	.005	.008	.0007	8	.002	.0001	.001	3.47	.001	.0000	30.0	.320	.003
October	7.7	88	0.37	60	238	158	2.1	24.1	.88	.00	3.7	51.1	1.35	0.00	.00	0.143	.001	.048	.0000	48	.000	.005	.012	[illegible]	10	.001	.0000	.002	3.03	.002	.0000	17.0	.246	.001
November	7.8	80	0.44	54	234	156	1.8	26.2	.89	.01	4.2	47.4	1.54	0.00	.00	0.122	.000	.031	.0000	47	.000	.004	.024	[illegible]	8	.005	.0000	.001	3.56	.000	.0000	13.4	.198	.001
December	8.0	80	0.30	46	175	120	1.7	18.8	.93	.00	4.6	31.8	2.24	0.00	.00	0.058	.000	.030	.0000	36	.001	.004	.026	.0003	7	.005	.0000	.001	2.88	.000	.0000	7.8	123	.001
Average	7.8	72	0.40	64	206	138	2.1	21.8	.91	.01	3.3	43.9	1.98	0.00	.00	0.148	.000	.038	.0000	41	.001	.004	.018	.0006	8	.004	.0000	.001	2.79	.001	.0000	12.4	167	.003
Maximum	8.1	91	0.50	83	264	171	2.3	32.3	1.07	.04	4.6	67.3	2.80	0.00	.01	0.466	.001	.071	.0002	48	.002	.005	.031	.0019	12	.014	.0002	.002	4.40	.002	.0001	30.0	.346	.017
Minimum	7.5	54	0.30	38	154	107	1.7	12.7	.77	.00	1.8	31.8	.96	0.00	.00	0.045	.000	.022	.0000	33	.000	.001	.008	.0000	5	.001	.0000	.001	1.90	.000	.0000	5.3	110	.000

McNILLAN WATER TREATMENT PLANT FINISHED WATER

1987	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphorous	Silicates	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	8.1	63	0.46	38	232	120	1.7	20.5	1.10	.00	2.4	48.3	2.32	0.00	.00	0.152	.000	.023	.0[illegible]	35	.001	.005	.007	.0018	8	.001	.0001	.001	2.47	.003	.0000	8.6	114	.088
February	8.0	58	0.24	42	179	117	2.2	24.5	1.17	.00	2.7	41.3	2.24	0.00	.00	0.530	.000	.026	.0000	35	.002	.011	.018	.0006	6	.005	.0000	.001	2.14	.002	.0000	11.5	146	.007
March	8.1	90	0.89	44	148	115	2.1	16.8	1.18	.01	1.3	38.1	1.90	0.00	.00	0.032	.000	.030	.0003	34	.000	.004	.011	.0010	6	.001	.0001	.000	2.04	.000	.0000	11.7	130	.004
April	8.0	90	0.40	50	190	102	2.1	14.8	1.11	.01	2.3	34.5	1.20	0.00	.00	0.114	.001	.033	.0001	31	.001	.006	.013	.0015	5	.002	.0000	.002	2.08	.001	.0000	6.0	113	.000
May	8.0	53	0.67	60	196	106	2.1	13.3	1.06	.01	4.2	24.6	1.23	0.00	.00	0.124	.000	.036	.0000	32	.001	.006	.013	.0003	5	.006	.0000	.001	2.00	.001	.0000	5.7	148	.010
June	7.7	72	0.96	65	164	131	1.8	18.0	.94	.02	3.5	34.0	1.46	0.00	.01	0.126	.001	.037	.0000	40	.000	.006	.015	.0007	7	.006	.0000	.002	2.30	.000	.0000	6.8	131	.006
July	7.8	79	0.96	77	236	142	2.2	23.2	.76	.02	3.4	41.4	1.77	0.00	.00	0.110	.001	.050	.0000	42	.001	.078	.032	.0001	8	.006	.0000	.002	3.94	.001	.0000	10.2	154	.004
August	7.7	86	1.22	78	284	161	2.1	31.0	.83	.03	2.2	63.7	.82	0.00	.00	0.136	.001	.049	.0000	46	.000	.006	.023	.0002	11	.002	.0000	.002	3.40	.001	.0000	17.3	.210	.006
September	7.6	77	1.45	73	246	156	2.1	34.0	.82	.01	4.4	72.2	1.11	0.00	.00	0.357	.001	.072	.0001	47	.001	.062	.014	.0008	8	.002	.0001	.001	3.40	.001	.0000	28.6	.305	.007
October	7.8	80	0.78	62	275	151	2.1	24.2	.86	.00	2.5	49.6	1.36	0.00	.00	0.071	.001	.046	.0000	46	.000	.086	.014	.0001	9	.001	.0000	.002	3.15	.002	.0000	13.2	.332	.004
November	7.7	84	0.85	54	82	163	1.4	28.8	.10	.01	2.8	53.5	1.55	0.00	.00	0.182	.000	.035	.0000	48	.001	.036	.030	.0001	9	.005	.0000	.002	3.72	.000	.0000	18.1	.232	.006
December	8.1	56	0.36	46	176	119	1.7	17.8	.97	.00	4.4	36.1	1.78	0.00	.00	0.083	.000	.036	.0001	36	.000	.025	.011	.0000	7	.001	.0000	.001	3.33	.000	.0000	8.2	.128	.006
Average	7.8	66	0.73	57	207	132	2.0	22.2	.86	.01	3.0	44.8	1.36	0.00	.00	0.201	.001	.039	.0001	38	.001	.032	.017	.0006	7	.003	.0000	.001	2.80	.001	.0000	12.3	.172	.006
Maximum	8.1	86	1.46	78	284	163	2.2	34.0	1.18	.03	4.4	72.2	2.32	0.00	.01	0.530	.001	.060	.0003	48	.002	.086	.032	.0018	5	.006	.0001	.002	3.94	.003	.0000	28.8	.305	.023
Minimum	7.6	50	0.24	38	148	102	1.4	13.3	.78	.00	1.3	24.8	.82	0.00	.00	0.032	.000	.023	.0000	31	.000	.004	.007	.0000	6	.001	.0000	.000	2.00	.000	.0000	5.7	.14	.003

NAB Form 648 rev. JUNE "86"

W.A. Dwg. No. 100.1-4.14-5

WASHINGTON AQUEDUCT DIVISION

U.S. ARMY ENGINEER DISTRICT, BALTIMORE

COMPOSITE ANALYSIS OF WATER
BY DALECARLIA LABORATORY

POTOMAC RIVER RAW WATER SUPPLY

1987	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Total Trihalomethanes ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohms/cm	Total Coliform MPN / 100 ml	Fecal Coliform MPN / 100 ml	Fecal Strep MPN / 100 ml	Algae Count Org/ml	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226 - 228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l
January	2.4	.0	.0	.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.04	8	9.4	383	17416	2479	464	-					
February	2.8	.1	.2	.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.05	2	8.2	381	587	74	23	-					
March	1.8	.2	.1	.2	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.05	6	8.1	292	12850	378	608	-					
April	2.1	.4	.3	.3	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.03	14	7.1	243	11381	2415	363	-					
May	3.5	.4	.0	.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	12	7.0	275	3606	380	404	-					
June	3.4	.3	.0	.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.02	11	7.4	345	3346	195	17296	985					
July	4.4	.4	.0	.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.03	14	7.7	349	7396	1101	290	992					
August	6.7	1.7	.3	.1	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.04	9	7.7	445	258	79	21	1088					
September	2.3	.6	.3	.3	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.05	10	7.8	330	17279	1448	855	-					
October	1.3	1.6	.8	.3	15.9	0.0	0.0	0.0	0.0	0.0	0.0	0.05	7	8.3	292	1540	224	12	179					
November	2.8	.5	.3	.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.02	13	8.0	274	13641	810	9	-					
December	5.8	.7	.4	.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	3	7.3	174	56405	2763	469	-					
Average	4.3	.8	.2	.1	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.04	9	7.8	304	12384	1064	1736	814					
Maximum	1.3	1.7	.8	.3	15.9	0.0	0.0	0.0	0.0	0.0	0.0	0.05	14	8.4	445	56405	2762	17296	1088					
Minimum	1.8	.0	.0	.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.02	2	7.0	174	258	74	9	175					

DALECARLIA WATER TREATMENT PLANT FINISHED WATER

1987	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Total Trihalomethanes ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohms/cm	Total Coliform MPN / 100 ml	Fecal Coliform MPN / 100 ml	Fecal Strep MPN / 100 ml	Algae Count Org/ml	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226 - 228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l
January	14.8	5.1	1.4	.0	21	0.0	0.0	0.0	0.0	0.0	0.0	0.00	3	10.4	342	.40				<1.0	3.8		<0.5	<470
February	16.9	6.0	1.8	.0	25	0.0	0.0	0.0	0.0	0.0	0.0	0.00	1	8.3	353	.40								
March	20.5	7.5	1.9	.2	30	0.0	0.0	0.0	0.0	0.0	0.0	0.00	6	8.3	313	.08								
April	24.7	6.4	1.0	.1	32	0.0	0.0	0.0	0.0	0.0	0.0	0.00	3	8.1	263	.00				<0.9	2.2		<0.7	<590
May	43.5	11.1	1.2	.0	56	0.0	0.0	0.0	0.0	0.0	0.0	0.00	1	8.1	306	.00								
June	66.8	15.1	1.9	.0	84	0.0	0.0	0.0	0.0	0.0	0.0	0.00	2	8.2	370	.00								
July	102.8	13.9	1.0	.0	118	0.0	0.0	0.0	0.0	0.0	0.0	0.00	6	8.3	367	.00				<1.2	3.8		<0.9	<570
August	88.8	20.8	2.7	.1	92	0.0	0.0	0.0	0.0	0.0	0.0	0.00	5	8.4	470	.00								
September	81.5	15.4	2.3	.3	100	0.0	0.0	0.0	0.0	0.0	0.0	0.00	6	8.3	356	.00								
October	53.5	17.8	2.4	.4	74	0.0	0.0	0.0	0.0	0.0	0.0	0.00	6	8.4	313	.38								
November	52.8	14.4	1.5	.1	69	0.0	0.0	0.0	0.0	0.0	0.0	0.00	9	7.8	304	.0								
December	25.4	10.3	1.8	.1	38	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	8.0	202	.0				<1.4	3.1		-	<590
Average	47.7	12.0	1.7	.1	62	0.0	0.0	0.0	0.0	0.0	0.0	0.00	4	8.4	334	0.10								
Maximum	102.8	20.8	2.7	.4	118	0.0	0.0	0.0	0.0	0.0	0.0	0.01	9	10.4	470	.40								
Minimum	14.8	5.1	1.0	.0	21	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0	7.8	202	0								

McMILLAN WATER TREATMENT PLANT FINISHED WATER

1987	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Total Trihalomethanes ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohms/cm	Total Coliform MPN .00 ml	Fecal Coliform MPN / 100 ml	Fecal Strep MPN / 100 ml	Algae Count Org/ml	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226 - 228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l
January	14.6	4.7	.9	.0	20	0.0	0.0	0.0	0.0	0.0	0.0	0.00	3		320	0				<1.0	2.6		<0.5	<470
February	17.9	5.5	1.3	.0	25	0.0	0.0	0.0	0.0	0.0	0.0	0.00	3		350	.013								
March	20.9	8.3	2.3	.5	32	0.0	0.0	0.0	0.0	0.0	0.0	0.00	5		316	0								
April	25.5	7.7	1.4	.1	35	0.0	0.0	0.0	0.0	0.0	0.0	0.00	1		284	.013				<0.9	<1.9		<0.6	<590
May	41.8	10.8	1.8	.1	54	0.0	0.0	0.0	0.0	0.0	0.0	0.00	2		290	.014								
June	56.7	13.5	1.9	.0	72	0.0	0.0	0.0	0.0	0.0	0.0	0.01	1		340	0								
July	78.2	15.3	1.7	.1	93	0.0	0.0	0.0	0.0	0.0	0.0	0.00	4		352	0				<1.1	<4.4		<0.81	<580
August	48.3	15.7	2.6	.1	66	0.0	0.0	0.0	0.0	0.0	0.0	0.02	4		405	.23								
September	58.4	15.1	2.6	.3	76	0.0	0.0	0.0	0.0	0.0	0.0	0.00	3		359	0								
October	54.8	16.5	2.5	.4	74	0.0	0.0	0.0	0.0	0.0	0.0	0.00	3		317	0								
November	48.6	17.8	1.8	.1	68	0.0	0.0	0.0	0.0	0.0	0.0	0.00	6		350	0								
December	34.0	10.8	1.5	.1	47	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0		243	0				<1.3	3.0		-	<590
Average	41.8	11.8	1.8	.15	56	0.0	0.0	0.0	0.0	0.0	0.0	0.00	3		327	.023								
Maximum	78.2	17.8	2.6	.5	93	0.0	0.0	0.0	0.0	0.0	0.0	0.02	6		405	.23								
Minimum	14.6	4.7	.9	.0	20	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0		243	0								

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W A Dwg No 1001-4 14-4

WASHINGTON AQUEDUCT DIVISION
U.S. ARMY ENGINEER DISTRICT, BALTIMORE

COMPOSITE ANALYSIS OF WATER
BY DALECARLIA LABORATORY

POTOMAC RIVER RAW WATER SUPPLY

1988	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphate	Silicates	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	7.8	81	26.2	36	183	110		13.2	.22	*	*	26.1	2.27	.03	.02	.120	.001	.090	.0000	28	.006	.007	.311	.0041	8	.185	.0000	.005	3.70	.000	.0000	8.7	.090	.014
February	7.7	86	16.0	40	173	98		17.2	.15	.100	8.2	24.0	2.56	.07	.03	.647	.001	.032	.0000	26	.001	.004	.456	.0005	8	.029	.0000	.008	2.13	.000	.0000	7.6	.120	.002
March	8.0	82	12.1	50	136	102		15.1	.16	.053	6.8	27.0	2.12	.06	.07	.139	.000	.028	.0000	28	.001	.002	.250	.001	7	.034	.0000	.002	2.48	.000	.0000	8.8	.163	.002
April	7.7	58	12.0	58	158	96		12.7	.20	.080	3.9	27.8	1.54	.03	.09	.450	.001	.038	.0000	27	.001	.005	.741	.0008	9	.056	.0000	.004	2.07	.000	.0000	5.2	.091	.004
May	7.6	52	45.5	63	178	97		9.8	.15	.077	7.5	25.8	1.24	.00	.05	.100	.001	.034	.0000	24	.001	.003	.230	.0005	6	.025	.0000	.001	2.03	.001	.0000	5.8	.114	.002
June	7.8	63	11.1	76	198	119		16.6	.21	.076	5.2	32.4	1.94	.00	.02	.082	.000	.028	.0000	35	.000	.003	.480	.0010	7	.058	.0000	.001	2.30	.000	.0000	6.1	.134	.003
July	7.6	90	14.8	82	245	133		25.2	.20	.147	6.2	57.6	1.20	.00	.02	.224	.000	.145	.0001	39	.001	.002	.340	[illegible]	9	.087	.0000	.003	2.81	.002	.0000	27.5	.240	.003
August	7.6	97	7.1	83	275	147		28.6	.22	.201	7.7	54.5	.94	.00	.03	.302	.000	.051	.0000	38	.001	.003	.197	.0009	10	.091	.0000	.002	3.88	.000	.0000	27.5	.237	.001
September	8.1	95	6.4	72	275	151		27.9	.22	.206	5.8	58.3	1.36	.00	.03	.154	.000	.038	.0000	44	.000	.004	.099	.0003	9	.030	.0000	.002	4.05	.000	.0000	18.0	.280	.001
October	8.3	104	5.4	56	318	173		28.7	.18	.131	2.5	78.7	.49	.00	.04	.180	.000	.034	.0000	50	.000	.003	.195	.0000	11	.020	.0000	.001	1.85	.000	.0000	27.7	.319	.001
November	8.1	93	8.9	51	272	155		28.8	.17	.586	1.6	87.7	.74	.00	.02	.103	.000	.059	.0000	50	.000	.003	.103	.0003	10	.023	.0001	.002	3.80	.000	.0000	25.8	.288	.003
December	8.3	84	5.0	41	226	134		21.7	.18	.117	1.7	45.7	2.09	.00	.03	.256	.000	.030	.0001	39	.003	.002	.798	.0005	8	.023	.0000	.002	2.95	.000	.0000	9.2	.223	.003
Average	7.9	77	14.3	59	220	125		20.5	.19	.163	5.4	43.8	1.54	.02	.04	.227	.000	.039	.0000	36	.001	.003	.578	.0009	9	.046	.0000	.002	2.98	.000	.0000	13.4	.198	.003
Maximum	8.3	104	45.5	83	318	173		28.8	.22	.586	8.2	78.7	2.56	.07	.09	.647	.001	.059	.0001	50	.006	.007	.311	.0041	11	.185	.0001	.005	4.05	.002	.0000	27.7	.319	.014
Minimum	7.8	52	5.0	36	138	87		9.8	.15	.053	1.6	24.0	.49	.00	.02	.082	.000	.028	.0000	24	.000	.002	.099	.0000	6	.021	.0000	.001	2.03	.000	.0000	5.2	.080	.001

DALECARLIA WATER TREATMENT PLANT FINISHED WATER

1988	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphate	Silicates	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	8.1	82	.38	39	192	117	1.8	12.0	.97	*	*	37.5	2.13	.03	.00	.048	.001	.057	.0001	34	.001	.003	.011	.0000	7	.004	.0000	.001	2.33	.000	.0000	12.0	.144	.001
February	8.3	86	.32	42	177	110	1.7	10.8	.94	.030	7.1	38.8	2.80	.08	.00	.060	.000	.032	.0000	33	.000	.002	.015	.0000	8	.007	.0000	.001	2.13	.000	.0000	7.6	.126	.001
March	8.4	63	.33	51	150	109	1.6	18.6	.110	.017	5.7	36.8	2.18	.06	.00	.052	.000	.035	.0000	34	.000	.002	.014	.0012	5	.008	.0000	.002	2.00	.000	.0000	8.8	.131	.001
April	8.2	81	.38	58	164	104	1.7	14.8	.90	.015	4.1	34.8	1.50	.02	.00	.068	.000	.032	.0000	33	.001	.004	.039	.0001	5	.080	.0000	.001	2.19	.001	.0000	8.7	.118	.002
May	8.5	94	.28	64	175	104	1.8	13.8	.83	.021	5.7	36.4	1.43	.00	.01	.065	.000	.029	.0000	31	.000	.003	.013	.0002	8	.004	.0000	.001	2.03	.002	.0000	5.8	.114	.003
June	7.8	88	.31	79	201	129	1.9	20.8	.88	.016	3.8	38.2	1.88	.00	.01	.046	.000	.031	.0000	39	.000	.004	.011	.0006	7	.004	.0000	.002	2.26	.000	.0000	6.1	.139	.001
July	7.8	93	.34	81	207	150	2.0	32.0	.85	.061	5.2	69.8	1.24	.00	.10	.187	.000	.046	.0000	43	.000	.004	.017	.0003	9	.009	.0000	.001	2.73	.000	.0000	13.7	.238	.001
August	7.7	98	.38	82	290	180	2.1	33.2	.86	.035	6.8	80.2	.84	.00	.01	.133	.000	.044	.0000	44	.000	.005	.013	.0006	11	.002	.0000	.001	3.89	.000	.0000	22.3	.307	.002
September	7.8	85	.36	72	292	163	2.2	28.8	.84	.066	5.6	58.8	1.31	.00	.02	.202	.000	.040	.0000	47	.000	.004	.028	.0001	10	.005	.0000	.001	4.02	.000	.0000	18.8	.275	.002
October	7.9	102	.43	59	318	178	2.2	33.5	.71	.031	2.2	85.2	.52	.00	.00	.173	.000	.048	.0000	53	.000	.003	.006	.0005	11	.002	.0000	.000	3.64	.000	.0000	28.0	.347	.000
November	7.9	93	.50	52	293	169	2.2	34.8	.86	.109	1.0	80.9	.78	.00	.00	.122	.000	.034	.0000	50	.000	.003	.022	.0004	10	.002	.0000	.001	3.75	.000	.0000	26.0	.328	.000
December	8.1	81	.52	42	230	143	2.2	23.8	1.02	.042	2.8	50.2	1.83	.00	.02	.188	.000	.047	.0000	43	.002	.010	.022	.0006	8	.002	*	.001	2.96	.000	.0000	10.0	.188	.000
Average	8.0	79	.40	60	229	136	2.0	23.9	.90	.042	4.8	51.8	1.35	.02	.01	.118	.000	.039	.0000	40	.000	.004	.018	.0004	8	.006	.0000	.001	2.83	.000	.0000	13.8	.195	.001
Maximum	8.4	102	.52	82	318	178	2.2	34.8	1.10	.109	7.1	85.2	2.60	.08	.02	.237	.000	.057	.0001	53	.002	.010	.039	.0012	11	.020	.0000	.002	4.02	.002	.0000	28.0	.347	.003
Minimum	7.8	54	.31	39	150	104	1.8	12.0	.71	.010	1.0	32.8	.52	.00	.00	.048	.000	.029	.0000	31	.000	.002	.006	.0000	5	.002	.0000	.000	2.00	.000	.0000	5.8	.114	.000

McMILLAN WATER TREATMENT PLANT FINISHED WATER

1988	pH	M.O. Alkalinity as $CaCO_3$	Turbidity	Temperature	Total Solids	Hardness as $CaCO_3$	Chlorine Residual DPD Free	Chloride	Fluoride	Total Dissolved phosphate	Silicates	Sulfates Dissolved	Nitrate Nitrogen	Nitrite Nitrogen	Ammonia Nitrogen	Aluminum	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Zinc
		mg/l	NTU	°F	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
January	8.2	82	.32	38	187	119	1.7	10.2	1.08	*	*	38.9	1.85	.05	.00	.049	.000	.034	.0000	34	.000	.007	.006	.0000	8	.006	.0000	.001	2.14	.000	.0000	10.2	.150	.002
February	8.2	48	.31	38	189	108	1.8	20.2	1.02	.010	7.1	37.2	2.31	.07	.00	.118	.000	.033	.0000	31	.000	.007	.016	.0000	8	.013	.0000	.001	2.32	.000	.0000	9.2	.115	.002
March	8.4	53	.28	44	148	109	1.8	18.3	1.04	.017	6.7	38.1	2.43	.06	.00	.040	.000	.029	.0000	33	.000	.005	.010	.0008	6	.003	.0000	.001	2.80	.000	.0000	8.8	.140	.002
April	8.2	54	.31	53	173	108	1.7	18.2	1.06	.020	4.3	37.8	1.57	.02	.00	.075	.000	.028	.0000	31	.001	.007	.015	.0001	6	.003	.0000	.001	2.31	.001	.0000	8.4	.149	.002
May	8.4	50	.30	60	174	103	1.8	14.7	.88	.010	5.1	36.3	1.46	.00	.01	.064	.000	.032	.0000	30	.000	.016	.020	.0004	8	.001	.0000	.001	1.98	.001	.0000	5.2	.111	.002
June	8.1	68	.47	69	184	118	1.8	20.5	1.03	.016	5.4	38.3	1.81	.00	.01	.044	.000	.033	.0000	38	.000	.040	.013	.0003	6	.002	.0000	.001	2.85	.001	.0000	4.7	.097	.002
July	7.8	88	.48	78	205	148	1.9	33.5	1.02	.070	4.4	68.1	1.13	.00	.00	.187	.000	.046	.0000	42	.000	.085	.014	.0001	10	.005	.0000	.001	2.59	.000	.0000	11.2	.231	.003
August	7.8	88	.46	79	290	154	2.0	36.1	.98	.029	6.8	81.6	.88	.00	.01	.200	.000	.044	.0000	43	.000	.082	.002	.0010	10	.003	.0000	.002	4.08	.000	.0000	15.6	.199	.002
September	7.9	91	.44	72	291	157	2.1	36.5	.98	.044	4.8	86.2	1.20	.00	.02	.104	.000	.033	.0000	47	.000	.096	.003	.0000	9	.002	.0000	.002	3.70	.000	.0000	23.7	.36	.002
October	7.8	98	.36	63	313	177	2.1	32.4	.91	.028	3.1	84.1	.50	.00	.03	.112	.000	.044	.0000	51	.000	.034	.007	.0000	12	.002	.0000	.001	3.43	.000	.0000	20.8	.292	.002
November	7.9	93	.35	54	305	179	2.1	33.8	.92	.041	1.0	87.4	.37	.00	.00	.057	.000	.039	.0000	51	.000	.036	.012	.0005	11	.001	.0000	.001	3.68	.000	.0000	23.2	.288	.002
December	8.1	78	.38	44	234	140	2.1	23.3	.98	.035	3.5	48.9	1.98	.00	.02	.098	.000	.030	.0000	48	.003	.015	.023	.0004	8	.002	.0000	.002	3.60	.000	.0000	10.4	.190	.002
Average	8.1	73	.37	58	229	135	1.9	25.1	.98	.029	4.4	53.9	1.48	.02	.01	.092	.000	.035	.0000	39	.000	.034	.012	.0003	8	.004	.0000	.001	2.94	.000	.0000	12.8	.188	.002
Maximum	8.4	98	.48	79	313	179	2.1	36.5	1.08	.070	7.1	87.8	2.43	.07	.03	.200	.000	.046	.0000	51	.003	.096	.023	.0010	12	.013	.0000	.002	4.08	.002	.0000	23.2	.36	.002
Minimum	7.8	49	.28	38	148	103	1.6	10.2	.88	.010	1.0	37.2	.50	.00	.00	.040	.000	.028	.0000	30	.000	.005	.002	.0000	6	.001	.0000	.001	1.99	.000	.0000	4.7	.097	.002

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* No Data

W.A. Dwg. No. 100.1-4.14-5

WASHINGTON AQUEDUCT DIVISION

U.S. ARMY ENGINEER DISTRICT, BALTIMORE

COMPOSITE ANALYSIS OF WATER
BY DALECARLIA LABORATORY

POTOMAC RIVER RAW WATER SUPPLY

1988	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Total Trihalomethanes ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l											Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohms/cm	Total Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Strep MPN/100 ml	Algae Count Org/ml	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226 - 228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l
January	2.2	.2	.2	.0	2.6	.0	.0	.0	.0	.0	.0											*	10	8.6	143	23000	1100	417						
February	4.0	.4	.2	.1	4.7	.0	.0	.0	.0	.0	.0											.09	13	8.2	155	38400	2200	209						
March	2.0	.7	.5	.0	3.2	.0	.0	.0	.0	.0	.0											.04	5	8.6	177	14000	256	44						
April	3.1	.6	.3	.1	6.1	.0	.0	.0	.0	.0	.0											.02	9	8.6	187	1120	137	15						
May	5.8	.4	.1	.0	6.0	.0	.0	.0	.0	.0	.0											.04	25	9.3	163	23000	27400	2083						
June	18.6	.8	.1	.0	18.3	.0	.0	.0	.0	.0	.0											.04	29	7.9	279	3428	94	7	1333					
July	11.9	.5	.1	.0	11.7	.0	.0	.0	.0	.0	.0											.03	21	7.1	302	3000	280	84	2280					
August	10.8	1.1	.1	.0	12.0	.0	.0	.0	.0	.0	.0											.04	11	7.6	419	1240	29	29	5364					
September	14.8	1.8	.2	.0	16.8	.0	.0	.0	.0	.0	.0											.01	4	9.2	344	818	32	45						
October	7.5	1.3	.0	.1	11.6	.0	.0	.0	.0	.0	.0											.02	8	9.0	390	177	41	22						
November	1.7	.4	.0	.0	2.1	.0	.0	.0	.0	.0	.0											.00	1	8.6	303	2700	205	330						
December	.4	.1	.2	.0	.7	.0	.0	.0	.0	.0	.0											.04	6	9.7	220	1236	10	11						
Average	6.7	.7	.2	.0	7.8	.0	.0	.0	.0	.0	.0											.03	12	8.5	283	25250	2804	325	2364					
Maximum	14.8	1.8	.5	.1	16.8	.0	.0	.0	.0	.0	.0											.09	29	9.7	419	23000	27400	2083	5364					
Minimum	.4	.1	.0	.0	.7	.0	.0	.0	.0	.0	.0											.00	1	7.1	143	177	10	7	1333					

DALECARLIA WATER TREATMENT PLANT FINISHED WATER

1988	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Total Trihalomethanes ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Benzene ug/l	Carbon Tetrachloride ug/l	1,2-Dichloroethylene ug/l	Trichloroethylene ug/l	Para-Dichlorobenzene ug/l	1,1-Dichloroethylene ug/l	1,1,1-Trichloroethane ug/l	Vinyl Chloride ug/l			Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohms/cm	Total Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Strep MPN/100 ml	Algae Count Org/ml	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226 - 228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l
January	18.6	6.7	1.8	.1	29	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			*	4	10.1	175	.00				<1.3	2		<0.8	<300
February	28.1	10.1	2.2	.0	40	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.01	6	9.4	183	.00								
March	23.6	10.0	3.1	.1	37	.0	.0	.0	.0	.0	.0											.01	3	9.3	203	.00								
April	44.6	11.4	2.2	.0	58	.0	.0	.0	.0	.0	.0											.01	4	8.1	215	.00				<1.2	2.1		<0.8	<30
May	46.4	8.6	1.4	.1	57	.0	.0	.0	.0	.0	.0											.00	6	8.9	208	.00								
June	44.2	12.4	1.8	.0	58	.0	.0	.0	.0	.0	.0											.01	9	8.3	305	.00								
July	66.9	14.5	1.1	.0	83	.0	.0	.0	.0	.0	.0											.03	9	7.9	400	.00				<3.2	3.1		<0.8	<300
August	83.8	21.8	1.9	.1	107	.0	.0	.0	.0	.0	.0											.02	8	7.9	446	.00								
September	44.5	15.4	1.2	.1	61	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.00	5	9.3	384	.00								
October	36.6	13.1	1.4	.0	49	.0	.0	.0	.0	.0	.0											.02	3	9.2	410	.00								
November	33.4	7.7	1.4	.0	43	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.00	9	9.2	341	.00				<2.4	3.1		<0.7	<300
December	64.0	15.3	4.4	.0	84	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.08	8	10.4	347	.00								
Average	44.5	12.3	2.0	.0	59	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.02	7	9.1	296	.00				<2.0	2.6		<.85	<302
Maximum	83.8	21.4	4.4	.1	107	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.08	9	10.4	446	.00				<3.2	3.1		<.7	<300
Minimum	18.6	6.7	1.1	.0	28	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.00	3	7.9	175	.00				<1.2	2.1		<.8	<310

McMILLAN WATER TREATMENT PLANT FINISHED WATER

1988	Chloroform ug/l	Bromodichloromethane ug/l	Chlorodibromomethane ug/l	Bromoform ug/l	Total Trihalomethanes ug/l	Endrin ug/l	Lindane ug/l	Methoxychlor ug/l	Toxaphene ug/l	2,4-D ug/l	2,4,5-TP (Silvex) ug/l	Benzene ug/l	Carbon Tetrachloride ug/l	1,2-Dichloroethylene ug/l	Trichloroethylene ug/l	Para-Dichlorobenzene ug/l	1,1-Dichloroethylene ug/l	1,1,1-Trichloroethane ug/l	Vinyl Chloride ug/l			Methylene Blue Active Substances mg/l	Chemical Oxygen Demand mg/l	Dissolved Oxygen mg/l	Conductivity mohms/cm	Total Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Strep MPN/100 ml	Algae Count Org/ml	Gross Alpha pCi/l	Gross Beta pCi/l	Radium 226 - 228 pCi/l	Strontium-90 pCi/l	Tritium pCi/l
January	23.7	7.2	1.7	.0	33	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			*	2		213	.00				<1.3	2.5		<0.7	<300
February	24.6	8.8	2.0	.1	35	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.03	1		197	.00								
March	26.7	9.8	2.5	.1	38	.0	.0	.0	.0	0	.0											.02	5		209	.00								
April	46.9	11.3	2.2	.0	58	.0	.0	.0	.0	.0	.0											.01	4		204	.00				<1.3	1.7		<0.8	<300
May	66.6	10.2	1.4	.1	78	.0	.0	.0	.0	.0	.0											.00	8		205	.00								
June	44.6	10.7	1.8	.0	57	.0	.0	.0	.0	.0	.0											.02	12		220	.00								
July	75.0	16.8	1.9	.0	98	.0	.0	.0	.0	.0	.0											.03	8		354	.00				<3.2	2.9		<0.8	<370
August	88.0	20.2	2.5	.2	108	.0	.0	.0	.0	.0	.0											.01	7		398	.00								
September	54.1	16.8	1.3	.1	72	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.01	5		374	.00								
October	29.9	12.2	2.0	.1	40	.0	.0	.0	.0	.0	.0											.02	3		363	.00								
November	56.9	12.4	2.2	.0	71	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.00	9		386	.00				<2.4	3.6		<0.7	<320
December	46.7	13.1	4.2	.0	67	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.02	10		272	.00								
Average	47.8	11.8	2.1	.1	63	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.02	6		290	.00				<2.1	2.73		<.88	<320
Maximum	88.0	20.2	4.2	.2	109	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.03	12		398	.00				<3.2	3.6		<.7	<370
Minimum	23.7	7.2	1.3	.0	33	.0	.0	.0	.0	.0	.0	<ND	<ND	<ND	<ND	<ND	<ND	<ND	<ND			.00	1		197	.00				<1.3	1.7		<.8	<400

NAB Form 648 rev. JUNE "86"

ND= Less than detectable limit (0.5 ug/l)

* No Data

W A Dwg No 1001 4 14 4

APPENDIX D

SUMMARY SPREADSHEET
OF SERVICE LINE INSTALLATION

YEAR	WARD 1 TOTAL SERVICES	WARD 1 KNOWN SERVICES	WARD 1 UNKNOWN SERVICES	WARD 1 % KNOWN	WARD 1 LEAD SERVICES	WARD 1 % LEAD	WARD 1 ASSUM LEAD	WARD 1 TOTAL LEAD	WARD 2 TOTAL SERVICES	WARD 2 KNOWN SERVICES	WARD 2 UNKNOWN SERVICES	WARD 2 % KNOWN	WARD 2 LEAD SERVICES	WARD 2 % LEAD	WARD 2 ASSUM LEAD	WARD 2 TOTAL LEAD
1900	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1901	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1902	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1903	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1904	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1905	0	0	0	0.00	0	0.00	0	0	1	1	0	1.00	0	0.00	0	0
1906	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1907	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1908	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1909	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1910	0	0	0	0.00	0	0.00	0	0 **	0	0	0	0.00	0	0.00	0	0 **
1911	5260	1090	4170	0.21	356	0.33	1362	1718	4387	872	3515	0.20	196	0.22	790	986
1912	159	15	144	0.09	14	0.93	134	148	101	1	100	0.01	0	0.00	0	0
1913	464	61	403	0.13	7	0.11	46	53	162	7	155	0.04	1	0.14	22	23
1914	324	33	291	0.10	9	0.27	79	88	110	6	104	0.05	0	0.00	0	0
1915	319	42	277	0.13	4	0.10	26	30	142	10	132	0.07	4	0.40	53	57
1916	180	16	164	0.09	5	0.31	51	56	141	12	129	0.09	2	0.17	22	24
1917	68	12	56	0.18	3	0.25	14	17	86	4	82	0.05	0	0.00	0	0
1918	46	7	39	0.15	0	0.00	0	0	105	11	94	0.10	3	0.27	26	29
1919	157	47	110	0.30	8	0.17	19	27	76	9	67	0.12	4	0.44	30	34
1920	156	43	113	0.28	12	0.28	32	44 **	82	4	78	0.05	2	0.50	39	41 **
1921	239	101	138	0.42	26	0.26	36	62	92	12	80	0.13	4	0.33	27	31
1922	293	74	219	0.25	18	0.24	53	71	170	21	149	0.12	3	0.14	21	24
1923	264	105	159	0.40	27	0.26	41	68	230	58	172	0.25	10	0.17	30	40
1924	179	55	124	0.31	9	0.16	20	29	263	33	230	0.13	2	0.06	14	16
1925	180	74	106	0.41	13	0.18	19	32	209	39	170	0.19	2	0.05	9	11
1926	213	145	68	0.68	12	0.08	6	18	161	76	85	0.47	6	0.08	7	13
1927	73	52	21	0.71	21	0.40	8	29	174	111	63	0.64	46	0.41	26	72
1928	72	59	13	0.82	27	0.46	6	33	111	89	22	0.80	39	0.44	10	49
1929	67	54	13	0.81	14	0.26	3	17	77	45	32	0.58	10	0.22	7	17
1930	40	30	10	0.75	6	0.20	2	8 **	81	70	11	0.86	18	0.26	3	21 **
1931	52	48	4	0.92	3	0.06	0	3	80	57	23	0.71	13	0.23	5	18
1932	42	36	6	0.86	3	0.08	1	4	67	44	23	0.66	10	0.23	5	15
1933	44	41	3	0.93	0	0.00	0	0	68	51	17	0.75	4	0.08	1	5
1934	14	14	0	1.00	1	0.07	0	1	87	75	12	0.86	10	0.13	2	12
1935	50	47	3	0.94	1	0.02	0	1	117	95	22	0.81	8	0.08	2	10
1936	62	57	5	0.92	0	0.00	0	0	192	165	27	0.86	8	0.05	1	9
1937	88	77	11	0.88	1	0.01	0	1	148	134	14	0.91	4	0.03	0	4
1938	70	65	5	0.93	0	0.00	0	0	131	117	14	0.89	5	0.04	1	6

YEAR	WARD 1 TOTAL SERVICES	WARD 1 KNOWN SERVICES	WARD 1 UNKNOWN SERVICES	WARD 1 % KNOWN	WARD 1 LEAD SERVICES	WARD 1 % LEAD	WARD 1 ASSUM LEAD	WARD 1 TOTAL LEAD		WARD 2 TOTAL SERVICES	WARD 2 KNOWN SERVICES	WARD 2 UNKNOWN SERVICES	WARD 2 % KNOWN	WARD 2 LEAD SERVICES	WARD 2 % LEAD	WARD 2 ASSUM LEAD	WARD 2 TOTAL LEAD	
1939	72	67	5	0.93	1	0.01	0	1		151	137	14	0.91	1	0.01	0	1	
1940	49	46	3	0.94	0	0.00	0	0	**	188	171	17	0.91	3	0.02	0	3	**
1941	86	82	4	0.95	1	0.01	0	1		272	238	34	0.88	3	0.01	0	3	
1942	14	9	5	0.64	0	0.00	0	0		139	117	22	0.84	8	0.07	2	10	
1943	51	50	1	0.98	6	0.12	0	6		56	55	1	0.98	18	0.33	0	18	
1944	19	16	3	0.84	8	0.50	2	10		73	66	7	0.90	37	0.56	4	41	
1945	18	18	0	1.00	5	0.28	0	5		80	73	7	0.91	15	0.21	1	16	
1946	34	32	2	0.94	4	0.13	0	4		153	140	13	0.92	21	0.15	2	23	
1947	103	56	47	0.54	2	0.04	2	4		319	174	145	0.55	3	0.02	3	6	
1948	45	44	1	0.98	0	0.00	0	0		154	134	20	0.87	0	0.00	0	0	
1949	37	23	14	0.62	0	0.00	0	0		161	140	21	0.87	0	0.00	0	0	
1950	54	49	5	0.91	1	0.02	0	1	**	171	132	39	0.77	0	0.00	0	0	**
1951	52	38	14	0.73	0	0.00	0	0		146	113	33	0.77	0	0.00	0	0	
1952	46	37	9	0.80	0	0.00	0	0		97	78	19	0.80	0	0.00	0	0	
1953	35	31	4	0.89	0	0.00	0	0		134	100	34	0.75	1	0.01	0	1	
1954	43	34	9	0.79	0	0.00	0	0		135	111	24	0.82	3	0.03	1	4	
1955	25	23	2	0.92	0	0.00	0	0		146	122	24	0.84	0	0.00	0	0	
1956	22	18	4	0.82	0	0.00	0	0		146	115	31	0.79	0	0.00	0	0	
1957	32	27	5	0.84	0	0.00	0	0		195	147	48	0.75	0	0.00	0	0	
1958	67	58	9	0.87	3	0.05	0	3		253	223	30	0.88	2	0.01	0	2	
1959	131	122	9	0.93	5	0.04	0	5		211	180	31	0.85	2	0.01	0	2	
1960	49	46	3	0.94	1	0.02	0	1	**	193	156	37	0.81	1	0.01	0	1	**
1961	34	32	2	0.94	1	0.03	0	1		172	128	44	0.74	1	0.01	0	1	
1962	39	26	13	0.67	0	0.00	0	0		204	151	53	0.74	3	0.02	1	4	
1963	34	25	9	0.74	0	0.00	0	0		170	119	51	0.70	1	0.01	0	1	
1964	79	67	12	0.85	1	0.01	0	1		198	134	64	0.68	0	0.00	0	0	
1965	43	35	8	0.81	0	0.00	0	0		223	182	41	0.82	1	0.01	0	1	
1966	39	33	6	0.85	1	0.03	0	1		237	194	43	0.82	1	0.01	0	1	
1967	17	14	3	0.82	0	0.00	0	0		347	311	36	0.90	2	0.01	0	2	
1968	26	23	3	0.88	0	0.00	0	0		183	139	44	0.76	0	0.00	0	0	
1969	126	78	48	0.62	0	0.00	0	0		106	57	49	0.54	0	0.00	0	0	
1970	31	3	28	0.10	1	0.33	9	10	**	107	5	102	0.05	0	0.00	0	0	**
1971	46	2	44	0.04	0	0.00	0	0		160	15	145	0.09	0	0.00	0	0	
1972	24	1	23	0.04	1	1.00	23	24		157	2	155	0.01	0	0.00	0	0	
1973	127	11	116	0.09	2	0.18	21	23		239	9	230	0.04	2	0.22	51	53	
1974	36	3	33	0.08	0	0.00	0	0		170	10	160	0.06	1	0.10	16	17	
1975	13	0	13	0.00	0	0.00	0	0		158	1	157	0.01	0	0.00	0	0	
1976	24	0	24	0.00	0	0.00	0	0		90	10	80	0.11	0	0.00	0	0	
1977	43	0	43	0.00	0	0.00	0	0		174	10	164	0.06	1	0.10	16	17	

YEAR	WARD 1 TOTAL SERVICES	WARD 1 KNOWN SERVICES	WARD 1 UNKNOWN SERVICES	WARD 1 % KNOWN	WARD 1 LEAD SERVICES	WARD 1 % LEAD	WARD 1 ASSUM LEAD	WARD 1 TOTAL LEAD	WARD 2 TOTAL SERVICES	WARD 2 KNOWN SERVICES	WARD 2 UNKNOWN SERVICES	WARD 2 % KNOWN	WARD 2 LEAD SERVICES	WARD 2 % LEAD	WARD 2 ASSUM LEAD	WARD 2 TOTAL LEAD
1978	22	0	22	0.00	0	0.00	0	0	101	5	96	0.05	0	0.00	0	0
1979	20	0	20	0.00	0	0.00	0	0	33	0	33	0.00	0	0.00	0	0
1980	0	0	0	0.00	0	0.00	0	0 **	0	0	0	0.00	0	0.00	0	0 **
1981	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1982	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1983	0	0	0	0.00	0	0.00	0	0	1	0	1	0.00	0	0.00	0	0
1984	0	0	0	0.00	0	0.00	0	0	1	0	1	0.00	0	0.00	0	0
1985	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1986	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1987	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1988	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1989	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
TOTAL	11082	3779	7303	0.34	664		2017	2661	14655	6633	8022	0.45	545		1252	1797

YEAR	WARD 3 TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD	WARD 4 TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD
1900	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1901	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1902	0	0	0	0.00	0	0.00	0	0	1	0	1	0.00	0	0.00	0	0
1903	0	0	0	0.00	0	0.00	0	0	11	3	8	0.27	0	0.00	0	0
1904	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1905	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1906	0	0	0	0.00	0	0.00	0	0	1	0	1	0.00	0	0.00	0	0
1907	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1908	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1909	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1910	0	0	0	0.00	0	0.00	0	0 **	0	0	0	0.00	0	0.00	0	0 **
1911	619	254	365	0.41	72	0.28	103	175	936	255	681	0.27	97	0.38	259	356
1912	69	6	63	0.09	1	0.17	11	12	56	15	41	0.27	2	0.13	5	7
1913	103	16	87	0.16	2	0.13	11	13	156	22	134	0.14	2	0.09	12	14
1914	97	14	83	0.14	0	0.00	0	0	182	20	162	0.11	4	0.20	32	36
1915	146	41	105	0.28	3	0.07	8	11	276	32	244	0.12	4	0.13	31	35
1916	131	35	96	0.27	2	0.06	5	7	384	48	336	0.13	9	0.19	63	72
1917	69	15	54	0.22	1	0.07	4	5	151	18	133	0.12	1	0.06	7	8
1918	100	27	73	0.27	0	0.00	0	0	228	32	196	0.14	5	0.16	31	36
1919	172	84	88	0.49	18	0.21	19	37	479	131	348	0.27	40	0.31	106	146
1920	118	49	69	0.42	9	0.18	13	22 **	379	121	258	0.32	32	0.26	68	100 **
1921	258	104	154	0.40	23	0.22	34	57	487	175	312	0.36	43	0.25	77	120
1922	455	195	260	0.43	67	0.34	89	156	1008	333	675	0.33	100	0.30	203	303
1923	614	334	280	0.54	98	0.29	82	180	794	263	531	0.33	95	0.36	192	287
1924	709	366	343	0.52	91	0.25	85	176	766	269	497	0.35	96	0.36	177	273
1925	897	556	341	0.62	81	0.15	50	131	1426	700	726	0.49	135	0.19	140	275
1926	871	641	230	0.74	104	0.16	37	141	1107	829	278	0.75	120	0.14	40	160
1927	588	519	69	0.88	180	0.35	24	204	576	507	69	0.88	141	0.28	19	160
1928	555	529	26	0.95	321	0.61	16	337	324	320	4	0.99	120	0.38	2	122
1929	439	421	18	0.96	219	0.52	9	228	502	495	7	0.99	308	0.62	4	312
1930	416	403	13	0.97	161	0.40	5	166 **	335	331	4	0.99	139	0.42	2	141 **
1931	510	499	11	0.98	232	0.46	5	237	549	530	19	0.97	213	0.40	8	221
1932	275	264	11	0.96	64	0.24	3	67	410	406	4	0.99	136	0.33	1	137
1933	255	245	10	0.96	50	0.20	2	52	198	193	5	0.97	38	0.20	1	39
1934	277	272	5	0.98	31	0.11	1	32	225	225	0	1.00	25	0.11	0	25
1935	601	595	6	0.99	37	0.06	0	37	707	704	3	1.00	32	0.05	0	32
1936	701	687	14	0.98	7	0.01	0	7	749	738	11	0.99	10	0.01	0	10
1937	679	676	3	1.00	11	0.02	0	11	448	448	0	1.00	8	0.02	0	8
1938	655	650	5	0.99	1	0.00	0	1	271	269	2	0.99	1	0.00	0	1

YEAR	WARD 3 TOTAL SERVICES	WARD 3 KNOWN SERVICES	WARD 3 UNKNOWN SERVICES	WARD 3 % KNOWN	WARD 3 LEAD SERVICES	WARD 3 % LEAD	WARD 3 ASSUM LEAD	WARD 3 TOTAL LEAD	WARD 4 TOTAL SERVICES	WARD 4 KNOWN SERVICES	WARD 4 UNKNOWN SERVICES	WARD 4 % KNOWN	WARD 4 LEAD SERVICES	WARD 4 % LEAD	WARD 4 ASSUM LEAD	WARD 4 TOTAL LEAD
1939	772	768	4	0.99	6	0.01	0	6	412	406	6	0.99	3	0.01	0	3
1940	731	722	9	0.99	3	0.00	0	3 **	388	387	1	1.00	2	0.01	0	2 **
1941	676	660	16	0.98	2	0.00	0	2	376	370	6	0.98	0	0.00	0	0
1942	104	100	4	0.96	28	0.28	1	29	100	100	0	1.00	0	0.00	0	0
1943	36	32	4	0.89	22	0.69	3	25	89	89	0	1.00	6	0.07	0	6
1944	15	15	0	1.00	11	0.73	0	11	4	3	1	0.75	2	0.67	1	3
1945	26	26	0	1.00	4	0.15	0	4	20	20	0	1.00	1	0.05	0	1
1946	108	105	3	0.97	17	0.16	0	17	84	83	1	0.99	10	0.12	0	10
1947	157	153	4	0.97	0	0.00	0	0	371	362	9	0.98	0	0.00	0	0
1948	247	244	3	0.99	0	0.00	0	0	261	256	5	0.98	0	0.00	0	0
1949	253	237	16	0.94	9	0.04	1	10	318	315	3	0.99	0	0.00	0	0
1950	359	353	6	0.98	0	0.00	0	0 **	547	539	8	0.99	1	0.00	0	1 **
1951	254	249	5	0.98	1	0.00	0	1	551	548	3	0.99	1	0.00	0	1
1952	254	247	7	0.97	0	0.00	0	0	291	289	2	0.99	0	0.00	0	0
1953	218	205	13	0.94	0	0.00	0	0	154	145	9	0.94	0	0.00	0	0
1954	250	238	12	0.95	0	0.00	0	0	159	156	3	0.98	0	0.00	0	0
1955	281	268	13	0.95	0	0.00	0	0	150	144	6	0.96	0	0.00	0	0
1956	138	131	7	0.95	1	0.01	0	1	105	100	5	0.95	0	0.00	0	0
1957	144	129	15	0.90	0	0.00	0	0	64	59	5	0.92	0	0.00	0	0
1958	158	144	14	0.91	1	0.01	0	1	115	111	4	0.97	0	0.00	0	0
1959	193	173	20	0.90	0	0.00	0	0	149	139	10	0.93	6	0.04	0	6
1960	113	106	7	0.94	0	0.00	0	0 **	113	113	0	1.00	0	0.00	0	0 **
1961	103	98	5	0.95	2	0.02	0	2	68	65	3	0.96	0	0.00	0	0
1962	85	79	6	0.93	0	0.00	0	0	49	45	4	0.92	0	0.00	0	0
1963	91	81	10	0.89	0	0.00	0	0	51	47	4	0.92	0	0.00	0	0
1964	97	80	17	0.82	2	0.03	0	2	64	54	10	0.84	0	0.00	0	0
1965	82	70	12	0.85	0	0.00	0	0	53	49	4	0.92	1	0.02	0	1
1966	42	36	6	0.86	0	0.00	0	0	51	48	3	0.94	1	0.02	0	1
1967	59	53	6	0.90	1	0.02	0	1	12	11	1	0.92	0	0.00	0	0
1968	47	43	4	0.91	0	0.00	0	0	51	48	3	0.94	0	0.00	0	0
1969	47	32	15	0.68	0	0.00	0	0	13	10	3	0.77	0	0.00	0	0
1970	42	5	37	0.12	0	0.00	0	0 **	15	0	15	0.00	0	0.00	0	0 **
1971	22	1	21	0.05	0	0.00	0	0	15	0	15	0.00	0	0.00	0	0
1972	23	4	19	0.17	0	0.00	0	0	14	1	13	0.07	0	0.00	0	0
1973	42	6	36	0.14	0	0.00	0	0	10	1	9	0.10	0	0.00	0	0
1974	55	2	53	0.04	0	0.00	0	0	19	1	18	0.05	0	0.00	0	0
1975	30	2	28	0.07	0	0.00	0	0	9	0	9	0.00	0	0.00	0	0
1976	75	6	69	0.08	0	0.00	0	0	22	4	18	0.18	0	0.00	0	0
1977	79	12	67	0.15	1	0.08	6	7	24	3	21	0.13	0	0.00	0	0

YEAR	WARD 3 TOTAL SERVICES	WARD 3 KNOWN SERVICES	WARD 3 UNKNOWN SERVICES	WARD 3 % KNOWN	WARD 3 LEAD SERVICES	WARD 3 % LEAD	WARD 3 ASSUM LEAD	WARD 3 TOTAL LEAD	WARD 4 TOTAL SERVICES	WARD 4 KNOWN SERVICES	WARD 4 UNKNOWN SERVICES	WARD 4 % KNOWN	WARD 4 LEAD SERVICES	WARD 4 % LEAD	WARD 4 ASSUM LEAD	WARD 4 TOTAL LEAD
1978	68	7	61	0.10	0	0.00	0	0	33	11	22	0.33	0	0.00	0	0
1979	41	4	37	0.10	0	0.00	0	0	2	0	2	0.00	0	0.00	0	0
1980	0	0	0	0.00	0	0.00	0	0 **	0	0	0	0.00	0	0.00	0	0 **
1981	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1982	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1983	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1984	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1985	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1986	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1987	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1988	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1989	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
TOTAL	17996	14423	3573	0.80	1997		628	2625	19518	13564	5954	0.69	1990		1482	3472

YEAR	WARD 5 TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD	WARD 6 TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD
1900	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1901	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1902	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1903	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1904	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1905	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1906	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1907	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1908	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1909	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1910	0	0	0	0.00	0	0.00	0	0 **	0	0	0	0.00	0	0.00	0	0 **
1911	3003	660	2343	0.22	230	0.35	817	1047	6630	1835	4795	0.28	441	0.24	1152	1593
1912	109	3	106	0.03	2	0.67	71	73	121	13	108	0.11	2	0.15	17	19
1913	175	14	161	0.08	4	0.29	46	50	247	23	224	0.09	1	0.04	10	11
1914	144	15	129	0.10	4	0.27	34	38	284	27	257	0.10	4	0.15	38	42
1915	210	22	188	0.10	7	0.32	60	67	206	22	184	0.11	5	0.23	42	47
1916	200	36	164	0.18	4	0.11	18	22	186	36	150	0.19	6	0.17	25	31
1917	163	46	117	0.28	13	0.28	33	46	114	36	78	0.32	9	0.25	20	29
1918	80	23	57	0.29	7	0.30	17	24	52	17	35	0.33	4	0.24	8	12
1919	119	31	88	0.26	4	0.13	11	15	94	36	58	0.38	5	0.14	8	13
1920	119	32	87	0.27	10	0.31	27	37 **	38	12	26	0.32	3	0.25	7	10 **
1921	232	84	148	0.36	22	0.26	39	61	88	17	71	0.19	4	0.24	17	21
1922	392	137	255	0.35	44	0.32	82	126	225	91	134	0.40	26	0.29	38	64
1923	475	179	296	0.38	52	0.29	86	138	331	120	211	0.36	30	0.25	53	83
1924	735	282	453	0.38	73	0.26	117	190	399	157	242	0.39	53	0.34	82	135
1925	1326	715	611	0.54	108	0.15	92	200	452	206	246	0.46	39	0.19	47	86
1926	823	635	188	0.77	51	0.08	15	66	426	293	133	0.69	20	0.07	9	29
1927	421	391	30	0.93	98	0.25	8	106	323	251	72	0.78	72	0.29	21	93
1928	241	230	11	0.95	111	0.48	5	116	252	248	4	0.98	94	0.38	2	96
1929	285	276	9	0.97	108	0.39	4	112	167	153	14	0.92	49	0.32	4	53
1930	216	206	10	0.95	34	0.17	2	36 **	226	214	12	0.95	60	0.28	3	63 **
1931	358	350	8	0.98	63	0.18	1	64	181	173	8	0.96	68	0.39	3	71
1932	129	124	5	0.96	24	0.19	1	25	120	114	6	0.95	45	0.39	2	47
1933	63	62	1	0.98	5	0.08	0	5	31	30	1	0.97	10	0.33	0	10
1934	97	95	2	0.98	5	0.05	0	5	47	45	2	0.96	5	0.11	0	5
1935	277	273	4	0.99	3	0.01	0	3	192	190	2	0.99	3	0.02	0	3
1936	388	384	4	0.99	8	0.02	0	8	304	300	4	0.99	4	0.01	0	4
1937	525	517	8	0.98	4	0.01	0	4	323	314	9	0.97	5	0.02	0	5
1938	375	373	2	0.99	1	0.00	0	1	394	386	8	0.98	7	0.02	0	7

YEAR	WARD 5 TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD	WARD 6 TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD
1939	403	392	11	0.97	2	0.01	0	2	472	471	1	1.00	2	0.00	0	2
1940	520	517	3	0.99	0	0.00	0	0 **	434	428	6	0.99	1	0.00	0	1 **
1941	664	659	5	0.99	1	0.00	0	1	269	266	3	0.99	2	0.01	0	2
1942	155	142	13	0.92	8	0.06	1	9	125	120	5	0.96	13	0.11	1	14
1943	37	35	2	0.95	16	0.46	1	17	69	64	5	0.93	30	0.47	2	32
1944	14	14	0	1.00	11	0.79	0	11	34	31	3	0.91	10	0.32	1	11
1945	66	64	2	0.97	7	0.11	0	7	114	112	2	0.98	8	0.07	0	8
1946	165	160	5	0.97	10	0.06	0	10	81	78	3	0.96	9	0.12	0	9
1947	351	337	14	0.96	1	0.00	0	1	75	71	4	0.95	2	0.03	0	2
1948	394	390	4	0.99	0	0.00	0	0	128	125	3	0.98	0	0.00	0	0
1949	312	303	9	0.97	0	0.00	0	0	127	123	4	0.97	1	0.01	0	1
1950	314	308	6	0.98	0	0.00	0	0 **	131	128	3	0.98	0	0.00	0	0 **
1951	498	489	9	0.98	0	0.00	0	0	121	118	3	0.98	0	0.00	0	0
1952	412	408	4	0.99	1	0.00	0	1	111	104	7	0.94	0	0.00	0	0
1953	178	175	3	0.98	2	0.01	0	2	99	89	10	0.90	1	0.01	0	1
1954	293	281	12	0.96	1	0.00	0	1	49	47	2	0.96	0	0.00	0	0
1955	206	201	5	0.98	0	0.00	0	0	535	494	41	0.92	14	0.03	1	15
1956	95	90	5	0.95	0	0.00	0	0	116	104	12	0.90	1	0.01	0	1
1957	89	83	6	0.93	0	0.00	0	0	50	48	2	0.96	0	0.00	0	0
1958	74	65	9	0.88	0	0.00	0	0	159	152	7	0.96	4	0.03	0	4
1959	185	177	8	0.96	1	0.01	0	1	90	83	7	0.92	0	0.00	0	0
1960	145	137	8	0.94	6	0.04	0	6 **	91	87	4	0.96	0	0.00	0	0 **
1961	178	169	9	0.95	2	0.01	0	2	120	110	10	0.92	0	0.00	0	0
1962	104	92	12	0.88	0	0.00	0	0	96	91	5	0.95	0	0.00	0	0
1963	65	58	7	0.89	0	0.00	0	0	98	89	9	0.91	1	0.01	0	1
1964	59	57	2	0.97	0	0.00	0	0	105	100	5	0.95	0	0.00	0	0
1965	60	57	3	0.95	0	0.00	0	0	99	90	9	0.91	0	0.00	0	0
1966	44	40	4	0.91	0	0.00	0	0	139	125	14	0.90	2	0.02	0	2
1967	38	33	5	0.87	0	0.00	0	0	98	89	9	0.91	1	0.01	0	1
1968	23	20	3	0.87	0	0.00	0	0	116	110	6	0.95	1	0.01	0	1
1969	31	23	8	0.74	0	0.00	0	0	90	70	20	0.78	1	0.01	0	1
1970	52	8	44	0.15	3	0.38	17	20 **	125	17	108	0.14	2	0.12	13	15 **
1971	22	3	19	0.14	1	0.33	6	7	80	7	73	0.09	1	0.14	10	11
1972	37	5	32	0.14	0	0.00	0	0	84	7	77	0.08	2	0.29	22	24
1973	76	0	76	0.00	0	0.00	0	0	91	9	82	0.10	0	0.00	0	0
1974	103	4	99	0.04	2	0.50	50	52	118	4	114	0.03	1	0.25	29	30
1975	22	2	20	0.09	0	0.00	0	0	127	22	105	0.17	2	0.09	10	12
1976	65	0	65	0.00	0	0.00	0	0	160	15	145	0.09	0	0.00	0	0
1977	83	1	82	0.01	0	0.00	0	0	87	5	82	0.06	0	0.00	0	0

YEAR	WARD 5 TOTAL SERVICES	WARD 5 KNOWN SERVICES	WARD 5 UNKNOWN SERVICES	WARD 5 % KNOWN	WARD 5 LEAD SERVICES	WARD 5 % LEAD	WARD 5 ASSUM LEAD	WARD 5 TOTAL LEAD	WARD 6 TOTAL SERVICES	WARD 6 KNOWN SERVICES	WARD 6 UNKNOWN SERVICES	WARD 6 % KNOWN	WARD 6 LEAD SERVICES	WARD 6 % LEAD	WARD 6 ASSUM LEAD	WARD 6 TOTAL LEAD
1978	53	1	52	0.02	0	0.00	0	0	64	5	59	0.08	0	0.00	0	0
1979	4	1	3	0.25	0	0.00	0	0	21	1	20	0.05	0	0.00	0	0
1980	0	0	0	0.00	0	0.00	0	0 **	0	0	0	0.00	0	0.00	0	0 **
1981	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1982	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1983	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1984	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1985	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1986	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1987	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1988	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1989	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
TOTAL	18369	12196	6173	0.66	1174		1662	2836	17851	9668	8183	0.54	1186		1698	2884

YEAR	WARD 7 TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD	WARD 8 TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD
1900	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1901	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1902	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1903	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1904	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1905	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1906	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1907	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1908	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1909	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1910	0	0	0	0.00	0	0.00	0	0 **	0	0	0	0.00	0	0.00	0	0 **
1911	78	21	57	0.27	2	0.10	5	7	72	16	56	0.22	1	0.06	4	5
1912	6	0	6	0.00	0	0.00	0	0	35	6	29	0.17	0	0.00	0	0
1913	6	0	6	0.00	0	0.00	0	0	26	4	22	0.15	0	0.00	0	0
1914	31	2	29	0.06	1	0.50	15	16	28	3	25	0.11	0	0.00	0	0
1915	18	3	15	0.17	0	0.00	0	0	29	4	25	0.14	0	0.00	0	0
1916	20	2	18	0.10	0	0.00	0	0	29	2	27	0.07	1	0.50	14	15
1917	73	6	67	0.08	2	0.33	22	24	15	2	13	0.13	0	0.00	0	0
1918	86	9	77	0.10	3	0.33	26	29	5	0	5	0.00	0	0.00	0	0
1919	45	12	33	0.27	5	0.42	14	19	5	2	3	0.40	1	0.50	2	3
1920	37	5	32	0.14	2	0.40	13	15 **	11	1	10	0.09	0	0.00	0	0 **
1921	65	9	56	0.14	0	0.00	0	0	15	1	14	0.07	0	0.00	0	0
1922	47	11	36	0.23	5	0.45	16	21	16	6	10	0.38	4	0.67	7	11
1923	49	14	35	0.29	6	0.43	15	21	18	3	15	0.17	1	0.33	5	6
1924	55	13	42	0.24	5	0.38	16	21	53	9	44	0.17	4	0.44	20	24
1925	90	35	55	0.39	6	0.17	9	15	40	19	21	0.48	2	0.11	2	4
1926	148	103	45	0.70	5	0.05	2	7	41	31	10	0.76	6	0.19	2	8
1927	155	111	44	0.72	13	0.12	5	18	33	30	3	0.91	11	0.37	1	12
1928	194	180	14	0.93	42	0.23	3	45	69	66	3	0.96	11	0.17	1	12
1929	223	216	7	0.97	32	0.15	1	33	42	41	1	0.98	9	0.22	0	9
1930	265	256	9	0.97	44	0.17	2	46 **	34	33	1	0.97	11	0.33	0	11 **
1931	229	226	3	0.99	72	0.32	1	73	41	41	0	1.00	12	0.29	0	12
1932	128	124	4	0.97	31	0.25	1	32	54	52	2	0.96	9	0.17	0	9
1933	69	69	0	1.00	20	0.29	0	20	15	15	0	1.00	2	0.13	0	2
1934	115	115	0	1.00	9	0.08	0	9	31	31	0	1.00	1	0.03	0	1
1935	175	172	3	0.98	3	0.02	0	3	68	66	2	0.97	2	0.03	0	2
1936	229	228	1	1.00	1	0.00	0	1	84	82	2	0.98	0	0.00	0	0
1937	302	298	4	0.99	2	0.01	0	2	96	95	1	0.99	0	0.00	0	0
1938	425	423	2	1.00	4	0.01	0	4	42	40	2	0.95	0	0.00	0	0

YEAR	WARD 7 TOTAL SERVICES	WARD 7 KNOWN SERVICES	WARD 7 UNKNOWN SERVICES	WARD 7 % KNOWN	WARD 7 LEAD SERVICES	WARD 7 % LEAD	WARD 7 ASSUM LEAD	WARD 7 TOTAL LEAD	WARD 8 TOTAL SERVICES	WARD 8 KNOWN SERVICES	WARD 8 UNKNOWN SERVICES	WARD 8 % KNOWN	WARD 8 LEAD SERVICES	WARD 8 % LEAD	WARD 8 ASSUM LEAD	WARD 8 TOTAL LEAD
1939	655	654	1	1.00	5	0.01	0	5	152	151	1	0.99	1	0.01	0	1
1940	720	713	7	0.99	1	0.00	0	1 **	154	153	1	0.99	0	0.00	0	0 **
1941	1030	1029	1	1.00	2	0.00	0	2	413	402	11	0.97	1	0.00	0	1
1942	439	433	6	0.99	102	0.24	1	103	251	243	8	0.97	49	0.20	2	51
1943	291	166	125	0.57	79	0.48	59	138	180	164	16	0.91	119	0.73	12	131
1944	362	362	0	1.00	215	0.59	0	215	132	115	17	0.87	59	0.51	9	68
1945	930	888	42	0.95	103	0.12	5	108	149	146	3	0.98	23	0.16	0	23
1946	614	586	28	0.95	24	0.04	1	25	350	349	1	1.00	88	0.25	0	88
1947	658	648	10	0.98	3	0.00	0	3	370	367	3	0.99	0	0.00	0	0
1948	411	406	5	0.99	0	0.00	0	0	278	274	4	0.99	1	0.00	0	1
1949	315	315	0	1.00	0	0.00	0	0	143	134	9	0.94	0	0.00	0	0
1950	570	566	4	0.99	0	0.00	0	0 **	253	245	8	0.97	0	0.00	0	0 **
1951	472	470	2	1.00	0	0.00	0	0	243	236	7	0.97	0	0.00	0	0
1952	511	507	4	0.99	0	0.00	0	0	383	382	1	1.00	0	0.00	0	0
1953	498	494	4	0.99	0	0.00	0	0	206	192	14	0.93	0	0.00	0	0
1954	357	345	12	0.97	0	0.00	0	0	94	86	8	0.91	1	0.01	0	1
1955	393	390	3	0.99	1	0.00	0	1	30	30	0	1.00	0	0.00	0	0
1956	160	156	4	0.98	0	0.00	0	0	13	11	2	0.85	0	0.00	0	0
1957	118	115	3	0.97	0	0.00	0	0	7	6	1	0.86	0	0.00	0	0
1958	182	175	7	0.96	0	0.00	0	0	26	22	4	0.85	0	0.00	0	0
1959	128	114	14	0.89	0	0.00	0	0	43	41	2	0.95	0	0.00	0	0
1960	86	84	2	0.98	0	0.00	0	0 **	25	25	0	1.00	0	0.00	0	0 **
1961	108	101	7	0.94	0	0.00	0	0	24	23	1	0.96	0	0.00	0	0
1962	144	143	1	0.99	0	0.00	0	0	32	29	3	0.91	0	0.00	0	0
1963	181	172	9	0.95	1	0.01	0	1	57	56	1	0.98	0	0.00	0	0
1964	230	222	8	0.97	0	0.00	0	0	43	39	4	0.91	0	0.00	0	0
1965	219	218	1	1.00	0	0.00	0	0	47	40	7	0.85	0	0.00	0	0
1966	198	179	19	0.90	0	0.00	0	0	59	55	4	0.93	0	0.00	0	0
1967	90	88	2	0.98	0	0.00	0	0	32	23	9	0.72	0	0.00	0	0
1968	91	89	2	0.98	0	0.00	0	0	42	41	1	0.98	0	0.00	0	0
1969	84	47	37	0.56	0	0.00	0	0	6	4	2	0.67	0	0.00	0	0
1970	70	24	46	0.34	1	0.04	2	3 **	16	0	16	0.00	0	0.00	0	0 **
1971	50	3	47	0.06	1	0.33	16	17	11	0	11	0.00	0	0.00	0	0
1972	39	8	31	0.21	0	0.00	0	0	10	1	9	0.10	0	0.00	0	0
1973	42	1	41	0.02	0	0.00	0	0	4	0	4	0.00	0	0.00	0	0
1974	31	0	31	0.00	0	0.00	0	0	17	0	17	0.00	0	0.00	0	0
1975	36	2	34	0.06	1	0.50	17	18	19	3	16	0.16	0	0.00	0	0
1976	55	0	55	0.00	0	0.00	0	0	80	27	53	0.34	0	0.00	0	0
1977	33	0	33	0.00	0	0.00	0	0	49	0	49	0.00	0	0.00	0	0

YEAR	WARD 7 TOTAL SERVICES	WARD 7 KNOWN SERVICES	WARD 7 UNKNOWN SERVICES	WARD 7 % KNOWN	WARD 7 LEAD SERVICES	WARD 7 % LEAD	WARD 7 ASSUM LEAD	WARD 7 TOTAL LEAD	WARD 8 TOTAL SERVICES	WARD 8 KNOWN SERVICES	WARD 8 UNKNOWN SERVICES	WARD 8 % KNOWN	WARD 8 LEAD SERVICES	WARD 8 % LEAD	WARD 8 ASSUM LEAD	WARD 8 TOTAL LEAD
1978	17	2	15	0.12	0	0.00	0	0	29	0	29	0.00	0	0.00	0	0
1979	23	1	22	0.04	0	0.00	0	0	30	0	30	0.00	0	0.00	0	0
1980	0	0	0	0.00	0	0.00	0	0 **	0	0	0	0.00	0	0.00	0	0 **
1981	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1982	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1983	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1984	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1985	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1986	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1987	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1988	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1989	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
TOTAL	15004	13579	1425	0.91	854		268	1122	5549	4816	733	0.87	430		79	509

YEAR	WARD NOT INDICATED: TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD	TOTAL FOR THE DISTRICT: TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD
1900	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1901	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1902	0	0	0	0.00	0	0.00	0	0	1	0	1	0.00	0	0.00	0	0
1903	0	0	0	0.00	0	0.00	0	0	11	3	8	0.27	0	0.00	0	0
1904	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1905	0	0	0	0.00	0	0.00	0	0	1	1	0	1.00	0	0.00	0	0
1906	0	0	0	0.00	0	0.00	0	0	1	0	1	0.00	0	0.00	0	0
1907	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1908	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1909	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1910	0	0	0	0.00	0	0.00	0	0 **	0	0	0	0.00	0	0.00	0	0
1911	260	9	251	0.03	1	0.11	28	29	21245	5012	16233	0.24	1396	0.28	4521	5917
1912	51	1	50	0.02	1	1.00	50	51	707	60	647	0.08	22	0.37	237	259
1913	87	2	85	0.02	2	1.00	85	87	1426	149	1277	0.10	19	0.13	163	182
1914	92	2	90	0.02	0	0.00	0	0	1292	122	1170	0.09	22	0.18	211	233
1915	59	0	59	0.00	0	0.00	0	0	1405	176	1229	0.13	27	0.15	189	216
1916	61	0	61	0.00	0	0.00	0	0	1332	187	1145	0.14	29	0.16	178	207
1917	61	1	60	0.02	0	0.00	0	0	800	140	660	0.18	29	0.21	137	166
1918	74	1	73	0.01	1	1.00	73	74	776	127	649	0.16	23	0.18	118	141
1919	44	1	43	0.02	0	0.00	0	0	1191	353	838	0.30	85	0.24	202	287
1920	33	0	33	0.00	0	0.00	0	0 **	973	267	706	0.27	70	0.26	185	255
1921	46	3	43	0.07	1	0.33	14	15	1522	506	1016	0.33	123	0.24	247	370
1922	69	7	62	0.10	2	0.29	18	20	2675	875	1800	0.33	269	0.31	553	822
1923	59	2	57	0.03	0	0.00	0	0	2834	1078	1756	0.38	319	0.30	520	839
1924	73	2	71	0.03	0	0.00	0	0	3232	1186	2046	0.37	333	0.28	574	907
1925	29	7	22	0.24	0	0.00	0	0	4649	2351	2298	0.51	386	0.16	377	763
1926	52	21	31	0.40	0	0.00	0	0	3842	2774	1068	0.72	324	0.12	125	449
1927	30	13	17	0.43	4	0.31	5	9	2373	1985	388	0.84	586	0.30	115	701
1928	40	21	19	0.53	13	0.62	12	25	1858	1742	116	0.94	778	0.45	52	830
1929	70	47	23	0.67	36	0.77	18	54	1872	1748	124	0.93	785	0.45	56	841
1930	35	15	20	0.43	5	0.33	7	12 **	1648	1558	90	0.95	478	0.31	28	506
1931	36	20	16	0.56	6	0.30	5	11	2036	1944	92	0.95	682	0.35	32	714
1932	33	12	21	0.36	3	0.25	5	8	1258	1176	82	0.93	325	0.28	23	348
1933	31	15	16	0.48	5	0.33	5	10	774	721	53	0.93	134	0.19	10	144
1934	60	22	38	0.37	3	0.14	5	8	953	894	59	0.94	90	0.10	6	96
1935	46	19	27	0.41	0	0.00	0	0	2233	2161	72	0.97	89	0.04	3	92
1936	47	31	16	0.66	1	0.03	1	2	2756	2672	84	0.97	39	0.01	1	40
1937	55	40	15	0.73	1	0.03	0	1	2664	2599	65	0.98	36	0.01	1	37
1938	38	19	19	0.50	0	0.00	0	0	2401	2342	59	0.98	19	0.01	0	19

YEAR	WARD NOT INDICATED: TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD	TOTAL FOR THE DISTRICT: TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD
1939	66	33	33	0.50	0	0.00	0	0	3155	3079	76	0.98	21	0.01	1	22
1940	77	48	29	0.62	0	0.00	0	0 **	3261	3185	76	0.98	10	0.00	0	10
1941	54	25	29	0.46	0	0.00	0	0	3840	3731	109	0.97	12	0.00	0	12
1942	37	7	30	0.19	2	0.29	9	11	1364	1271	93	0.93	210	0.17	15	225
1943	99	47	52	0.47	33	0.70	37	70	908	702	206	0.77	329	0.47	97	426
1944	70	14	56	0.20	8	0.57	32	40	723	636	87	0.88	361	0.57	49	410
1945	36	20	16	0.56	4	0.20	3	7	1439	1367	72	0.95	170	0.12	9	179
1946	69	49	20	0.71	2	0.04	1	3	1658	1582	76	0.95	185	0.12	9	194
1947	306	40	266	0.13	2	0.05	13	15	2710	2208	502	0.81	13	0.01	3	16
1948	43	17	26	0.40	0	0.00	0	0	1961	1890	71	0.96	1	0.00	0	1
1949	157	109	48	0.69	5	0.05	2	7	1823	1699	124	0.93	15	0.01	1	16
1950	140	105	35	0.75	1	0.01	0	1 **	2539	2425	114	0.96	3	0.00	0	3
1951	74	59	15	0.80	0	0.00	0	0	2411	2320	91	0.96	2	0.00	0	2
1952	54	43	11	0.80	4	0.09	1	5	2159	2095	64	0.97	5	0.00	0	5
1953	70	46	24	0.66	0	0.00	0	0	1592	1477	115	0.93	4	0.00	0	4
1954	80	63	17	0.79	4	0.06	1	5	1460	1361	99	0.93	9	0.01	1	10
1955	192	124	68	0.65	3	0.02	2	5	1958	1796	162	0.92	18	0.01	2	20
1956	180	122	58	0.68	0	0.00	0	0	975	847	128	0.87	2	0.00	0	2
1957	42	33	9	0.79	0	0.00	0	0	741	647	94	0.87	0	0.00	0	0
1958	121	105	16	0.87	0	0.00	0	0	1155	1055	100	0.91	10	0.01	1	11
1959	198	162	36	0.82	1	0.01	0	1	1328	1191	137	0.90	15	0.01	2	17
1960	151	133	18	0.88	2	0.02	0	2 **	966	887	79	0.92	10	0.01	1	11
1961	111	90	21	0.81	0	0.00	0	0	918	816	102	0.89	6	0.01	1	7
1962	85	69	16	0.81	0	0.00	0	0	838	725	113	0.87	3	0.00	0	3
1963	179	160	19	0.89	2	0.01	0	2	926	807	119	0.87	5	0.01	1	6
1964	146	133	13	0.91	0	0.00	0	0	1021	886	135	0.87	3	0.00	0	3
1965	104	82	22	0.79	0	0.00	0	0	930	823	107	0.88	2	0.00	0	2
1966	144	120	24	0.83	0	0.00	0	0	953	830	123	0.87	5	0.01	1	6
1967	95	81	14	0.85	0	0.00	0	0	788	703	85	0.89	4	0.01	0	4
1968	112	99	13	0.88	0	0.00	0	0	691	612	79	0.89	1	0.00	0	1
1969	103	84	19	0.82	1	0.01	0	1	606	405	201	0.67	2	0.00	1	3
1970	120	1	119	0.01	0	0.00	0	0 **	578	63	515	0.11	7	0.11	57	64
1971	116	2	114	0.02	1	0.50	57	58	522	33	489	0.06	4	0.12	59	63
1972	111	2	109	0.02	0	0.00	0	0	499	31	468	0.06	3	0.10	45	48
1973	201	13	188	0.06	4	0.31	58	62	832	50	782	0.06	8	0.16	125	133
1974	154	17	137	0.11	2	0.12	16	18	703	41	662	0.06	6	0.15	97	103
1975	101	2	99	0.02	0	0.00	0	0	515	34	481	0.07	3	0.09	42	45
1976	77	2	75	0.03	0	0.00	0	0	648	64	584	0.10	0	0.00	0	0
1977	82	4	78	0.05	1	0.25	20	21	654	35	619	0.05	3	0.09	53	56

YEAR	WARD NOT INDICATED: TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD	TOTAL FOR THE DISTRICT: TOTAL SERVICES	KNOWN SERVICES	UNKNOWN SERVICES	% KNOWN	LEAD SERVICES	% LEAD	ASSUM LEAD	TOTAL LEAD
1978	9	0	9	0.00	0	0.00	0	0	396	31	365	0.08	0	0.00	0	0
1979	5	0	5	0.00	0	0.00	0	0	179	7	172	0.04	0	0.00	0	0
1980	1	0	1	0.00	0	0.00	0	0 **	1	0	1	0.00	0	0.00	0	0
1981	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1982	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1983	0	0	0	0.00	0	0.00	0	0	1	0	1	0.00	0	0.00	0	0
1984	2	0	2	0.00	0	0.00	0	0	3	0	3	0.00	0	0.00	0	0
1985	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1986	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1987	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1988	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
1989	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00	0	0.00	0	0
TOTAL	6045	2698	3347	0.45	167		583	750	126069	81356	44713	0.65	8987		9538	18525

APPENDIX F

WATER SAMPLING INSTRUCTIONS

DPW - WASUA

WATER SAMPLING INSTRUCTIONS

Step 1 Fill the bottle labeled "A" with cold water from the kitchen faucet.

Step 2 Fill the bottle labeled "B" with cold water from the kitchen faucet.

Step 3 Fill the one gallon container with cold water from the kitchen faucet, then pour this water down the drain.

Step 4 Fill the bottle labeled "C" with cold water from the kitchen faucet.

Step 5 Fill and empty the one gallon container with cold water from the kitchen faucet two times.

Step 6 Fill the bottle labeled "D" with cold water from the kitchen faucet.

Step 7 Place the four sample bottles outside of your home's front door where a District representative can pick them up during the day.

Thank you very much for your kind assistance!

APPENDIX G

WATER SAMPLING QUESTIONNAIRE

WATER SAMPLING QUESTIONNAIRE

ADDRESS _____

_____

DATE SAMPLES WERE TAKEN _____

HOW LONG WAS THE WATER OFF BEFORE SAMPLING ? _____

HOW OLD IS THE HOUSE ? _____

HAS ANY PLUMBING WORK BEEN DONE IN THE HOUSE WITHIN THE LAST 2 YEARS ? IF YES, PLEASE DESCRIBE BRIEFLY.

_____

_____

_____

WERE ANY PROBLEMS ENCOUNTERED WHILE TAKING THE WATER SAMPLES ? IF YES, PLEASE DESCRIBE BRIEFLY.

_____

_____

_____

APPENDIX H

TAP FILE DATABASE
USER'S GUIDE

SECTION 3

TAP FILE DATABASE

3.1 INTRODUCTION

The Tap File Database was developed using a variety of data sources. The main source of data was the Tap File located at the Bryant Street Pumping Station. Other data sources were used to fill in gaps in the Tap File, and to update the data based on recent service line replacement activities.

One of the main purposes of the Tap File Database was to develop a computerized database to analyze trends of lead service line installation. For this purpose, two fields are most significant. The field PIPEMATL records the material of the District's portion of the service line. The field CUSTSERV records the service line material on the customer's side.

3.2 DESCRIPTION OF THE TAP FILE DATABASE FIELDS

This subsection describes the various sources of data that were used to compile the Tap File Database. The following data sources were used:

- Tap File
- Meter File
- Maintenance File
- Planning Commission File
- Lead Service Replacement Program File
- Meter Relocation Program File
- Street Replacement Program File
- Project Locator Data File

Table 3-1 lists each data source, its location, the form in which the data were found, and how each source was used in creating the Tap File Database. Figure 3-1 shows the schematic interaction of the various data files in relation to the final Tap File Database.

The database was set up on IBM-compatible personal computers using dBASE IV software. Table 3-2 shows the final structure of the Tap File Database record.

3.2.1 Tap File

The major source of information was the Tap File, which is a collection of index cards stored in the Bureau of Water Measurement and Billing (BWMB) offices at the Bryant Street Pumping Station. The database created from the Tap File records formed the base on which all of the other information sources were compiled.

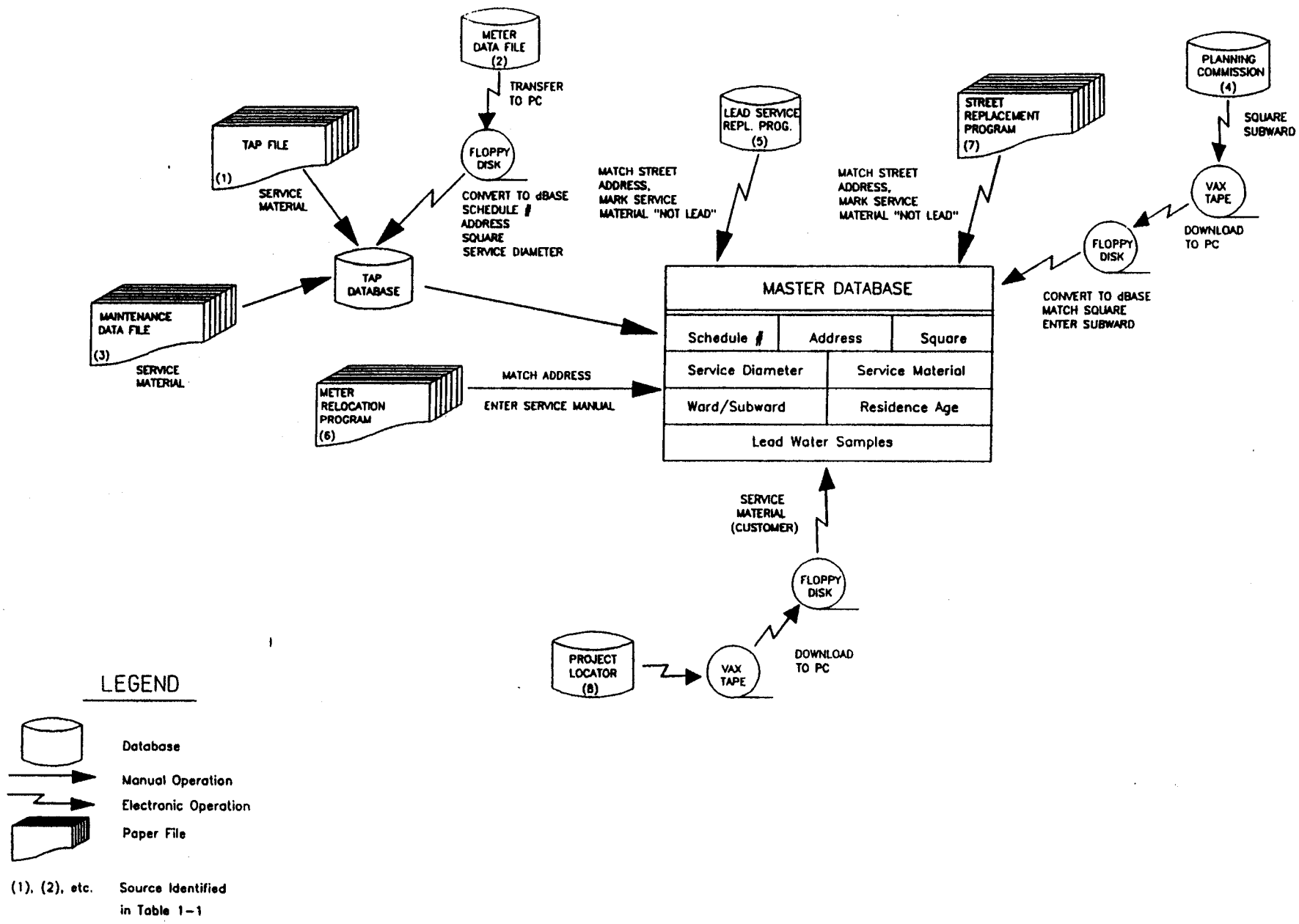

FIGURE 3-1 SCHEMATIC OF INTERACTION OF VARIOUS DATABASES

The Tap File contains cards that are submitted every time a water main is tapped for a new water service connection. All residential taps were supposedly recorded in this file, ordered by schedule number, which is a sequential, unique number assigned to every tap. Approximately 188,000 schedule numbers have been issued by the District. The Tap Cards typically contained the following information:

- Schedule number.
- Address.
- Square.
- Lot.
- Date of connection.
- Property owner and plumber names.
- Size of service line.
- Location of curb-cock.
- Location and size of main.

3.2.2 Meter File

The Tap File did not contain the cards for the first 67,000 taps. Obtaining this information was imperative because these locations are the oldest in the District (pre-1915), and are the most likely to have had originally installed lead service lines. BWMB maintains a Meter File that contains the information that BWMB calls up on its computer screens for billing and customer service purposes.

The Meter File information consisted of selected fields from the master database that the Office of Information Systems maintains on its mainframe computer. Data were extracted for all active residential addresses throughout the District. These data contained the following information for schedule numbers 000000 through 999999:

- Schedule number.
- House number.
- Street name.
- Quadrant.
- Square.

The data from the Meter File were input on the project computers at BWMB. Since the Meter File does not contain all of the necessary information, data entry personnel were instructed to look up each address in the Maintenance File and attempt to fill in the missing data (see Subsection 3.2.3).

It should be noted that only 20,400 of the first 67,000 taps were still active. This is not surprising, since most of these residences were located in the center of the District and, as such, were probably torn down and replaced by commercial or government buildings, or by open space (especially the Mall) or new roads.

However, to complete the data collection for the first 67,000 taps (obtained from the Meter File), the following data had to be obtained from the Maintenance File for each address:

- Date of tap installation.
- Service line material.
- Service line diameter.

The database was sorted to match the organization of the Maintenance File. Nevertheless, the volume of information available for any address that had to be sorted greatly diminished productivity. To ensure that the effort was completed on time, the data entry staff were instructed to concentrate only on obtaining the service line material for each address, which was the most important piece of information of the three. The staff were then free to look through all of the service orders for each address as well as the Tap Card, thus increasing the chances of obtaining a definite service material indication.

3.2.4 Planning Commission File

All data analyses were to be performed on the basis of political ward. The District is divided into eight wards, with each ward being divided further into five subwards. The District's Planning Commission provided a database giving the relationship between square and ward for every square in the District.

The Ward-Versus-Square Database enabled each ward field to be filled easily for any record in the Tap File Database, as long as the record contained the proper value in the square field. The merge was highly successful; more than 90 percent of the records now had a ward location. Those records that did not get a ward had Tap Cards that did not have the square specified, which was fairly common in the older Tap File records.

3.2.5 Lead Service Replacement Program

The District's Lead Service Replacement Program, which has been in operation since late 1987, replaces District-owned, noncopper residential service lines (i.e., the portion of the service line that lies between the main and the curb shut-off valve). The Lead Service Replacement Program Database contains the following fields of interest:

- House number.
- Street name.
- Quadrant.
- Material type replaced.
- Date.

The objective in using these data was to match each replaced service line with its corresponding entry in the Tap File Database and mark the service material as being copper. It was desirable to perform this matching and marking function electronically;

The Meter Relocation Program management was advised to modify its program in the following two ways:

- Instruct all crews to excavate down to the service line so that they could determine the type of service line on both the customer and the District sides.

- Have the crews fill out a simple form and return it at the end of the day to a central location.

Program management has implemented these recommendations, which has resulted in the collection of approximately 200 additional identified service lines to date.

3.2.7 Street Replacement Program

The Street Replacement Program is a result of the District's requirement that all noncopper service lines (as well as other utilities) be replaced whenever a street construction contract is awarded. All available street inspector logs that identified the service line material were obtained for project use.

As was found with the Meter Replacement Program information, the Street Replacement Program information is not computerized; moreover, the information is not centrally located. Data were obtained by contacting the inspectors, who then pulled their logs from their personal files.

The format of the information also lends itself to manual entry into the Tap File Database. The time required is minimal because of the consistent nature of the information.

Since each group of addresses represents a replaced street, almost all of the records to be changed are located on one street and, therefore, will appear together in the Tap File Database. The database was sorted to facilitate entry of this information. For each address found, the original service line material was marked to match that indicated on the Street Replacement Sheet, and the service line was marked as having been replaced.

3.2.8 Project Locator Data File

The Project Locator Data File is the end product of an extensive study performed in 1983 to 1984 by the Office of Engineering Services for the BWMB. Project Locator was a house-to-house survey, the objective of which was to improve the quality and accuracy of water billing. As part of this survey the service line material was recorded for the customer's portion of the line for those houses with inside meters.

The service line material information from the Project Locator Database was merged with the Tap File Database by matching the schedule numbers in the two databases. To accommodate the service line material information, a new field was created in the Tap File

SECTION 4

USING THE MENU SYSTEM

A simple menu system was created using the dBASE IV programming language to facilitate using the Tap File Database. The present menu system allows the user to add new records to the database, edit existing records, retrieve data in various forms, and recreate certain basic indexes. The menu system can be updated easily by users familiar with simple dBASE IV commands as new applications are developed for using the database.

4.1 OVERVIEW

The first step in accessing the Tap File Database main menu is to enter into dBASE IV from the DOS environment. The specifics of this step will depend on the setup of the user's particular computer. Upon entering dBASE IV, the user will be presented with the dBASE Assistant, the user-friendly menu system that drives dBASE IV. To access the Tap File Database menu system, the user simply presses the <ESCAPE> key. At the Yes/No prompt that appears next, answer Yes by pressing the "Y" key, or moving the cursor to "Yes" and pressing <RETURN>.

At this point the user is at the dBASE IV dot prompt. From here the user can perform any dBASE IV function by typing in the appropriate commands. To access and work with the Tap File Database, type in DO TAP and <RETURN>. The Tap File Database main menu will appear as shown in Table 4-1.

Table 4-1

District of Columbia Water and Sewer Utility Administration
Tap File Database Main Menu

```
(1) Input New Records
(2) Edit Existing Records
(3) Listing of Service Line Materials for a Series of Years
(4) Listing of Service Line Materials for Individual Addresses
(5) Count of Service Lines of a Given Material
(6) Summary of Replaced Service Lines by Ward and Year
(7) Summary of Service Line Installations by Ward and Year
(8) Re-Index Database
(9) Quit to Dot Prompt
(X) Quit to DOS

     ENTER MENU CHOICE ->
```

FIGURE 4-1 TAP FILE DATABASE DATA ENTRY SCREEN

ADDRESS INFORMATION

SCHEDULE NUMBER [ ] INSTALLATION YEAR [ ]

ADDRESS [ ] [ ] [ ]

SQUARE [ ] WARD [ ]

SERVICE LINE INFORMATION

PIPE SIZE [ ]

PIPE MATERIAL:

DISTRICT SIDE ☐

CUSTOMER SIDE ☐

REPLACED ? (True or False) ☐

ABANDONED ? ☐

WESTON

As an example, assume the user has responded to these prompts as follows:

- ENTER WARD TO REPORT -> **4**
- ENTER PIPE MATERIAL TO REPORT -> **L**
- ENTER FIRST YEAR TO REPORT -> **1930**
- ENTER LAST YEAR TO REPORT -> **1935**

These responses would generate a report (see Table 4-2) which would appear on the screen.

Table 4-2

Example of Report 3

ADDRESS	QUAD	WARD	INSTALL YEAR	TAP	PIPE MATERIAL RECORD	PROJ	LOCATOR
7125 16TH ST	NW	4A	1931		L		N
7627 16TH ST	NW	4A	1932		L		I
7721 16TH ST	NW	4A	1933		L		I
7755 16TH ST	NW	4A	1933		L		N
4312 17TH ST	NW	4A	1933		L		N
4316 18TH ST	NW	4A	1933		L		N
7801 16TH ST	NW	4A	1934		L		N
7815 16TH ST	NW	4A	1934		L		I
7809 16TH ST	NW	4A	1935		L		I
5610 1ST PL	NW	4B	1935		L		N
5611 1ST PL	NW	4B	1935		L		
5614 1ST PL	NW	4B	1935		L		
5615 1ST PL	NW	4B	1935		L		
5618 1ST PL	NW	4B	1935		L		
5619 1ST PL	NW	4B	1935		L		

Press any key to continue . . .

Menu Choice 4 allows the user to retrieve information about a particular address. The user is prompted to enter the address in three parts as follows:

- ENTER STREET NUMBER TO REPORT ->
- ENTER STREET NAME TO REPORT ->
- ENTER QUADRANT TO REPORT ->
- DO YOU WISH TO PRINT THE RESULTS ? (Y OR N)

Again, the form of the responses is very important. All responses must be in capital letters. The street name must be spelled correctly to match the addresses in the database. This includes

Table 4-4

Example of Report 5

IN 1935 THERE WERE 7 LEAD SERVICE LINES INSTALLED IN WARD 4

Press any key to continue . . .

Menu Choice 6 focuses on the number of lead service lines that have been replaced. The user selects the ward and date range to report on, and the dBASE IV program produces a count of the number of lead service lines in that ward that have been replaced. Table 4-5 is an example of the output produced by the following user responses:

- ENTER WARD TO REPORT -> **4**
- ENTER FIRST YEAR TO REPORT -> **1930**
- ENTER LAST YEAR TO REPORT -> **1935**

Table 4-5

Example of Report 6

ADDRESS	QUAD	WARD	INSTALL YEAR	PIPE MATERIAL	REPLACED?
7755 16TH ST	NW	4A	1933	L	T

Press any key to continue . . .

Menu Choice 7 produces a summary report of service line installations in all wards throughout the District for a given material. This report lists the number of service lines of that material that were installed in each year in each ward. The user is prompted to enter this material and a range of years to report on as follows:

- ENTER FIRST YEAR TO REPORT ->
- ENTER LAST YEAR TO REPORT ->
- ENTER PIPE MATERIAL TO REPORT ->

Table 4-6 gives an example of this report. It was produced by the following responses to the user prompts:

- ENTER FIRST YEAR TO REPORT -> **1930**
- ENTER LAST YEAR TO REPORT -> **1935**
- ENTER PIPE MATERIAL TO REPORT -> **L**

Table 4-8 lists the indexes that are used by the five reports. If a particular report must be generated quickly, the index needed for that report only can be recreated. However, when more time is available all the indexes should be recreated. The schedule number index is the basic index, and is used only when inputting new data or modifying existing records.

Table 4-8

Indexes Used by the Report Programs

Report Number	Index
3	Ward/Date
4	Address
5	Ward/Date
6	Ward/Date
7	Date

Selecting any of Menu Choices 1 through 5 performs a dBASE IV command to index the database. As the indexes already exist, the user will be prompted by dBASE IV that the index file already exists. The user should select to overwrite the existing file, as the menu system is geared to using the existing files. Only if the user decides to abandon the operation should the "Cancel" option be selected.

4.2.4 Exiting the Menu System

The Tap File Database main menu includes two menu choices that allow the user to exit from the menu system. Menu Choice 9 allows the user to return to the dBASE IV dot prompt. Experienced users will use this choice to allow them to work with the Tap File Database outside of the menu environment. Entering an "X" at the menu prompt will exit the user from dBASE IV completely.

SECTION 5

ADDITIONAL DATABASE TOPICS AND APPLICATIONS

The User's Guide gives an overview of the Tap File Database and shows how to edit and query the file. There are additional applications available to users that have not been discussed herein, such as acquiring printed reports, inserting memo fields, and database maintenance and management. These areas tend to be unique to the user's environment and must be developed after gaining experience with the database.

This section describes three additional topics and gives suggestions on possible future user projects. These topics are: maintenance and management techniques, obtaining printed reports, and advanced applications.

5.1 SYSTEM MAINTENANCE AND MANAGEMENT

A database must be maintained for it to be an effective information management tool. New data must be entered into the database in a timely manner, old or incorrect records must be deleted or edited as necessary, and user problems and requests must receive immediate attention. The most effective way to achieve these goals is to assign a Database Administrator (DBA).

The DBA is essential to the success of a database, especially in the early stages of use. The DBA assists users, maintains the database, and responds to requests for new applications. He/she should be experienced in all areas of dBASE IV, with special emphasis on writing reports and custom programmed applications for management information systems. The Tap File Database is not complicated; however, it does require maintenance and attention from a reasonably knowledgeable DBA.

The system maintenance needs of the Tap File Database are no different than any other large database. There are three main types of maintenance: addition of new information, removal of old records, and editing of incorrect information. Although, the various users of the system will be the source of the information, the actual changes to the database must be made by the DBA or his/her designee. This level of control must be maintained to ensure the integrity of the database.

The last area of responsibility for the DBA involves disaster recovery. The DBA must follow a strict backup schedule to minimize the inconvenience caused by computer or human failures. It is suggested that two sets of backup disks be kept and that the database be backed up on one set of disks at least once a week, rotating between sets. This system will limit the data loss to a maximum of 2 weeks. If the database is heavily used and updated, the backup frequency can be increased to twice per week, or even daily if necessary.

TAP FILE DATABASE USER'S GUIDE

June 1990

Prepared for

The Government of The District of Columbia
Department of Public Works
Water and Sewer Utility Administration
Washington, D.C.

Prepared by

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ATTACHMENT

D

MEMORANDUM

To: **DC Water**
From: Rich Luettchau
Date: May 19, 2021
Page: 1 of 33
Subject: **InfoAsset Planner LFDC Model Development**

1. Background

Over the past two decades, DC Water has worked to remove lead service lines from the city's water system to ensure safe drinking water for its customers. However, since lead was the predominant service line material used in the city until the mid-1950's, and as late as 1977, there are still over 20,000 known lead service lines in the system. Therefore, as a component of the Lead Free DC (LFDC) program, DC Water has agreed to develop a plan to remove all lead service lines from the city over the next 10 years. Since approximately 1/5 of the services are still lead today and since these are dispersed throughout the city, it was necessary to devise a methodology for prioritizing these replacements. As DC Water has utilized Innovyze' s InfoAsset Planner software to aid in the risk prioritization and planning of capital improvement projects (CIP), it was determined that this software should be used to assist with the LFDC effort as well.

2. Purpose of the Memo

The purpose of this memorandum is to:

(1) Discuss the prioritization matrix and the data gathered for use in the model.

(2) List and detail the consequence of lead (CoL) and likelihood of lead (LoL) parameters.

(3) Review the decision tree development and the project groups.

(4) Detail the verification process that was conducted to ensure model accuracy

(5) Provide a summary of results and recommendations for future updates.

3. Risk Prioritization Matrix

In conjunction with key stakeholders, DC Water's LFDC team developed a prioritization matrix to identify high priority service line replacements. The prioritization matrix was designed to be similar to the current risk matrix used for CIP planning. The matrix consists of parameters that were divided into two groups: consequence of lead (CoL) and likelihood of lead (LoL). Consequence of lead parameters focus on identifying vulnerable populations and poorer communities where privately funded service replacements may not have occurred. Likelihood of lead parameters identify locations where there is an increased probability of exposure to lead. Each parameter was assigned a weight equating to a percentile of the total CoL or LoL score. The combined CoL and LoL scores were multiplied together to calculate the overall prioritization score. This score is ultimately used in determining the replacement schedule. By utilizing the prioritization score when planning lead service line replacements, DC Water is ensuring that underserved communities with vulnerable populations are targeted. The below sections further

discuss the CoL and LoL prioritization matrixes. The CoL and LoL matrixes have been attached to this document as Appendix A and B, respectively.

3a. Consequence of Lead

As indicated, the consequence of lead matrix focuses on identifying communities where the potential health impacts of lead services are highest. Therefore, the CoL is broken into two categories: Health/Social Equity and Vulnerable Populations. The following describes each category, how it is weighted, and the data used in the scoring process.

- ***Health/Social Equity*** – Data on socio-economic status accounting for 50 percent of the total CoL score. The only parameter of this scoring category was the Area Deprivation Index (ADI). The ADI was developed by the University of Wisconsin based on calculations developed by the Health Resources & Services Administration (HRSA). The purpose of the ADI was to aid in health delivery and policy for the most disadvantaged neighborhoods. It systematically ranks neighborhoods by socioeconomic disadvantage at both the national level and state level,in Washington DC's case the city. Included in the calculation are factors for income, education, employment, and housing quality.[1] The 2018 version of the index, at the census block group level, was used for the initial prioritization model. Table 3a.1 defines the scoring parameters that were used in the prioritization matrix.

Prioritization Model Score	Criteria
1	ADI Score of 1 or 2
3	ADI Score of 3 or 4
5	ADI Score of 5 or 6
7	ADI Score of 7 or 8
10	ADI Score of 9 or 10

Table 3a.1: Health/Social Equity CoL Scoring

- ***Vulnerable Populations*** – Data targeting the locations of children throughout the city accounting for 50 percent of the total CoL score. Since young children have the greatest health risks when exposed to lead in drinking water this category ranks locations based on the population of children and the existence of childcare facilities. Details on the parameters are listed below.
    - *Population of Children* – Demographic data on the count of children under the age of 18, per census tract, accounting for 40 percent of the Vulnerable Population score. The dataset was included as a component of the population data from the Office of the Chief Technology Officer (DC OCTO) data catalog. The 2017 version of the data was used for the initial prioritization model. Table 3a.2 defines the scoring parameters that were used in the prioritization matrix.

[1] University of Wisconsin School of Medicine and Public Health, *Neighborhood Atlas* [website], https://www.neighborhoodatlas.medicine.wisc.edu, (accessed 20 February 2021).

Prioritization Model Score	Criteria
1	≤400 children under the age of 18
3	400 to ≤800 children under the age of 18
5	800 to ≤1200 children under the age of 18
7	1200 to ≤1600 children under the age of 18
10	>1600 children under the age of 18

Table 3a.2: Population of Children CoL Scoring

- *Licensed Childcare Facilities* – Facility data on the location of licensed childcare facilities accounting for 60 percent of the Vulnerable Population score. Table 3a.3 defines the scoring parameters that were used in the prioritization matrix.

Prioritization Model Score	Criteria
1	All other services/locations
10	Within 200 feet of a facility

Table 3a.3: Licensed Childcare Facility CoL Scoring

3b. Likelihood of Lead

The LoL matrix utilizes data on water main breaks, water quality sampling, and the existence of lead to determine the likelihood of lead exposure. Like the CoL matrix the LoL matrix is broken into two categories: Physical Condition and Performance. The below describes each category, how it was weighted, and the data used in the scoring process.

- ***Physical Condition*** – Data on the physical condition of the water main, accounting for 10 percent of the total LoL score. The scoring was based on the water main repair locations dataset that includes main break data as far back as 1960. Although there are gaps in the data, significant ones between 1980 and 2000, the entire dataset was used to maintain consistency with the risk model used for CIP planning. The only records that were excluded are those referencing abandoned water mains or records that have not been correlated to a water main. Since service laterals tend to be tapped to small diameter water mains (<16 inch) only failures on small diameter mains were counted. Table 3b.1 defines the scoring parameters that were used in the prioritization matrix.

Prioritization Model Score	Criteria
1	No water main failures on block
2	1 to 3 water main failures per block
5	4 or 5 water main failures per block
10	6 or more water main failures per block

Table 3b.1: Physical Condition LoL Scoring

- ***Performance*** – Data on how well the water main has performed, accounting for 90 percent of the total LoL score. This category focused on identifying mains with water quality issues that may increase lead exposure and identifying areas where the service line material indicates a lead service. Details on the parameters are listed below.

    - *Service Line Material* – Data on service line material identifying locations supplied by lead services, accounting for 60 percent of the performance score. For the initial model development, the data was exported from the DC Premex database on February 22, 2021. Any updates to the database after that time were not included in the initial model development. In addition to lead service lines, services that are classified as galvanized in the inventory were categorized as lead. Table 3b.4 defines the scoring parameters that were used in the prioritization matrix. It should be noted, as discussed later, the scoring used in the InfoAsset Planner model was modified to accommodate scoring the system at the block level.

Prioritization Model Score	Criteria
1	Public & private non-lead services
2	Public side material is unknown
3	Public side is non-lead and private side is lead
7	Public side is lead
10	Public & private sides are lead

Table 3b.4: Service Line Material LoL Scoring

    - *Water Quality Iron Content Sampling* – Water quality sampling data identifying areas with high iron content, accounting for 30 percent of the performance score. Sampling data from known water quality problem areas was used to identify areas where customers may experience red water and increased lead exposure. The sampling data used was limited to results from 2019 and 2020 and only took into account the most recent sample. The data was supplemented with the locations of automatic flushing units. Automatic flushing units are installed in areas with severe water quality issues to regularly flush the water mains. The list of automatic flushing units was last updated in February 2021. Table 3b.2 defines the scoring parameters that were used in the prioritization matrix.

Prioritization Model Score	Criteria
1	No known water quality issues
2	Within 300 ft of a sampling site with an iron content of <0.4 mg/L
4	Within 300 ft of a sampling site with an iron content of ≥0.4 mg/L and <0.7 mg/L
6	Within 300 ft of a sampling site with an iron content of ≥0.7 mg/L and <1 mg/L
8	Within 300 ft of a sampling site with an iron content of ≥1 mg/L and <2 mg/L
10	Within 300 ft of a sampling site with an iron content of ≥2 mg/L OR within 300 ft of an automatic flushing unit

Table 3b.2: Water Quality Iron Content LoL Scoring

- *Water Quality Chlorine Residual Sampling* – Water quality sampling data identifying areas with low chlorine residual, accounting for 10 percent of the performance score. Sampling data from hydrant retests were used to identify areas where customers may experience low chlorine and possible lead exposure. The sampling data used was limited to results from 2019 and 2020 and only took into account the most recent sample. As with the previous parameter, the data was supplemented with the locations of automatic flushing units. Table 3b.3 defines the scoring parameters that were used in the prioritization matrix.

Prioritization Model Score	Criteria
1	No known water quality issues
2	Within 300 ft of a sampling site with a chlorine residual ≥1.75 mg/L
5	Within 300 ft of a sampling site with a chlorine residual of ≥1 mg/L and <1.75 mg/L
10	Within 300 ft of a sampling site with a chlorine residual of <1 mg/L OR within 300 ft of an automatic flushing unit

Table 3b.3: Water Quality Chlorine Residual LoL Scoring

4. Data Preparation

The original prioritization matrix was designed to score the individual service lines for each CoL and LoL parameter. However, since the lead service line program is targeting replacements at the block level, the InfoAsset Planner model was developed using the block centerline as the primary input. This resulted in the need to develop specific parameters at the block level rather than at the individual service level. The following sections discusses the development of the block centerline data, the processing of the service line data and the merging of water main information to the block level.

4a. Block Centerline Network

Since the GIS database did not contain a layer dividing the city into blocks, it was necessary to generate one. The street centerline feature class, from the Enterprise GIS database, served as the starting point. Since the centerline file contains a record for every street, alley, and service road in the city and since each line is broken at all intersections, the centerline is not necessarily continuous across the length of a block. Therefore, the records for streets and named alleys (all other records were excluded from the dataset) were dissolved based on the Street Segment ID. This street segment ID serves as a unique identifier for all centerline features between two intersections. For example, Adams St NE between 3rd and 4th Sts consists of 3 segments all with the same IDs. By dissolving these three segments into a single line, Adams St NE is represented as a single continuous road between 3rd and 4th Sts. As the street segment ID is unique, the value was maintained and will be used as the unique identifier throughout the LFDC prioritization model. If a street segment ID did not exist, as was the case for some alleys, a unique value was generated.

Once the street centerline data was dissolved, each block was named based on the address range of the block. The lowest, non-zero, address was rounded to the nearest 100 and merged with the street name to generate a block name for each road in the city. For address ranges where the lowest address was between 1 and 99, the block was identified as the “Unit Block” of the street. While limited, there are instances of duplicate block names and address ranges spanning more than 100 addresses. A systematic review of these were not conducted but should be considered in the future.

4b. Lead Service Line Summary Table

To assign a service line material score to each centerline feature it was necessary to take the individual service lines and assign each to a block. Since the GIS database does not maintain the exact location of all services in the system, nor does it indicate how they are tapped, an analysis was conducted to correlate the services to the block centerlines. While a spatial join to the nearest block centerline would be the simplest method of linking the data, service lines do not always connect to the closest water main or street. Therefore, to ensure continuity of the data, services were assumed to be connected to the street where the property faces. In most cases this is the nearest centerline feature; however, this is not always the case, and the analysis included reviewing the three closest centerline features to identify the best match. To determine this connection, the service line address was compared to the block name and address range of each centerline. As this was an iterative process, records that did not match the closest centerline were then compared to the second closest and then the third. Where no match was found, the service line address was again compared to the three closest centerline features, but only the street name was used in the comparison. If this process did not yield a match a simple spatial relationship was used to assign the service line feature to the nearest block, regardless of the block name. In all cases, the block segment ID of the matched centerline feature was migrated to the service line point feature.

While this methodology is more complex than a simple spatial relationship it yields better results. That being said, corner properties may be serviced from the side of buildings or properties may be backfed from an alley. Services that connect in this manner were not identified during the analysis. Therefore, a more thorough review, including a manual review, should be conducted to confirm the service line connectivity. If a service line is identified to be

associated to the wrong block centerline, the street segment ID of the service line should be updated to the correct block's ID.

Once the connection between the blocks and service line inventory was established, the inventory was linked to the scoring table provided by the Department of Water Quality. The scoring table assigned a score to each service line record, based on the material, in accordance with Table 3b.4. In order, to apply this score to the block level, the sum of the scores for each service on the block was calculated. To avoid lower priority streets with a high density of service outscoring other higher priority blocks the total score was normalized per 100-feet of roadway. Additionally, the total number of service line, the count of full LSRs (public side lead), partial private-only LSRs (public side non-lead, private side lead), and public side unknown materials were calculated.

4c. Water Main Summary Table

To assign water main information to the block centerlines a summary table, similar to the one for the service lines, was also created. The table contained key information pertaining to water main on each block that was used to create LoL parameters for the both the prioritization model and the decision tree. For the initial model development, data from the Enterprise GIS water distribution network was used (from February 15, 2021). The pressure main data was limited to active DC Water owned water mains longer than 50-feet. The 50-foot limit was applied to eliminate small segments of main that typically have the same diameter, material and install information as surrounding mains and to remove segments that reside solely in the intersections where service lines are not present. Additionally, data was limited to small diameter mains and only those large mains (greater than 16 inch) that are known to have services attached to them. This removed the majority of the transmission mains from the summary, limiting the data to only mains that are connected to the service line inventory.

The summary table was developed by first converting the water main features to centroid points (at the mid-point). A series of spatial analyses were conducted to identify the block centerline that was closest to the water main centroid feature. Once the spatial analysis identified which block a water main corresponded to, the associated street segment ID was migrated to the water main feature. This process was conducted for 10-foot proximity buffers around each centerline. Once a water main was assigned a street segment ID it was removed from the analysis pool and the spatial analysis repeated at the next 10-foot interval (20-feet, 30-feet, etc). This process was repeated through 100-feet. The iterative process was used instead of a single proximity buffer to more accurately correlate water mains in the vicinity of intersections. Using the Planned Capital Improvement Project Table, which carries the asset ID of all water mains scheduled to be rehabbed, water mains scheduled for replacement were flagged. Likewise, using the Asset ID, the pressure main data was linked to the risk assessment results used for CIP planning. Data on consequence of failure (CoF), likelihood of failure (LoF) and total risk were migrated to the pressure main feature class. A summary table was then generated against the Street Segment ID to dissolve data with the same street segment ID. The following statistics were included in the summary table: total mileage of main, smallest diameter, largest diameter, if the water main is scheduled for rehab, highest CoF score, highest LoF score, and the highest risk score.

A manual, secondary review was then conducted to confirm that blocks identified as being a part of the capital improvement program under the small diameter water main renewal program (SDWMR) were accurately represented. This review verified that all small diameter water mains on the block were scheduled for replacement and not a select portion of the mains. Any block

falling into the later, were removed from the list. In addition to the blocks falling under the SDWMR program (up to and including SDWMR 19c), the water main summary table was updated to include blocks where there are known water main work being conducted under a DDOT project. At the time of the initial model development, these included the Florida Avenue, Florida Avenue Virtual Circle, and Oregon Avenue projects.

5. InfoAsset Planner Model Development

For ease of development, the existing CIP InfoAsset Planner model was used as a starting point for the Lead Free DC model. Since the existing model used the water main features as the basis for the scoring, the block centerline features were loaded to this feature class. All attributes, including functional class, street segment ID and road type were migrated. All other feature classes from the CIP model were deleted to avoid confusion between the existing model and the LFDC model.
Once the block centerlines were loaded to the model, the individual model parameters were developed. The following sections outline each CoL and LoL parameter and the multi-parameters used in the scoring. It should be noted that some parameters were developed explicitly for use in the decision tree and were not included in the prioritization calculations.

5a. Individual Consequence of Lead Parameters

The consequence of lead parameters was built off of the specific criteria in the CoL matrix. Individual parameters were developed for each criteria in the matrix. When multiple queries were used in a single criteria, two distinct parameters were developed to accommodate the limitations of InfoAsset Planner. Since the previous CIP model was used as the basis for the LFDC model, the CIP model parameters were preloaded into the model. In most instances these were deleted; however, parameters that may be of importance in further analyses, like proximity to schools, were maintained and suffixed with 'Not Used'. In the model the six CoL parameters related to the LFDC model are identified as COF56 through COF61, and are prefixed with 'LFDC'. These parameters are later combined into multi-parameter functions to derive the CoL score. Each of the individual parameters is detailed below. Although there may be multiple values scored per parameter, only a few values are actually used to calculate the CoL score in the multi-parameter functions.

It should be noted that all distances in the model, to maintain consistency with DC Water's data, are reported in meters. However, for this memo those lengths have been converted to feet. All counts of block centerlines are based off the initial model development and may change in future iterations if data updates are conducted.

- ***LFDC – Child Development Centers (COF56) –*** The CoL parameter developed to score block centerlines for proximity to a child development center. The spatial analysis was limited to 1,000 meters or 3,280 feet. Any centerline not within that distance was scored a 1. Table 5a.1 shows the remaining parameter scoring.

Parameter Score	Distance to Child Development Center	Count of Block Centerlines
1	>3,280 feet	390
2	400 feet to 3,280 feet	9,783
3	300 to 400 feet	1,106
4	200 to 300 feet	952
5	100 to 200 feet	876
10	≤100 feet	473

Table 5a.1: Child Development Centers InfoAsset Planner Scoring

- ***LFDC – Children <18 Count (COF57) –*** The CoL parameter developed to score each block centerline based on the population of children within the related census tract. The centerlines received a score based on the census tract they reside in. In instances were a centerline spanned multiple census tracts, the centerline was assigned to the tract containing the highest number of children. The B01001_c_2 attribute field of the ACS_2017_Population_Variables_Tract feature class was used to conduct the scoring. Where the centerline did not intersect a census tract the centerline was scored a 1. Table 5a.2 shows the parameter scoring for COF57.

Parameter Score	Population of Children <18	Count of Block Centerlines
1	Not intersecting a census tract	136
1	≤400 children	2,983
3	800 to 400 children	4,611
4	1,200 to 800 children	3,951
5	1,600 to 1,200 children	776
10	>1,600 children	1,123

Table 5a.2: Count of Children <18 InfoAsset Planner Scoring

- ***LFDC – ADI (COF58) –*** The CoL parameter developed to score each block centerline based on the census block ADI score. The centerlines received a score based on the census block they reside in. In instances were a centerline spanned multiple census blocks, the centerline was assigned to the tract with the highest ADI score. The ADI_Staternk_Int attribute field of the ADI_ByCensusBlock feature class was used to conduct the scoring. Where the centerline did not intersect a census block the centerline was scored a 1. Table 5a.3 shows the parameter scoring for COF58.

Parameter Score	ADI Score	Count of Block Centerlines
1	Not intersecting a census block	136
1	1, 2	2,983
3	3, 4	4,611
4	5, 6	3,951

5	7, 8	776
10	9, 10	1,123

Table 5a.3: ADI InfoAsset Planner Scoring

- ***LFDC – Arterial Roads (COF59) –*** The CoL parameter developed to score each block centerline based on the functioning class of the road. This parameter was developed for use in the decision tree and was not used in the prioritization scoring. Table 5a.4 shows the parameter scoring for COF59.

Parameter Score	Functional Class	Count of Block Centerlines
1	Not Populated	118
1	Collector	1,949
1	Local	8,217
5	Minor Arterial	2,074
10	Principal Arterial	1,222

Table 5a.4: Arterial Roads InfoAsset Planner Scoring

- ***LFDC – Road Type (COF60) –*** The CoL parameter developed to score each block centerline based on the road type. This parameter was developed for use in the decision tree and was not used in the prioritization scoring. Table 5a.5 shows the parameter scoring for COF60.

Parameter Score	Road Type	Count of Block Centerlines
1	Alley	86
10	Street	13,494

Table 5a.5: Road Type InfoAsset Planner Scoring

- ***LFDC – Owner (COF61) –*** The CoL parameter developed to score each block centerline based on the owner of the roadway. This parameter was developed for use in the decision tree and was not used in the prioritization scoring. Table 5a.6 shows the parameter scoring for COF61.

Parameter Score	Road Type	Count of Block Centerlines
1	Air Force	185
1	Army	105
1	Military Reservation	6
1	Navy - Marines	121
1	Other DC Agencies	88
1	Other Federal Agencies	52
1	Private	243
1	Unknown	2
1	WMATA - Metro	2
3	Architect of the Capitol (AOC)	3
5	National Park Service (NPS)	123
10	DDOT	12,565

Table 5a.6: Road Owner InfoAsset Planner Scoring

5b. Multi-Parameter Consequence of Lead Functions

To mimic the CIP risk matrix, and allow for future compound parameters, three multi-parameter functions were developed, Multi_COF12 through Multi_COF14. Since the scoring for both health/social equity and vulnerable populations did not require compound parameters, and the multi-parameter functions require at least two parameters, the road type was used as a place holder in the development of these functions. Should DC Water wish to further develop these criteria, by adding additional parameters, these multi-parameter functions can be easily adjusted to accommodate the changes. All counts of block centerlines are based off the initial model development and may change in future iterations if data updates are conducted.

- ***LFDC – Health/Social Equity (Multi_COF12) –*** The CoL multi-parameter function developed to score block centerlines for health and social equity, utilizing ADI. The Health/Social Equity scoring accounts for 50% of the total CoL score. The ADI score (COF58) and road type (COF60), serving as a place holder, were used in the multi-parameter function. Table 5b.1 shows the parameter scoring for Multi_COF12.

Parameter Score	ADI Score (COF58)	Road Type (COF60)	Count of Block Centerlines
1	Blanks values, 1, 2	All Road Types	3,942
3	3, 4	All Road Types	2,116
5	5, 6	All Road Types	2,877
7	7, 8	All Road Types	2,374
10	9, 10	All Road Types	2,274

Table 5b.1: Health/Social Equity Multi-Parameter Scoring

- ***LFDC – Vulnerable Population Children <18 (Multi_COF13) –*** The CoL multi-parameter function developed to score block centerlines for vulnerable population, utilizing population of children under the age of 18. The Vulnerable Population Children <18 scoring accounts for 20% of the total CoL score. The count of children under the age of 18 score (COF57) and road type (COF60), serving as a place holder, were used in this multi-parameter function. Table 5b.2 shows the parameter scoring for Multi_COF13.

Parameter Score	Population of Children (COF57)	Road Type (COF60)	Count of Block Centerlines
1	Blank values, ≤400 children	All Road Types	2,986
3	800 to 400 children	All Road Types	4,747
5	1200 to 800 children	All Road Types	3,951
7	1600 to 1200 children	All Road Types	776
10	>1600 children	All Road Types	1,123

Table 5b.2: Vulnerable Population Children <18 Multi-Parameter Scoring

- ***LFDC – Vulnerable Population Licensed Childcare –*** The CoL multi-parameter function developed to score block centerlines for vulnerable population, via their proximity to a licensed childcare facility. The Vulnerable Population - Licensed Childcare scoring accounts for 30% of the total CoL score. The proximity to a childcare facility score (COF56) and road type (COF60), serving as a place holder, were used in this multi-parameter function. Table 5b.3 shows the parameter scoring for Multi_COF14.

Parameter Score	Proximity to a Childcare Facility (COF56)	Road Type (COF60)	Count of Block Centerlines
1	>100 feet	All Road Types	12,2234
10	≤100 feet	All Road Types	1,349

Table 5b.3: Vulnerable Population Licensed Childcare Multi-Parameter Scoring

5c. Individual Likelihood of Lead Parameters

Similar to the consequence of lead parameters, the likelihood of lead parameters was built from the specific criteria in the LoL matrix. Parameters related to pipeline condition, fire flow and operational issues from the existing CIP model were deleted, while those related to main breaks and water quality were maintained. Those parameters related to water quality flushing locations and zone assessment samples were not used in the LFDC model and thus were suffixed with 'Not Used'. Twelve new LoL parameters were developed, LOF21 through LOF32, specifically for the LFDC model. The parameters for chlorine and iron hydrant sampling, automatic flushing units, count of lead services and main breaks from the CIP model were reused or slightly modified to fit the LFDC model. Each of the individual parameters is detailed below. Similar to the CoL parameters, only some parameters were used in the prioritization model even though there are multiple values scored in each parameter

All distances in the model, to maintain consistency with DC Water's data, are reported in meters. However, for this memo those lengths have been converted to feet. All counts of block centerlines are based off the initial model development and may change in future iterations if data updates are conducted.

- ***Main Break Count (LOF2) –*** An LoL parameter maintained from the CIP prioritization model. The parameter identifies the number of small diameter water main breaks that have occurred on the block. The parameter was originally normalized per 100 ft of water main. However, since the LFDC model is based off the block centerlines and most blocks are similar in distance, the normalization was removed in favor of a discrete count. Table 5c.1 shows the parameter scoring for LOF2.

Parameter Score	Count of Main Breaks	Count of Block Centerlines
1	0 main breaks	9,872
2	1 or 2 main breaks	3,077
5	3 or 4 main breaks	343
10	>4 main breaks	288

Table 5c.1: Main Break InfoAsset Planner Scoring

- ***Cl2 Levels from Hydrant Readings – 300' Buffer (LOF5) –*** An LoL parameter maintained from the CIP prioritization model. Each centerline within 300 feet of a hydrant sample received a score based on the sample's residual chlorine level. Sample results near 0 mg/L are scored higher than those exceeding 1.75 mg/L. However, since samples are only taken at locations with known water quality concerns, block centerlines within 300 feet of samples exceeding 1.75 mg/L are scored a 2 instead of a 1. While these locations do not necessarily have water quality issues, they are still areas of customer complaints and are therefore scored higher than the rest of the system. Any centerline intersecting multiple proximity buffers was assigned the score of the lowest chlorine sample recorded or the highest parameter score. Table 5c.2 shows the parameter scoring for LOF5.

Parameter Score	Chlorine Residual Sample Results	Count of Block Centerlines
1	Not within 300 feet of a Sample Site	11,945
2	≥1.75 mg/L	945
5	1 mg/L to 1.75 mg/L	291
10	<1 mg/L	399

Table 5c.2: Chlorine Residual InfoAsset Planner Scoring

- ***Fe Levels from Hydrant Readings – 300' Buffer (LOF8) –*** An LoL parameter maintained from the CIP prioritization model. As with LOF5, each centerline within 300 feet of a hydrant sample received a score based on the sample's iron content. In this case, sample results near 0 mg/L are scored lower. However, since samples are only taken at locations with known water quality concerns, block centerlines within 300 feet of samples where the result was 0 mg/L are scored a 2 instead of a 1. While these locations do not necessarily have water quality issues, they are still areas of customer complaints and are therefore scored higher than the rest of the system. Any centerline intersecting multiple proximity buffers was assigned the score of the highest iron content sample recorded or the higher parameter score. Table 5c.3 shows the parameter scoring for LOF5.

Parameter Score	Iron Content Sample Results	Count of Block Centerlines
1	Not within 300 feet of a Sample Site	12,958
2	≤.4 mg/L	151
4	.4 mg/L to ≤.7 mg/L	49
6	.7 mg/L to ≤1 mg/L	92
8	1 mg/L to ≤2 mg/L	234
10	>2 mg/L	96

Table 5c.3: Iron Content InfoAsset Planner Scoring

- ***Proximity to AutoFlushers (LOF13) –*** An LoL parameter maintained from the CIP prioritization model that scores each block centerline by proximity to either a temporary or permanent automatic flushing unit. All centerline features within 300 feet of the automatic flusher are scored. Where the centerline is beyond 300 feet from a unit the centerline was scored a 1. Table 5c.4 shows the parameter scoring for COF58.

Parameter Score	Automatic Flushing Unit Type	Count of Block Centerlines
1	Not within 300 feet of an auto-flusher	13,513
3	Permanent Auto-Flusher	4
10	Temporary Auto-Flusher	63

Table 5c.4: Auto-Flusher InfoAsset Planner Scoring

- ***LFDC – LSL Score (LOF21) –*** The LoL parameter developed to score each block centerline based on the lead score per 100 feet of road as discussed in section 4b. The parameter scoring mimicked the scoring for the individual services, so that at worse case a block would receive the score of the highest scoring service. For example, a block with all non-lead services and a single lead service would still score a 10. Blocks where there are no services are scored a 1. Table 5c.5 shows the parameter scoring for LOF21.

Parameter Score	Lead Service Line Score	Count of Block Centerlines
1	Blank values	2,788
1	No Lead Service Lines	5
2	>0 - ≤2	4,064
3	>2 - ≤3	1,302
4	>3 - ≤4	975
5	>4 - ≤5	750
6	>5 - ≤6	625
7	>6 - ≤7	502
8	>7 - ≤8	403
10	>8	2,166

Table 5c.5: Lead Service Line Score InfoAsset Planner Scoring

- ***LFDC – Water Main Minimum Diameter (LOF22) –*** The LoL parameter developed to score each block based on the smallest diameter water main on the block. Blocks where there are no water mains are scored a 1. This parameter was developed for use in the decision tree and was not used in the prioritization scoring. Table 5c.6 shows the parameter scoring for LOF22.

Parameter Score	Minimum Water Main Diameter	Count of Block Centerlines
1	No Water Main on Block	2,360
3	≥16 inches	105

5	8, 10, 12 inches	9,488
7	6 inch	1,428
10	≤4 inch	199

Table 5c.6: Minimum Diameter InfoAsset Planner Scoring

- ***LFDC – Water Main Maximum Diameter (LOF23) –*** The LoL parameter developed to score each block based on the largest diameter water main on the block. This parameter was set up in the same format as LOF22. Blocks where there are no water mains are scored a 1. This parameter was developed for use in the decision tree and was not used in the prioritization scoring. Table 5c.6 shows the parameter scoring for LOF23.

Parameter Score	Maximum Water Main Diameter	Count of Block Centerlines
1	No Water Main on Block	2,360
3	≥16 inches	164
5	8, 10, 12 inches	10,218
7	6 inch	784
10	≤4 inch	54

Table 5c.7: Maximum Diameter InfoAsset Planner Scoring

- ***LFDC – Water Main Maximum LoF (LOF25) –*** The LoL parameter developed to score each block based on the associated water main's likelihood of failure (LoF) score. Only the maximum LoF score on the block was used in the parameter. Blocks where there are no water mains are scored a 1. This parameter was developed for use in the decision tree and was not used in the prioritization scoring. Table 5c.8 shows the parameter scoring for LOF25.

Parameter Score	Maximum Water Main LoF Score	Count of Block Centerlines
1	No Water Main on Block	2,360
1	1	5,417
3	3	4,065
5	5	1,541
7	7	197
10	10	0

Table 5c.8: Maximum Water Main LoF InfoAsset Planner Scoring

- ***LFDC – Planned SDWMR Locations (LOF26) –*** The LoL parameter developed to score each block based on whether the water mains on the block are scheduled for replacement. Blocks where there are no water mains are scored a 1. This parameter was developed for use in the decision tree and was not used in the prioritization scoring. Table 5c.9 shows the parameter scoring for LOF26.

Parameter Score	Planned Water Main Work	Count of Block Centerlines
1	No Water Main on Block	2,353
1	No Planned Work	10,374
10	Planned Work	2,353

Table 5c.9: Planned Water Main Work InfoAsset Planner Scoring

- ***LFDC – Percentage of Unknowns (LOF27) –*** The LoL parameter developed to score each block based on the percentage of services on the block that have a public side unknown material. Blocks where there are no service lines are scored a 1. This parameter was developed for use in the decision tree and was not used in the prioritization scoring. Table 5c.10 shows the parameter scoring for LOF27.

Parameter Score	Percentage of Unknown Service Line Materials	Count of Block Centerlines
1	No Services on Block	2,788
2	≤10% Unknowns	7,855
5	10% to ≤33% Unknowns	1,430
7	33% to ≤50%	765
10	50% to ≤100%	742

Table 5c.10: Planned Water Main Work InfoAsset Planner Scoring

- ***LFDC – Full LSR Count (LOF28) –*** The LoL parameter developed to score each block based on the number of full LSRs. Since new regulations ban partial lead service line replacements, any public side lead service line replacement is considered a full LSR since the replacement is anticipated to remove all lead from the ground. Similar to previous parameters, blocks where there are no service lines are scored a 1. This parameter was developed for use in the decision tree and was not used in the prioritization scoring. Table 5c.11 shows the parameter scoring for LOF28.

Parameter Score	Full LSR Count	Count of Block Centerlines
1	No Services on Block	2,788
1	0 Full LSRs	8,169
3	1 to 3 Full LSRs	1,718
5	4 to 6 Full LSRs	430
7	7 to 9 Full LSRs	206
10	≥10 Full LSRs	269

Table 5c.11: Full LSR Count InfoAsset Planner Scoring

- ***LFDC – Partial LSR Count (LOF29) –*** The LoL parameter developed to score each block based on the number of private side only lead service lines. Only services where the public side is a non-lead material and the private side is lead fall into this category. LSRs conducted on these services are identified as Partial Private Side Only LSRs. As with previous parameters, blocks where there are no service lines are scored a 1. This

parameter was developed for use in the decision tree and was not used in the prioritization scoring. Table 5c.12 shows the parameter scoring for LOF29.

Parameter Score	Partial Private Side Only LSR Count	Count of Block Centerlines
1	No Services on Block	2,788
1	0 Partial Private Side Only LSRs	6,819
2	1 Partial Private Side Only LSRs	1,155
3	2 Partial Private Side Only LSRs	574
5	3 Partial Private Side Only LSRs	442
7	4 to 9 Partial Private Side Only LSRs	1,161
10	≥9 Partial Private Side Only LSRs	641

Table 5c.11: Partial Private Only LSR Count InfoAsset Planner Scoring

- ***LFDC – Water Main Physical Condition Score (LOF31) –*** The LoL parameter developed to score each block based on the associated water main's LoF physical condition score. The physical condition score makes up 55% of the total water main LoF and represents information on the condition of the water main based on remaining useful life (RUL) and main breaks. To identify blocks with potentially poor condition water mains, only the maximum condition score on the block was used in the parameter. Blocks where there are no water mains are scored a 1. This parameter was developed for use in the decision tree and was not used in the prioritization scoring. Table 5c.8 shows the parameter scoring for LOF31.

Parameter Score	Maximum Water Main Physical Condition Score	Count of Block Centerlines
1	No Water Main on Block	2,354
1	1	6,445
3	3	1,715
5	5	2,947
7	7	89
10	10	30

Table 5c.12: Water Main Physical Condition InfoAsset Planner Scoring

- ***LFDC – Count of Public Unknowns (LOF32) –*** The LoL parameter developed to score each block based on the number of public side unknowns. As with previous parameters blocks where there are no service lines are scored a 1. This parameter was developed for use in the decision tree and was not used in the prioritization scoring. Table 5c.12 shows the parameter scoring for LOF32.

Parameter Score	Public Side Services with Unknown Material Count	Count of Block Centerlines
1	No Services on Block	2,788
1	0 Public Side Unknowns	6,961
3	1 Public Side Unknown	1,732
5	2, 3 Public Side Unknowns	1,052
10	≥4 Public Side Unknowns	625

Table 5c.13: Public Side Unknown Materials InfoAsset Planner Scoring

5d. Multi-Parameter Likelihood of Lead Functions

Like the scoring for the CoL, multi-parameter functions were used to calculate the overall LoL score. Four multi-parameter functions were developed, Multi_LOF4 to Multi_LOF7, with Multi_LOF4 accounting for the physical condition scoring and the remaining parameters accounting for the performance scoring. Multi_LOF4 and Multi_LOF7 used the minimum diameter as a place holder parameter. The other functions required at least two parameters to calculate the corresponding score, so no placeholder was required. As with previous sections, all counts of block centerlines are based off the initial model development and may change in future iterations if data updates are conducted.

- ***LFDC – Physical Condition (Multi_LOF4) –*** The LoL multi-parameter function developed to score block centerlines on the water main's physical condition, via the number of main breaks. The Physical Condition score accounts for 10% of the total LoL score. The count of main breaks (LOF2) and minimum diameter (LOF22), serving as a place holder, were used in the multi-parameter function. Table 5d.1 shows the parameter scoring for Multi_LOF4.

Parameter Score	Count of Main Breaks (LOF2)	Minimum Water Main Diameter (LOF22)	Count of Block Centerlines
1	Blanks values, 0	All Diameters	9,875
2	1, 2	All Diameters	3,077
5	3, 4	All Diameters	343
10	>4	All Diameters	288

Table 5d.1: Physical Condition Multi-Parameter Scoring

- ***LFDC – Performance Component - Chlorine (Multi_LOF5) –*** The LoL multi-parameter function developed to score block centerlines on performance, via the results of chlorine sampling. The Performance Component – Chlorine score accounts for 9% of the total LoL score. The chlorine residual hydrant sampling results (LOF5) and the proximity to an automatic flushing unit (LOF13) were used in the multi-parameter function. Table 5d.2 shows the parameter scoring for Multi_LOF5.

Parameter Score	Chlorine Sampling Results (LOF5)	Proximity to Automatic	Count of Block Centerlines

			Flushing Units (COF13)
1	No Sampling Results	>300 Feet	11,943
2	≥1.75 mg/L	>300 Feet	943
5	1 mg/L to 1.75 mg/L	>300 Feet	278
10	<1 mg/L	>300 Feet	352
10	Any Location	≤300 Feet	67

Table 5d.2: Chlorine Residual Sampling Multi-Parameter Scoring

- ***LFDC – Performance Component - Iron (Multi_LOF6) –*** The LoL multi-parameter function developed to score block centerlines on performance, via the results of iron sampling. The Performance Component – Iron score accounts for 27% of the total LoL score. The chlorine residual hydrant sampling results (LOF8) and the proximity to an automatic flushing unit (LOF13) were used in the multi-parameter function. Table 5d.3 shows the parameter scoring for Multi_LOF6.

Parameter Score	Iron Sampling Results (LOF8)	Proximity to Automatic Flushing Units (COF13)	Count of Block Centerlines
1	No Sampling Results	>300 Feet	12,939
2	≤0.4 mg/L	>300 Feet	142
4	0.4 mg/L to ≤0.7 mg/L	>300 Feet	42
6	0.7 mg/L to ≤1 mg/L	>300 Feet	91
8	1 mg/L to ≤2 mg/L	>300 Feet	206
10	>2 mg/L	>300 Feet	98
10	Any Location	≤300 Feet	65

Table 5d.3: Iron Content Sampling Multi-Parameter Scoring

- ***LFDC – Performance Component – LSL Score (Multi_LOF7) –*** The LoL multi-parameter function developed to score block centerlines based on the lead service line inventory, via the total lead service score per 100 feet of roadway. The Performance Component – LSL Score accounts for 54% of the total LoL score. The lead service line score (LOF21) and the minimum diameter (LOF22), serving as a place holder, were used in the multi-parameter function. Table 5d.4 shows the parameter scoring for Multi_LOF7.

Parameter Score	Lead Service Line Score per 100 Feet (LOF21)	Minimum Water Main Diameter (LOF22)	Count of Block Centerlines

1	Blanks values, No Lead Service Lines	All Diameters	2,793
2	>0 - ≤2	All Diameters	4,065
3	>2 - ≤3	All Diameters	1,304
4	>3 - ≤4	All Diameters	975
5	>4 - ≤5	All Diameters	750
6	>5 - ≤6	All Diameters	625
7	>6 - ≤7	All Diameters	502
8	>7 - ≤8	All Diameters	403
10	>8	All Diameters	2,166

Table 5d.4: Lead Service Line Scoring Multi-Parameter Scoring

5e. Risk Scoring

The total risk score identifies the highest priority blocks (from an equity and vulnerable populations standpoint) that have the highest likelihood of lead. The total score is calculated as the product of the total CoL and LoL. The CoL is comprised of the three multi-parameter functions discussed in Section 5b, while the LoL is comprised of the four multi-parameter functions from Section 5d. The below chart 5e.1 depicts the calculation used to determine the risk score.

CoL Multi-Parameter	Weight		LoL Multi-Parameter	Weight
Multi_COF12	0.5	X	Multi_LOF4	0.10
Multi_COF13	0.2		Multi_LOF5	0.09
Multi_COF14	0.3		Multi_LOF6	0.27
			Multi_LOF7	0.54

Table 5e.1: LFDC Risk Calculation

The resulting risk scores for the initial model development are shown below in Table 5e.2, with values ranging from 1 to 80.64.

Total Risk Score	Count of Block Centerlines
1 - 10	8,865
11 - 20	3,112
21 - 30	1,079
31 - 40	385
41 - 50	99
51 - 60	37
61 - 70	4
71 - 80	1
81 - 90	1
91 -100	0

Table 5e.2: LFDC Risk Model Results

6. InfoAsset Planner Model Validation

Once the model parameters were built and the development of the model completed, a detailed model validation was conducted. This validation included a review of each parameter, multi-parameter and the risk calculation to confirm that the correct data, weighting and parameters were being used in the analysis. Once confirmed a detailed scoring review was conducted on ten random blocks. The blocks were distributed throughout the city, with varying numbers of lead services, each with an array of different attributes. The below Table 6.1 shows the results of the review, identifying both the manual calculation and the InfoAsset Planner model scoring for the CoL, LoL and total risk scores.

Street Segment ID	Manual CoL Score	Model CoL Score		Manual LoL Score	Model LoL Score		Manual Risk Score	Model Risk Score	
704	6.3	6.3	✓	8.56	8.56	✓	53.928	53.928	✓
7218	1	1	✓	1.1	1.1	✓	1.1	1.1	✓
8125	2	2	✓	5.96	5.96	✓	11.92	11.92	✓
12471	1.4	1.4	✓	2.17	2.17	✓	3.038	3.038	✓
5529	3.8	3.8	✓	5.86	5.86	✓	22.268	22.268	✓
5832	3.8	3.8	✓	6.77	6.77	✓	25.726	25.726	✓
8559	6.1	6.1	✓	5.59	6.67	✓	34.099	40.687	✓
1	9	9	✓	3.8	3.8	✓	34.2	34.2	✓
1465	2.8	2.8	✓	5.42	5.42	✓	15.176	15.176	✓
414	9.4	9.4	✓	3.11	3.11	✓	29.234	29.234	✓

Table 6.1: LFDC Model Validation

As the table shows, the review confirmed the results of the model. All of the InfoAsset Planner scores matched with the manual scoring, verifying that the model was set-up accurately and that the parameters are interpreting the data accurately.

7. InfoAsset Planner Decision Tree

The second component of the Lead Free DC InfoAsset Planner model development was the creation of a decision tree to easily group blocks into project groups. The decision tree steps through a series of queries, using CoL and LoL parameters, to classify each block into a project group. The below figure 7.1 illustrates the decision tree with the queries displayed in the green ovals and the project groups in orange rectangles.

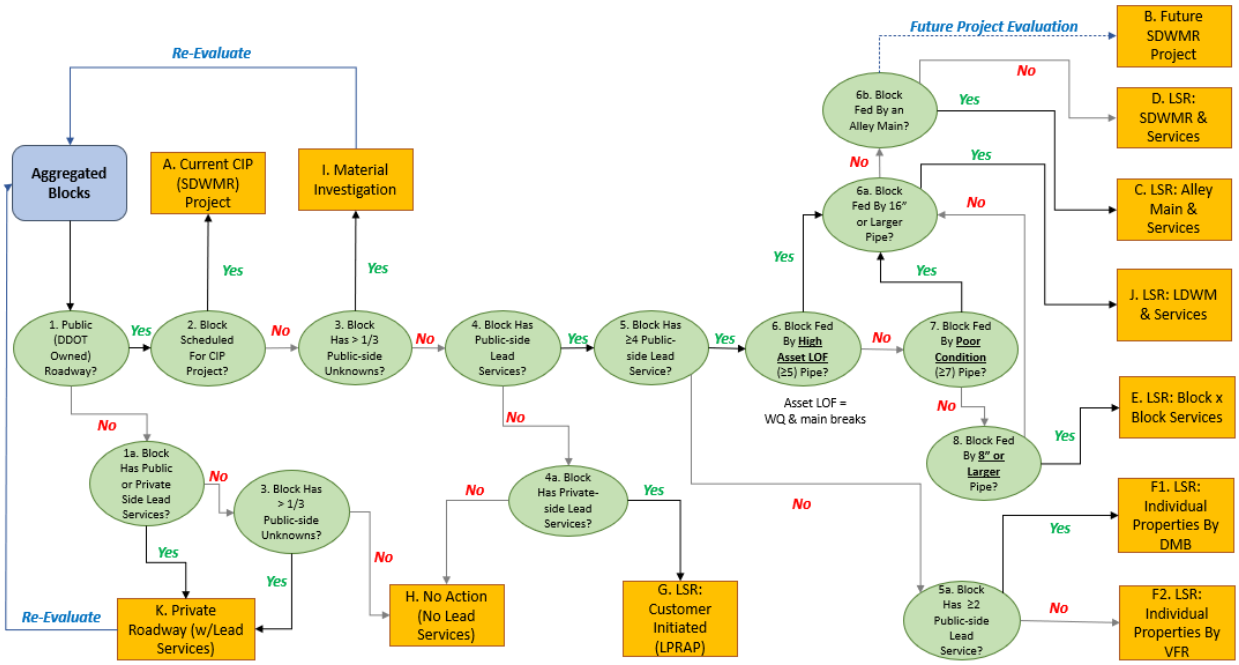

Figure 7.1: LFDC Decision Tree

While there are a total of 12 project groups, these can be classified into five major categories. These are No Action, Material Investigation, By Block – LSL replacements, By Block – LSLs and Water Main replacements, and By Premise – LSL replacements. The following sections summarize each category, the groups in these categories, the various steps that are used in classifying these groups and the anticipated actions for each group.

7a. No Action (No Lead Services)

Blocks where the service line inventory contains no lead records, public or private, and less than one third of the public service line materials are unknown. Blocks classified in this group are not included in the LSR program. It is assumed that any public side unknown on these blocks will be a non-lead material, based on the adjacent properties. Table 7a.1 summarizes the number of blocks and services within this group resulting from the initial model development.

Group	Count of Blocks	Full LSRs	Partial Private Only LSRs	Public Side Unknowns
H. No Action (No Lead Services)	8,155	0	0	1,609

Table 7a.1: No Action LSL Counts

It should be noted that there is no systematic review of unknowns in this group scheduled, however it is anticipated that these will be rectified in conjunction with other investigations and LSRs being conducted during the program.

7b. Material Investigations

Blocks where investigations, whether field or desktop, will be conducted to verify and identify service line materials. As the materials of these blocks are identified and confirmed, the blocks will be reclassified into one of the other groups. Blocks where no lead services are found will be migrated to No Action while those where lead services exist will be categorized into one of the LSR groups. It is assumed that these blocks will be reclassified within the first 5 years of the LFDC program and the LSRs conducted over the last 4 years of the program.

- ***Group I – Material Investigation –*** Blocks where at least one third of the services have a public service line material of unknown, regardless of the number of known lead service lines. This group does not include services residing on roads not owned by the District Department of Transportation (DDOT) or any roadway where the water main is being replaced as a part of a CIP project.

- ***Group K – Private Roadways (with Lead Services) –*** Per the LCR, water systems only need to include services that are directly connected to the utility owned distribution system in the inventory. Therefore, service lines connected to private water mains, which are typically on private roads, do not need to be logged. This includes roads with water mains owned by the National Parks Service (NPS), Architect of the Capitol (AOC), colleges, hospitals, government agencies, military and other non-DDOT entities. Therefore, blocks representing these private roads have been grouped together. Only roadways containing a lead service, public or private, or that have more than one third of the services identified with a public side material of unknown are included in this group, all others have been classified in the No Action group.

  These have been included in the material investigation category as DC Water has expressed interest in resolving any unknown values within this group and re-confirming any lead entry, despite not being required as part of the inventory. Since the analysis linking the premise point data to the block centerlines was conducted using a spatial relationship, Mott MacDonald also recommends a review of these records, especially those classified as lead, to confirm they are associated to the correct block centerline.

The below table 7b.1 summarizes the number of blocks and services in this group resulting from the initial model development.

Group	Count of Blocks	Full LSRs	Partial Private Only LSRs	Public Side Unknowns
I. Material Investigation	1,285	972	199	7,396
K. Private Roadways (with Lead Services)	124	5	0	1,758

Table 7c.1: Material Investigation Service Line Counts

7c. By Block – LSL Replacements

Blocks where the service line inventory contains at least 4 public-side lead records requiring Full LSRs. This category excludes all blocks currently in the CIP program, that are private roads or have at least one third of the public side materials identified as unknown. Additionally, this category excludes any service lines tapped to a water main identified as poor condition or a water main smaller than 8 inches. LSRs on these blocks are anticipated to be conducted by an external contractor in years two and three of the LFDC program. The highest scoring 60% of services are anticipated to be completed in year 2, with the remaining services completed in year 3. All blocks in this category are classified as Group E – LSR: Block by Block LSRs. The below table 7c.1 summarizes the number of blocks and services in this category per the initial model development.

Group	Count of Blocks	Full LSRs	Partial Private Only LSRs	Public Side Unknowns	Centerline Mileage
E. Block by Block LSRs	497	4,228	355	869	44.91

Table 7c.1: By Block LSL Counts

7d. By Block – LSLs & Water Main Replacements

Blocks where the lead service lines will be replaced in conjunction with the water main. As DC Water replaces all service lines, lead or non-lead, in conjunction with water main replacements, any block where the water main is planned or proposed for replacement as part of an improvement project is also included in this category. This includes blocks classified in Group A – Current CIP (SDWMR) Project, Group B – Future SDWMR, Group C – LSR: Alley Main & Services, Group D – LSR: SDWMR & Services, and Group J – LSR: LDWM & Services. The first two groups are related to the CIP program while the later three are related to the LFDC program. The below details each group and the blocks and services that are included in that group.

- ***Group A – Current CIP (SDWMR) Projects*** – Blocks where the water mains have previously been selected for replacement as part of the CIP program, specifically the small diameter water main rehabilitation (SDWMR) program. This includes blocks that are currently scheduled for replacement in conjunction with a DDOT road paving projects. Current blocks in this group are scheduled for completion over the next five years based on the CIP schedule. As additional locations are selected for inclusion in the CIP program they will be migrated to this group.

- ***Group B – Future SDWMR Projects*** – A place holder for blocks that will be included in CIP program over the final 4 years of the program. It is anticipated that at least 44 miles of water mains will be replaced during that timeframe. This group was used solely for budgeting purposes and is not used to classify any blocks nor will it be used in the future. Blocks selected for future CIP work will be classified in Group A once the location has been selected for inclusion in the CIP program.

- ***Group D – LSR: SDWMR & Services*** – Blocks where the service line inventory contains at least 4 public-side lead records requiring Full LSRs and where the water main is considered to be in poor condition. Since there is a concern re-tapping water

mains with an extensive break history, any water main with a high asset LoF of 5 or greater or a condition score of 7 or greater were included in this category. Additionally, blocks with water mains that are smaller than 8 inches are included in this group. Such water mains are older and would eventually be replaced with newer 8 inch water mains under future CIP work. As part of the LFDC program, any block categorized with the above will have the water main replaced in conjunction with the LSR work. Blocks in this group will have the water main and service lines replaced during years four to eight of the program. The highest priority locations will be completed in year 4 with the lowest priority locations in year 8. Since the replacement of water mains in alleyways may require special construction considerations, alleys were excluded from this group. Likewise, blocks where the service lines are connected to poor condition large diameter water mains have been removed. Likewise, additional planning may be required on these blocks.

- ***Group C – LSR: Alley Main & Services*** – Blocks where the service line inventory contains at least 4 public-side lead records requiring Full LSRs, where the water main is considered to be in poor condition and is an alley. This group is based on those blocks removed from Group D due to the need for additional planning efforts. Alleyways have a tendency to be narrower than streets and there may be issues maneuvering construction vehicles in these tight locations. Likewise, alleys tend to have paving stones instead of typical asphalt, significantly increasing the restoration costs. Therefore, alleys were removed from the Group D and placed in Group C. Group C will be replaced in conjunction with Group D during years four through eight of the program.

- ***Group J – LSR: LDWM & Services*** – Blocks where the service line inventory contains at least 4 public-side lead records requiring Full LSRs, where the water main is considered to be in poor condition and where the services are connected to a water main greater than 16 inches. Similar to Group C, this group is based on those blocks removed from Group D due to the necessity for additional planning efforts. As large diameter water mains, per the design manual, should not have residential services tapped to them and since there are extensive concerns tapping poor condition large diameter water mains, additional planning may be required for these blocks. In most instances it is anticipated that a parallel small diameter main will be installed to connect these services to. Group J will be replaced in conjunction with Group D during years four to eight of the program.

As part of the analysis conducted to identify locations where the water mains should be replaced in conjunction with the LSLs, it was assumed that all local, collector and minor arterial roadways will have a single small diameter water main installed regardless of the current water main alignment. Conversely, it was assumed that any major arterial road will have dual small diameter water mains installed. Such roadways are typically larger and would require services of at least 75 feet if a single water main were installed. Therefore, for determining the mileage of water main to be included in the project the centerline mileage was doubled for these blocks. While there will be exceptions to this policy identified during the design process, this analysis did not look to identify those.

Table 7d.1 summarizes the number of blocks and services in this category per the initial model development.

Group	Count of Blocks	Full LSRs	Partial Private Only LSRs	Public Side Unknowns	Centerline Mileage
A. Current CIP (SDWMR) Projects	853	1,344	1,378	1,088	71.67
B. Future SDWMR Projects	To Be Determined				
D. LSR: SDWMR & Services	208	1,783	180	620	20.83
Local & Minor Roads (Single Main)	*185*	*1,612*	*164*	*550*	*18.25*
Major Roads (Dual Main)	*23*	*171*	*16*	*70*	*2.58*
C. LSR: Alley Main & Services	1	7	0	1	0.03
J. LSR: LDWM & Services	7	63	3	12	0.95

Table 7d.1: By Block – LSLs and Water Main Counts

7e. By Premise – LSL Replacements

Blocks where the customer initiates the lead service line replacement. These include blocks with less than 4 public side lead services and blocks consisting of only partial private only LSRs. These exclude any block where the water mains are currently scheduled for replacement as part of the CIP program. Due to the limited number of LSRs (and the associated limited number of re-tapping required) the groups in this category do not take into account the condition of the water main. This category includes blocks included in Group F1 – LSR: Individual Properties By DMB, Group F2 – LSR: Individual Properties By VFR, Group G – Customer Initiated (LPRAP).

- ***Group F1 – LSR: Individual Properties by DMB –*** Blocks where the service line inventory contains less than four but more than one public-side lead record requiring Full LSRs. Services on these blocks will be replaced by DMB at the customer's request. The completion of these locations will span the entire length of the program.

- ***Group F2 – LSR: Individual Properties by VFR –*** Blocks where the service line inventory contains one public-side lead records requiring Full LSR. Services on these blocks will be replaced by DC Water at the customer's request. The completion of these locations will span the entire length of the program.

- ***Group G – LSR: Customer Initiated (LPRAP) –*** Blocks where the service line inventory contains no public side lead services, but at least one partial private only lead service. Services on these blocks will be replaced at the customer's request. The completion of these locations will span the entire length of the program.

It should be noted that since replacements on these blocks are relying on the customer initiating the work, planning related to this category is not entirely possibly. For planning purposes, a randomization of the blocks was used to predict the lead service line counts per year of the program.

The below table 7e.1 summarizes the number of blocks and services in this group resulting from the initial model development.

Group	Count of Blocks	Full LSRs	Partial Private Only LSRs	Public Side Unknowns
F1. LSR: Individual Properties by DMB	516	1,246	418	576
F2. LSR: Individual Properties by VFR	751	751	1,255	511
G. LSR: Customer Initiated (LPRAP)	1,189	0	7,245	255

Table 7e.1: By Premise – LSL Counts

8. Reporting of Results

The results of the LFDC prioritization model and decision tree are provided via MS Excel documents to the stakeholders. These results define the number of blocks, full LSRs, partial private only LSRs, and public side unknowns per group. In addition, the following calculation is used to yield a total expected number of LSRs per group.

$$Total\ LSRs = Full\ LSRs + Partial\ Private\ Only\ LSRs + .5 * Public\ Side\ Unknowns$$

Deploying this equation, a summary of the initial model results is shown in Table 8.1.

Group	Count of Blocks	Full LSRs	Partial Private Only LSRs	Public Side Unknowns	Total LSRs
A. Current CIP (SDWMR) Projects	853	1,344	1,378	1,088	3,266
B. Future SDWMR Projects	To Be Determined				
D. LSR: SDWMR & Services	208	1,783	180	620	2,273
C. LSR: Alley Main & Services	1	7	0	1	8
J. LSR: LDWM & Services	7	63	3	12	72
E. Block by Block LSRs	497	4,228	355	869	5,018
F1. LSR: Individual Properties by DMB	516	1,246	418	576	1,952
F2. LSR: Individual Properties by VFR	751	751	1,255	511	2,262
G. LSR: Customer Initiated (LPRAP)	1,189	0	7,245	255	7,373
H. No Action (No Lead Services)	8,155	0	0	1,609	805
I. Material Investigation	1,285	972	199	7396	4,869
K. Private Roadways (with Lead Services)	124	5	0	1758	884
Total	13,583	10,399	11,033	14,695	28,780

Table 8.1: Lead Service Line Replacements by Group

If a similar methodology is utilized with the unknowns and it is assumed that half will be classified as lead upon further review, Groups I and K from the initial model development can be reclassified as indicated below. Group D would also include 3.17 miles of water main replacement and Group C would include 0.08 miles. The below Table 8.2 shows the summary of the reclassification.

Group	Count of Blocks	Full LSRs	Partial Private Only LSRs	Public Side Unknowns	Total LSRs
A. Current CIP (SDWMR) Projects	No Blocks Reclassified to Group A				
B. Future SDWMR Projects	No Blocks Reclassified to Group B				
D. LSR: SDWMR & Services	35	242	29	388	465
C. LSR: Alley Main & Services	1	4	0	7	8
J. LSR: LDWM & Services	No Blocks Reclassified to Group J				
E. Block by Block LSRs	279	305	30	4,947	2,809
F1. LSR: Individual Properties by DMB	362	274	54	1,855	1,256
F2. LSR: Individual Properties by VFR	690	152	29	1,676	1,019
G. LSR: Customer Initiated (LPRAP)	39	0	57	281	198
H. No Action (No Lead Services)	No Blocks Reclassified to Group H				
I. Material Investigation	Reclassified to Other Groups				
K. Private Roadways (with Lead Services)	Reclassified to Other Groups				
Total	1,406	977	199	9,154	5,753

Table 8.2: Group I & K Reclassification

By combining the results from Tables 8.1 and 8.2 the estimated number of LSRs based on the data used during the initial model development is shown below in Table 8.3. Additionally, the total mileage of water main requiring replacement as part of the LFDC program is estimated to be 27.88 miles.

Group	Count of Blocks	Full LSRs	Partial Private Only LSRs	Public Side Unknowns	Total LSRs
A. Current CIP (SDWMR) Projects	853	1,344	1,378	1,088	3,266
B. Future SDWMR Projects	To Be Determined				
D. LSR: SDWMR & Services	243	2,025	209	1,008	2,738
C. LSR: Alley Main & Services	2	11	0	8	15
J. LSR: LDWM & Services	7	63	3	12	72
E. Block by Block LSRs	776	4,533	385	5,816	7,826
F1. LSR: Individual Properties by DMB	878	1,520	472	2,431	3,208
F2. LSR: Individual Properties by VFR	1,441	903	1,284	2,187	3,281
G. LSR: Customer Initiated (LPRAP)	1,228	0	7,302	536	7,570
H. No Action (No Lead Services)	8,155	0	0	1,609	805
I. Material Investigation	Reclassified to Other Groups				
K. Private Roadways (with Lead Services)	Reclassified to Other Groups				
Total	13,583	10,399	11,033	14,695	28,780

Table 8.3: Total Lead Service Line Replacements Including Reclassifications

9. Lead Density Mapping

In conjunction with reporting and mapping the results of the prioritization model and decision tree, WPM was asked to conduct an analysis to determine the yearly reduction of lead per city square. This analysis utilized the results of the model to calculate when each face or side of the square would be replaced. The analysis associated each service line with the square it resided in and, using the model results, combined this information with the planned replacement year. The count of services at the start of year one equates to the current lead totals as of February 2021. The count of services at the start of year two was determined by taking the year one

count and subtracting the count of services scheduled to be replaced in that year. This process was repeated for years three to ten. These counts were then displayed over 10 maps starting with the current lead density and ending with the final year of the program where no lead services remain in the system. An example of two of the maps are shown below in figure 9.1.

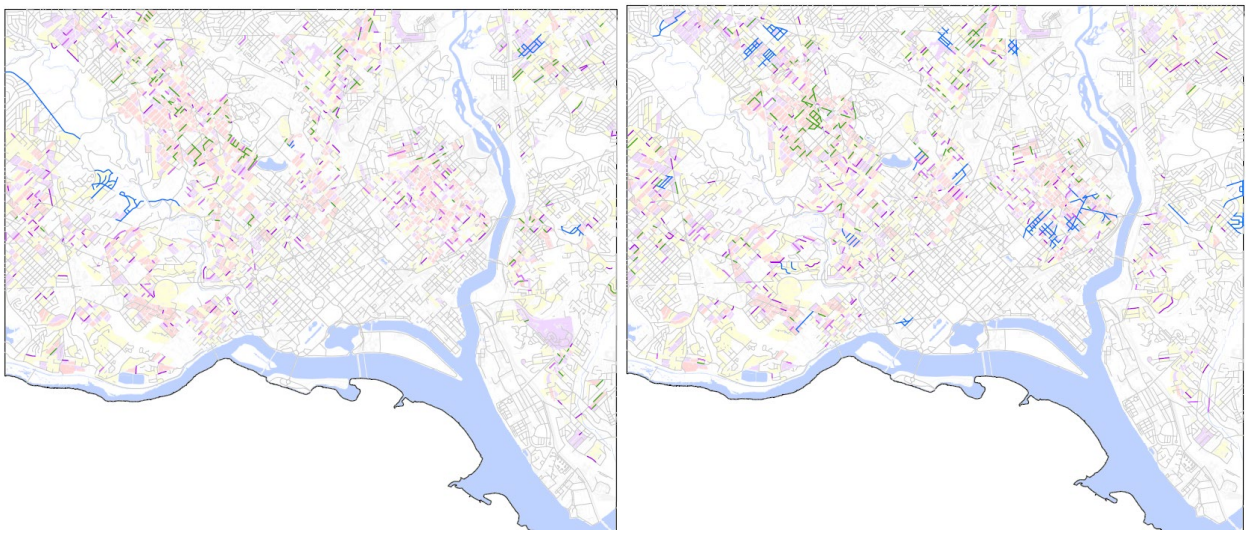

Table 9.1: Year 1 and Year 2 Lead Density Mapping

10. Recommendations

The LFDC model and decision tree were based on the input from the LFDC stakeholders and used data from February 2021. Since the program is in its initial phases it is anticipated that additional modifications to the model will be needed in the future. These may include modifications to data, inclusion of additional information, changes in reporting methodology and adjustments to the decision tree. Additionally, the WPM team recommends the following actions be taken in relation to the LFDC model:

- Updated service line inventory data should be loaded to the model at least every six months, with additional data uploads conducted when a significant number of changes are made to the inventory. The service line scoring, prioritization model and decision tree should be re-run to account for these changes.

- Updated water main risk scores should be loaded into the LFDC model yearly in conjunction with the scoring conducted for the SDWMR program. The decision tree should then be re-run to account for these changes.

- Revised data for population of children and ADI should be utilized once the information becomes available. The prioritization model should be re-run to account for these changes.

- A manual review should be conducted to confirm that service lines are connected to the correct block centerline. If locations are incorrect, the street segment ID stored with the service line inventory should be updated to accurately represent the block centerline that the service is connected to.

- DC Water should strongly consider conducting a review of public side unknowns that are clustered in developments. In most cases these were built after lead was phased out and can be classified as a non-lead material.

ATTACHMENT

H

SECTION 33 12 13

WATER SERVICE LINES

PART 1. GENERAL

1.1 SUMMARY:

A. Provide all labor, materials, and equipment necessary to install water service lines, two (2) inches and smaller, and remove and replace lead water service lines to properties including but not limited to excavating test pits, water service trench excavation and backfill, installation of meter box, curb stop, curb stop box, service saddles, corporation stops, and temporary surface restoration. Includes replacing galvanized iron and brass water service if directed by DC Water.

1.2 RELATED DOCUMENTS:

A. Drawings, Technical Specification Sections, General and Supplementary Conditions of the Contract and other Division 00 and Division 01 Specification Sections, apply to this Section.

B. Specifications throughout all Divisions of the Project Manual are directly pertinent to this Section, and this Section is directly pertinent to them.

1.3 REFERENCED SECTIONS:

A. Sections specified elsewhere may include but are not limited to:

1. Section 00 89 00: Project Permits and Approval.
2. Section 01 06 50: Public Notification – Water.
3. Section 01 33 00: Submittals.
4. Section 33 01 20: Abandonment of Underground Utilities.
5. Section 33 12 17: Service Saddles.

1.4 REFERENCED CODES AND STANDARDS:

A. ASTM International (ASTM):

1. ASTM B88: “Standard Specification for Seamless Copper Water Tube”.
2. ASTM C33: “Standard Specification for Concrete Aggregate”.
3. ASTM C534: “Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form”.
4. ASTM C552: “Standard Specification for Cellular Glass Thermal Insulation”.
5. ASTM C564: “Standard Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings”.
6. ASTM C920: “Standard Specification for Elastomeric Joint Sealants”.
7. ASTM D746: “Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact”.
8. ASTM D1248: “Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable”.
9. ASTM D1505: “Standard Test Method for Density of Plastics by the Density-Gradient Technique”.
10. ASTM D1785: “Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Schedules 40, 80, and 120”.

11. ASTM D2665: "Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings".

12. ASTM E84: "Standard Test Method for Surface Burning Characteristics of Building Materials".

B. American Water Works Association (AWWA)

1. AWWA C810: "Replacement and Flushing of Lead Service Lines".

C. Code of Federal Regulations:

1. 40 CFR 261: "Identification and Listing of Hazardous Waste".

2. 40 CFR 262: "Standards Applicable to Generators of Hazardous Waste".

3. 40 CFR 263: "Standards Applicable to Transporters of Hazardous Waste".

4. 40 CFR 264: "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities".

5. 40 CFR 265: "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities".

6. 40 CFR 268: "Land Disposal Restrictions".

D. District of Columbia Department of Consumer and Regulatory Affairs (DCRA):

1. District of Columbia Plumbing Code.

E. Safe Drinking Water Act (SDWA):

1. Reduction of Lead in Drinking Water Act.

1.5 SUBMITTALS:

A. Requirements for "Submittals" shall be in accordance with Section 01 33 00.

B. Submit the "Product Data Sheets" for each product used.

C. Submit "Field Data" for work performed including but not limited to permits, invoices, tap cards, and daily and weekly reporting sheets, customer outreach logs, completed and cancelled services orders.

D. Submit written evidence that the receiving lead waste treatment, storage, or disposal facility is approved to accept lead waste by the federal and district or local regulatory agencies.

E. Submit Private Property Side Agreement Documentation.

F. Submit proposed method of installation for service lines.

1.6 PERMITS:

A. Contractor shall obtain permits required by Section 00 89 00 – Project Permits and Approvals.

1.7 NOTIFICATIONS:

A. Notifications shall be made in accordance to Section 01 06 50 – Public Notification - Water.

B. Contractor shall notify DC Water a minimum of two (2) weeks prior to performing water service work, meter relocation, and/or new meter installation.

PART 2. PRODUCTS

2.1 GENERAL:

A. All service brass shall comply with the 2011 Reduction of Lead in Drinking Water Act which went into effect January 1, 2014. Products shall be marked “lead-free” or “Low Lead” to signify compliance.

B. The following materials shall comply with the District of Columbia Plumbing Code.

1. Shut-off valves.
2. Pressure reducing valves.
3. Copper-to-Copper Couplings.
4. Copper-to-Non-Copper Couplings.
5. Meter Yokes.
6. Reducers.
7. Meter Stops.
8. Meter Valves.
9. Seamless Copper Water Tube shall be ASTM B88, Type K.

2.2 CORPORATION STOPS:

A. Corporation Stops shall be per the District of Columbia Plumbing Code.

B. Acceptable manufacturers and models for one (1) inch corporation stop include Mueller Corporation Valve Model B25000N, A.Y. McDonald Model 74701B, or approved equal.

C. Acceptable manufacturers and models for one half (1-1/2) inch corporation stop include Mueller Corporation Valve Models B20003N and H10096N, A.Y. McDonald Models 73121 and 74000, or approved equal.

D. Acceptable manufacturers and models for two (2) inch corporation stop include Mueller Corporation Valve Models B20003N and H10096N, A.Y. McDonald Models 73121 and 74000, or approved equal.

2.3 CURB STOPS AND EXTENSION RODS:

A. Curb stops shall be an optimized design by combining a strong and reliable ball/stem connection with other designed features, including a blow-out-proof stem, double O-rings and a 300 psig working pressure rating. The design shall offer true bi-directional (two way) flow.

B. Extension rods shall be stainless steel. Rods shall be half (1/2) inch diameter for two (2) feet long and shorter 5/8-inch diameter for greater than two (2) feet. Rods shall be supplied with optional rod rings and stainless steel cotter pins. Acceptable models are A.Y. McDonald Model 5660SS, Bingham & Taylor Model Type ROD SS, or approved equal for the appropriate size required.

C. Acceptable manufacturers and models for one (1) inch curb stops include Mueller 300 Ball Corporation Valve Model B25204N, A.Y. McDonald Model 76100, or approved equal.

D. Acceptable manufacturers and models for one half (1-1/2) inch curb stops include Mueller 300 Ball Corporation Valve Model B25204N, A.Y. McDonald Model 76100, or approved equal.

E. Acceptable manufacturers and models for two (2) inch curb stops include Mueller 300 Ball Corporation Valve Model B25204N, A.Y. McDonald Model 76100, or approved equal.

2.4 CURB STOP BOXES:

A. Curb stop boxes shall be telescoping, two (2) piece, screw style. Lower section shall consist of full externally threaded shaft over a Buffalo style bell that is arched and flanged. Upper section shall consist of full internally threaded shaft that fits over lower section with cast iron rim on top of shaft to accommodate a cast iron cover (lid) with "WATER" imprinted on it.

B. Both the lower section and the upper section of the curb stop box shall be rigid acrylonitrile-butadiene-styrene (ABS.) plastic, either injection molded or extruded.

C. The cast iron lid and rim shall be of standard Buffalo new style design with standard pentagon head bolt and shall be interchangeable with the cast iron Buffalo old style boxes already in use.

D. Acceptable manufacturer and model includes Bingham & Taylor Model Series 250 for use outside the roadway or series 4901, Sliding Type P-94-E, for use within the roadway – Screw curb stop box, or approved equal.

2.5 METERS:

A. Meters will be furnished by DC Water.

2.6 METER BOXES:

A. Meter boxes shall be of durable, high-density polyethylene, molded with solid walls (containing no foam or corrugations) and shall have flanged bottom not only for added strength but also to retard settling or sinking into the ground. The nominal wall thickness of the box shall not be less than 0.55 inch and the box shall have nominal dimensions of 20 inch diameter (O.D.) by 30 inch depth. Other sizes may be used, if necessary, for larger settings.

B. The polyethylene (PE) plastic material specified for the box shall be Type III or Type IV High Density polyethylene per ASTM D1248, with densities of 0.95 g/c.c. and above, as determined by ASTM D1505 test method. The interior color of the box shall be white (natural) to aid in meter reading, but the exterior shall be black, compounded to improve strength and to protect against deterioration below ground. The low temperature brittleness shall be a maximum of 76 degrees Fahrenheit per ASTM D746.

C. Acceptable manufacturer and model includes Oldcastle Enclosure Solutions, Inc. Carson Plastics Model 0020-B 30 inch, or approved equal.

2.7 METER BOX FRAMES AND COVERS:

A. Meter box frame and cover to be used in conjunction with the meter boxes above.

B. Covers shall be Type A, 12-1/4-inch O.D. for one (1) inch meters and 21-1/4-inch O.D. for one half (1-1/2) inch and two (2) inch meters, and shall be constructed of polyolefin resin or similar material that is UV stabilized and RF transparent. Mountings for AMI devices shall be compatible with Hexagram meter transmission units. Each cover shall be fitted with one standard size bronze pentagon nut swaged to a cast iron locking worm gear and shall be labeled with "DC Water" in one-inch high letters.

C. Meter box frame castings for non-traffic areas shall be iron melted by any process following ASTM A48, Class 35 minimum. Surfaces shall be sandblast clean or other approved process. Paint clean and rust free surface with one (1) coat of asphalt.

D. Meter box frames for traffic areas shall be cast iron sized to suit cover and meter box furnished. Meter box frames and cover shall be tested to withstand AASHTO H20 loading and shall be approved by DC Water.

E. Acceptable manufacturers and models for meter box frame and cover for one (1) inch meter setting includes Bingham and Taylor frame Model 180-20-AWEH-TR for 20 inch diameter housing or approved equal.

F. 20 inch single recess meter box frame for 30 inch diameter housing for one half (1-1/2) inch and two (2) inch meter setting shall be assembly consisting of 20 inch diameter monitor ring and 20 inch x 30 inch extension ring. Extension ring shall be manufactured by Bingham and Taylor Model No. 4F-000, East Jordan Iron Works model No. 32320300, or Meter Box Covers, Inc. (Division of A.Y. McDonald Manufacturing Co.) Model No. 74MF1010 or approved equal.

2.8 METER SETTINGS:

A. Meter settings for one (1) inch meters:

1. Single meter setter shall be one (1)-piece factory assembled, including, ball valves, dual check valves, elbows and all connections as shown on standard details. All joints within the meter pit must be flared, brazed or threaded fittings.

2. Acceptable manufacturers and models for one (1) inch meter settings include Mueller Model 330B2489-6A-N, A.Y. McDonald Model 737412WDCC44, or approved equal.

B. Meter settings for one half (1-1/2) and two (2) inch meters:

1. Single meter setter shall be one (1) piece factory assembled, including high by-pass, ball valves, dual check valves, elbows and all connections as shown on standard details. All joints within the meter pit must be flared, brazed or threaded fittings.

2. Acceptable manufacturers and models for one half (1-1/2) inch meter setter includes Ford Meter Box Company Model VBHC76-27HBHC-11-66-NL, A.Y. McDonald Manufacturing Company Model 720R627WD-FF-66X427, Mueller Co. Model 096B2423-2-39N dated 1/5/16, or approved equal.

3. Acceptable manufacturers and models for two (2) inch meter setter includes Ford Meter Box Company Meter Model VBHC77-27HBHC-11-77-NL A.Y. McDonald Manufacturing Company Model 720-R727WD-FF-775.04X427, Mueller Co. Model 1096B2423-2-39N dated 1/5/16, or approved equal.

2.9 SERVICE SADDLES:

A. Service Saddles shall be in accordance with Section 33 12 17 – Service Saddles.

2.10 PIPE PENETRATION MATERIALS:

A. Sealant:

1. Pipe penetration sealant used with grout filler shall be one (1) component polyurethane, elastomeric non-sag sealant meeting ASTM C920, Type S, Grade NS, Class 35. Sikaflex 1a as manufactured by Sika Corporation, Lyndhurst, NJ or approved equal.

2. Pipe penetration sealant for full depth penetration (no grout filler) shall be two (2 component, polyurethane-based, elastomeric non-sag sealant with chemical cure meeting ASTM C920, Type M, Grade NS, Class 25. Sikaflex 2c NS as manufactured by Sika Corporation, Lyndhurst, NJ or approved equal.

B. Grout: Non-Shrink.

C. Sleeve: Schedule 40 PVC pipe sleeve shall conform to ASTM D1785 and ASTM D2665.

D. Transition Coupling: Transition couplings shall be rubber and conform to ASTM C564.

E. Stainless Steel Clamps: Stainless steel clamps with screw.

2.11 INSULATION:

A. Cellular-Glass Insulation:

1. Cellular-Glass Insulation shall be Foamglas One as manufactured by Pittsburgh Corning Corp. or approved equal.

2. Preformed pipe insulation shall comply with ASTM C552, Type II, Grade 6.

3. Insulation thickness shall be a minimum of 0.75-inches.

4. Insulation jacket shall be 50 mil thick self-sealing modified bituminous membrane, glass fabric with aluminum top film for direct bury conditions. Jacket shall be as recommend by the manufacturer of the insulation and may be field or factory applied.

B. Flexible Closed-Cell Elastomeric Insulation:

1. Flexible closed-cell elastomeric insulation shall be AP/Armaflex as manufactured by Armacell, or approved equal.

2. Preformed pipe insulation shall comply with ASTM C534, Type 1 – Grade 1.

3. Insulation materials shall have a flame spread index of less than 25 and a smoke-developed index of less than 50 when tested in accordance with ASTM E84.

4. Insulation wall thickness shall be minimum of 0.75-inches.

5. Insulation jacket shall be PVC in tubular or sheet form that is formaldehyde free, low VOC's, fiber free, dust free and resists mold and mildew. Jacket shall be as recommend by the manufacturer of the insulation and may be field or factory applied.

2.12 GRAVEL:

A. Gravel shall be size No. 57 or 67 Gravel per ASTM C33.

PART 3. EXECUTION

3.1 GENERAL:

A. Installation of water services shall be performed by Master Plumbers licensed in the District of Columbia or the Jurisdiction where the Work is performed if Work is performed outside of the District of Columbia. Journeyman and Apprentices working directly for and under the direct supervision of a licensed plumber may perform work provided the Master Plumber obtains the permit, inspects all work, and provides a certification for each service to DC Water that the work was performed in accordance with all codes.

B. Meters will be supplied by DC Water and shall be installed by the Contractor. The Contractor shall furnish and install pipe, yoke, couplings, shunt, meter valves, meter housing, meter housing gravel foundation, meter box frame and cover.

C. Water service components and/or lead water service line replacement to properties shall be removed, replaced, adjusted and/or maintained for water service line piping two (2) inch diameter and smaller as follows:

1. Public Space: Replace non-copper service lines, service lines that are copper and less than one (1) inch diameter, and services lines that are copper and one (1) inch or greater and cannot be adjusted.

2. Private Property: Lead water service lines on Private Property shall be replaced by the Contractor per valid Customer Agreements as directed by DC Water. Galvanized iron and brass water service lines shall be replaced if directed by DC Water, in which case, replacement and documentation requirements shall be the same as for lead water service.

3. Lead service replacement shall be completed in one shutoff. No partial replacements will be permitted.

3.2 PRECONSTRUCTION PHOTOS:

A. Photos shall be taken immediately before starting Work.

3.3 WORK PERFORMED BY DC WATER:

A. DC Water will retrieve the existing meters (removed and stored in the meter box by the Contractor), attach, and activate the MTU on the new cover (lid). Any existing meters found to be not automatic meter reading (AMR) type will be reviewed for replacement on a case-by-case basis by DC Water.

3.4 WORK ON PRIVATE PROPERTY:

A. DC Water Responsibility:

1. DC Water will contact all affected Property Owners to obtain a signed agreement that authorizes replacing lead services on Private Property.

2. After the Agreement is signed, DC Water will provide the Contractor with a list of addresses where the Property Owners have authorized lead service line replacement on Private Property and the corresponding Service Orders issued by DC Water.

3. If work scheduled on Private Property is subsequently cancelled by the Property Owner or DC Water, DC Water will notify the Contractor of the cancellation and that no work on the Private Property is authorized.

B. Contractor Responsibility:

1. Where no service order has been issued for work on Private Property, the Contractor shall provide a curb stop in Public Space as per DC Water's Standard Details.

2. The Contractor shall not begin work on Private Property until after receipt of a valid service order from DC Water. The Contractor shall make no claim for any time delay associated with obtaining permission to work on Private Property.

3. If a service order is cancelled directly with the Contractor by the Property Owner, the Contractor shall note the cancellation of service order in the outreach log and return the service order to DC Water with a status of "Cancelled by Homeowner."

4. Work on Private Property is subject to approval by the Property Owner. No compensation will be made to the Contractor if the Property Owner does not authorize any portion of the work on Private Property.

5. Contractor shall honor all Private Property service orders generated until final surface restoration has been completed.

6. Where the material on the Private Property segment of the water service line is determined to not be lead, the Contractor shall notify the Property Owner/Tenant that the scheduled appointment for water service line replacement on Private Property is not necessary unless directed otherwise by DC Water. Return the service order to DC Water with a status of "Closed – No Replacement Done."

7. Work performed by Contractor under Private Property side agreements made directly between the Contractor and the Property Owner shall be reported daily to DC Water. All pertinent information that is similar to that which is included on the Tap Card shall be documented.

8. For each address for which the Contractor has entered into a side agreement with the Property Owner, the Contractor shall provide to DC Water a copy of each permit procured to execute the work, a copy of the invoice, and a copy of a completed Tap Card for recording the relevant information on the work performed.

9. Contractor shall perform all work using appropriate methods to minimize the disturbance of Private Property including the existing interior wall finish and exterior foundation wall. The existing pipe penetration shall be removed and the opening sealed watertight. The Contractor shall restore the existing interior wall finish and/or exterior foundation wall when damaged by the Contractor at no additional cost to DC Water.

10. Upon completion of water service line work, the Contractor shall verify water service has been restored to each property by meeting with the owner or occupant of the property, visibly inspecting each water service line, verifying flow to the fixtures, and obtaining a written signature from the owner or occupant with a statement confirming that water service is restored. If required, the Contractor shall verify restoration of water service after normal working hours when the property is occupied. Submit copies of the signed statement verifying water

service is restored to DC Water. Return the service order to DC Water with a status of "Complete."

C. Pipe Penetrations:

1. Water Service line passing through concrete or cinder block walls and floors or other corrosive material shall be protected against external corrosion by a protective PVC pipe sleeve meeting the requirements of the DC Plumbing Code. The pipe sleeve shall allow for expansion and contraction of the water service line.

2. Pipe sleeves shall extend beyond the concrete or cinder walls and floors and a rubber transition coupling shall be installed at each end of the sleeve to provide a water tight seal.

3. The rubber transition couplings shall be secured to pipe sleeve, and also secured to the water service line using stainless steel clamps that are tightened to approximately 60 inch-lbs.

4. Sleeves shall be sealed to wall or floor with non-shrink grout and sealants as required for a watertight seal.

D. Pressure Reducing Valves:

1. Install pressure reducing valves if incoming pressure is greater than or equal to 80 psi.

2. Pressure reducing valves shall be preset to 80 psi and field adjusted by the Contractor if requested by the Property Owner and/or Tenant to reduce the pressure.

3.5 MAINTAINING WATER SERVICE:

A. Existing water service shall be kept in service until transfer connections are made. Where the water service line is replaced to the water main, the Contractor shall use a wet tapping machine to install a new corporation stop prior to disconnecting the old water service line. The new water service line shall be connected to the new corporation stop and installed within the time limits specified herein. The existing corporation stop shall be removed and a solid threaded brass plug installed in place of the removed corporation stop.

B. No more than three separate shutoffs will be permitted for any single water service line, and the duration of each shutoff shall not exceed two (2) hours, except in an emergency when DC Water will grant a time extension. The Contractor shall give sufficient, advance written notice to DC Water of the starting time and duration of proposed shutoff in-order to provide for emergency water supply.

C. If the proposed shutoff time conflicts with essential consumer use, it shall be rescheduled to alleviate interference. DC Water will determine action to be taken for essential consumer use requests. No additional payments will be made to the Contractor for working outside normal hours to accommodate essential service.

D. Overtime, weekend and holiday work may be ordered by DC Water to promptly complete temporary and/or permanent water service. The Contractor shall respond to emergency work within two (2) hours of notification.

3.6 SERVICE TAPS:

A. DC Water will install all service taps requested by organizations that are not performing work as part of a construction contract issued by DC Water. Contractors performing work as part of a construction contract issued by DC water shall install service taps in accordance with Section 33 12 17 – Service Saddles.

B. Install all new water service line taps at the water main and remove and plug all existing corporation stops.

C. Confirm the water service line tap is made to a pressurized water main.

3.7 METER, METER BOX, FRAME AND COVER INSTALLATION:

A. Contractor shall schedule all meter pickups with DC Water at least five (5) business days in advance of any proposed meter work.

B. Protection of Meters:

1. The Contractors shall provide safe transport and care of the meters to and from the point of installation. Replacement of any meter damaged, lost, or stolen while in the possession of the Contractor shall be at the Contractor's expense.

C. Installation:

1. Meters shall be reinstalled at their existing location unless specifically directed by DC Water or as follows:

   a. Wherever an existing meter is located on Private Property or inside a building, the Contractor shall install a new meter setter with jumper, meter box, frame and cover in Public Space and leave the existing meter in place. Contractor shall also notify DC Water that a meter needs relocation or abandonment.

   b. Where any unmetered water service is encountered, the piping, yoke, fittings, meter box, shunt, frame and cover will be installed in Public Space.

2. If the existing meter is an AMR type meter greater than or equal to one (1) inch diameter, the Contractor shall reinstall the existing meter. Otherwise, the Contractor shall:

   a. Request, coordinate, and pick-up a new water meter from DC Water;

   b. Remove existing meter, protect existing meter and place in a 42 gallon capacity, three (3) mil plastic bag with twist tie or other device to seal the bag, all provided by the Contractor. Place the bag containing the meter in the bottom of new meter box.

   c. Connect the new meter to the meter yoke.

3. If a new meter is not available, a temporary meter jumper line shall be furnished and installed by the Contractor until a new meter is available. When the new meter becomes available, Contractor shall remove the jumper line and install the new meter at no additional cost to DC Water.

3.8 ADJUSTING WATER SERVICE LINE:

A. Work consists of adjusting water service line pipe due to new water main work that affects water service.

1. If the existing water service piping is copper, is not less than one (1) inch diameter and enough slack exists in the piping to make the connection as determined by DC Water, the existing piping shall be connected to the new main without replacing any piping.

2. If insufficient slack is available or pipe cannot be bent by approved means to meet new corporation stop, adjustment under this subsection will not be feasible and a section of pipe shall be replaced as specified herein.

B. Work consists of trench excavation within the street including excavation, backfill and compaction. The Contractor shall abandon the old tap and install a new tap, adjust the existing one (1) inch through two (2) inch diameter copper service pipe to bring pipe to the connection point at the new corporation stop and, making the connection.

C. Install and maintain temporary asphalt patching until permanent restoration is performed.

3.9 REPLACE WATER SERVICE LINE:

A. Work consists of replacing water service line pipe in accordance with DC Water's Standard Details.

1. If existing water service piping is not copper, or is copper pipe less than one (1) inch diameter, the Contractor shall replace the water service piping with a single section of copper pipe not less than one (1) inch diameter with no joints, couplings or fittings from the new main to the new meter housing and from the meter to:

   a. The property line, along with a curb stop and curb stop box at the property line when there are no obstructions present in Public Space.

   b. The face of building projection, along with a curb stop and curb stop box close to the face of projection, when projection occupies Public Space.

2. Replacement piping shall be the same size as piping replaced except that all existing piping in public space smaller than one (1) inch shall be replaced with one (1) inch copper piping and all non-copper pipe shall be replaced with copper.

3. When the new copper pipe between the water main and meter will be one (1) inch diameter but existing service between meter and dwelling is non-copper pipe, DC Water will provide a new one (1) inch meter and the Contractor shall install one (1) inch copper pipe between the meter and property line or building projection, a curb stop, curb stop box, and appurtenances at the property line. All materials shall comply with the DC Plumbing Code.

B. Provide service Saddles as required by Section 33 12 17 – Service Saddles.

C. Install a curb stop box and set plumb over the curb stop so that the stop is centered within box. Top section of box shall be rotated so that box cover will be flush with finished ground surface. Backfill shall be carefully placed to avoid disturbance of curb stop or curb stop box.

D. Install extension rod for each curb stop. Extension roads shall extend as close to the curb box cover as possible using a manufacturer's standard length extension rod.

E. Install water services lines using trenchless or conventional excavation methods. Submit proposed method of installation to DC Water for review and approval. Installation shall include temporary and permanent restoration (except overlay) including seeding, sodding, curb and gutter, sidewalk, flexible pavement, PCC base, PCC pavement, excavation, backfill, compaction, and all other costs associated with the installation regardless of whether trenchless or conventional excavation methods are used.

F. If DC Water determines that a meter requires relocation or a new meter is necessary, the Contractor shall cut service line using a pipe cutter or shearing device (abrasive cutting methods are not permitted) at a location as directed by DC Water and provide and install new pipe, meter yoke and couplings, meter box, and frame and cover. Install the new meter provided by DC Water. If meter and housing adjustment in-place is necessary, the Contractor shall furnish and install new pipe and couplings.

G. Following installation of the water service line and prior to backfilling the areas of connections and joints, the new connection shall be activated and visually inspected to insure that all connections are leak free. Any leakage found shall be immediately corrected by the Contractor to the satisfaction of DC Water at no additional cost to DC Water.

H. Immediately following the replacement of the water service line, flush the service in accordance with AWWA C810 except that flushing at the external hose bib of the connected building shall be for at least 60 minutes, or as long as necessary as determined by DC Water. The Contractor shall also flush for at least one (1) minute at the meter and at least one (1) minute at the curb stop. Any damage to Private Property shall be restored to DC Water's satisfaction at the Contractor's expense.

1. If the Contractor is able to perform the flushing from the external hose bib, the Contractor shall provide the customer with the appropriate notification.

2. If the Contractor is unable to perform the flushing from an external hose bib, the Contractor shall inform DC Water of such and provide the customer with the appropriate notification. DC Water will provide the appropriate language to include in the notification.

3. Use a garden hose and other means to direct flows away from the building and dissipate flows to a velocity that will not erode property or discharge directly to curb and storm gutters.

3.10 PIPING INSULATION WITHIN CRAWL SPACES:

A. Contractor shall apply insulation materials, accessories, and finishes in accordance with the manufacturer's written instructions. Insulation shall be installed with smooth, straight, and even surfaces; free of voids throughout the length of piping, including fittings, valves and specialties and equipment.

B. Insulation jacketing may be factory or field installed.

C. The insulation and jacketing shall extend for a depth of 42 inches into the ground for freeze protection.

D. Contractor shall apply insulation to straight pipes and tubes as follows:

1. Secure each layer of insulation to pipe with wire, tape, or bands without deforming insulation materials.

2. Seal longitudinal seams and end joints with vapor-retarder mastic.

3. For insulation with factory-applied jackets, secure laps with outward clinched staples at six (6) inches o.c.

4. For insulation with factory-applied jackets with vapor retarders, do not staple longitudinal tabs but secure tabs with additional adhesive as recommended by the insulation manufacturer and seal with vapor-retarder mastic.

E. Contractor shall apply insulation to fittings and elbows as follows:

1. Apply pre-molded insulation sections of the same material as straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.

2. When pre-molded sections of insulation are not available, apply mitered sections of insulation. Secure insulation materials with wire, tape or bands. Cover fittings with standard PVC fittings covers. Overlap PVC covers on pipe insulation jackets at least one (1) inch at each end. Secure fittings cover with manufacturer's attachments and accessories. Seal seams with tape and vapor-retarder mastic.

F. Contractor shall apply insulation to valves and specialties as follows:

1. Apply pre-molded segments of insulation to valve body.

2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.

3. Use preformed standard PVC fitting covers for valve sizes where available.

4. Secure fitting covers with manufacturer's attachments and accessories.

5. Seal seams with tape and vapor-retarder mastic.

3.11 LEAD PIPE DISPOSAL:

A. Disposal of lead pipes shall be at a site approved by the U.S. Environmental Protection Agency (and the State) to accept lead waste. Handle, label, store, transport, and dispose of lead or lead-contaminated waste in accordance with the following Code of Federal Regulations: 40 CFR 261, 40 CFR 263, 40 CFR 264, and 40 CFR 265. Comply with land disposal restriction notification requirements as required by 40 CFR 268.

B. Submit written evidence that the receiving lead waste treatment, storage, or disposal facility is approved to accept lead waste by the federal and district or local regulatory agencies. Submit, within ten (10) days, one (1) copy of complete manifests, signed and dated by the transporter in accordance with 40 CFR 262.

C. Lead pipe (piping, fittings, etc.) removed as part of the work shall be recycled at a certified recycling facility in accordance with the required regulations.

D. No lead pipe shall be disposed of in excavated material.

E. Lead pipe abandoned in place shall have the ends sealed before backfilling.

3.12 ABANDONMENT OF EXISTING WATER SERVICE LINES:

A. Abandonment of existing water service lines shall be in accordance with Section 33 01 20 – Abandonment of Underground Utilities.

3.13 FIELD DATA:

A. Contractor shall complete and submit a DC Water Tap Card for each new installation within 48 hours of making the installation.

B. For each premise where service work, test pit, or service line replacement/adjustment is performed, the Contractor shall collect the necessary data to populate the daily and weekly reporting spreadsheets. The daily reporting sheet shall be completed and submitted to the DC Water Construction Project Manager each day no later than 2:00 p.m. that a full or partial lead service replacement (LSR) is performed.

C. The weekly reporting sheet shall be completed and submitted to DC Water Construction Project Manager every Monday. The weekly reporting sheet shall detail all of the week's prior work including replacements (lead and non-lead), adjustments, and test pits.

~ END OF SECTION 33 12 13 ~

SECTION 33 12 14

BACKFLOW PREVENTERS

PART 1. GENERAL

1.1 SUMMARY:

A. Furnish all labor, materials, equipment and install, complete in place, backflow preventers at locations indicated in the Contract Documents.

1.2 RELATED DOCUMENTS:

A. Drawings, Technical Specification Sections, General and Supplementary Conditions of the Contract and other Division 00 and Division 01 Specification Sections, apply to this Section.

B. Specifications throughout all Divisions of the Project Manual are directly pertinent to this Section, and this Section is directly pertinent to them.

1.3 REFERENCED SECTIONS:

A. Sections specified elsewhere may include but are not limited to:

1. Section 01 33 00: Submittals.

1.4 REFERENCED CODES AND STANDARDS:

A. American Society of Mechanical Engineers (ASME):

1. ASME A112.1.2: "Air Gaps in Plumbing Systems (For Plumbing Fixtures and Water-Connected Receptors)".

B. American Society of Sanitary Engineers (ASSE):

1. ASSE 1001: "Performance Requirements for Atmospheric Type Vacuum Breakers".
2. ASSE 1011: "Performance Requirements for Hose Connection Vacuum Breakers".
3. ASSE 1012: "Performance Requirements for Backflow Preventer with Intermediate Atmospheric Vent".
4. ASSE 1013: "Performance Requirements for Reduced Pressure Principle Backflow Preventers and Reduced Pressure Principle Fire Protection Backflow Preventers".
5. ASSE 1015: "Performance Requirements for Double Check Backflow Prevention Assemblies and Double Check Fire Protection Backflow Prevention Assemblies".
6. ASSE 1020: "Performance Requirements for Pressure Vacuum Breaker Assembly".
7. ASSE 1047: "Performance Requirements for Reduced Pressure Detector Fire Protection Backflow Prevention Assemblies".
8. ASSE 1048: "Performance Requirements for Double Check Detector Fire Protection Backflow Prevention Assemblies".
9. ASSE 1056: "Performance Requirements for Spill Resistant Vacuum Breaker Assemblies".

C. American Water Works Association (AWWA):

1. AWWA C510: "Double Check Valve Backflow Prevention Assembly".

ATTACHMENT

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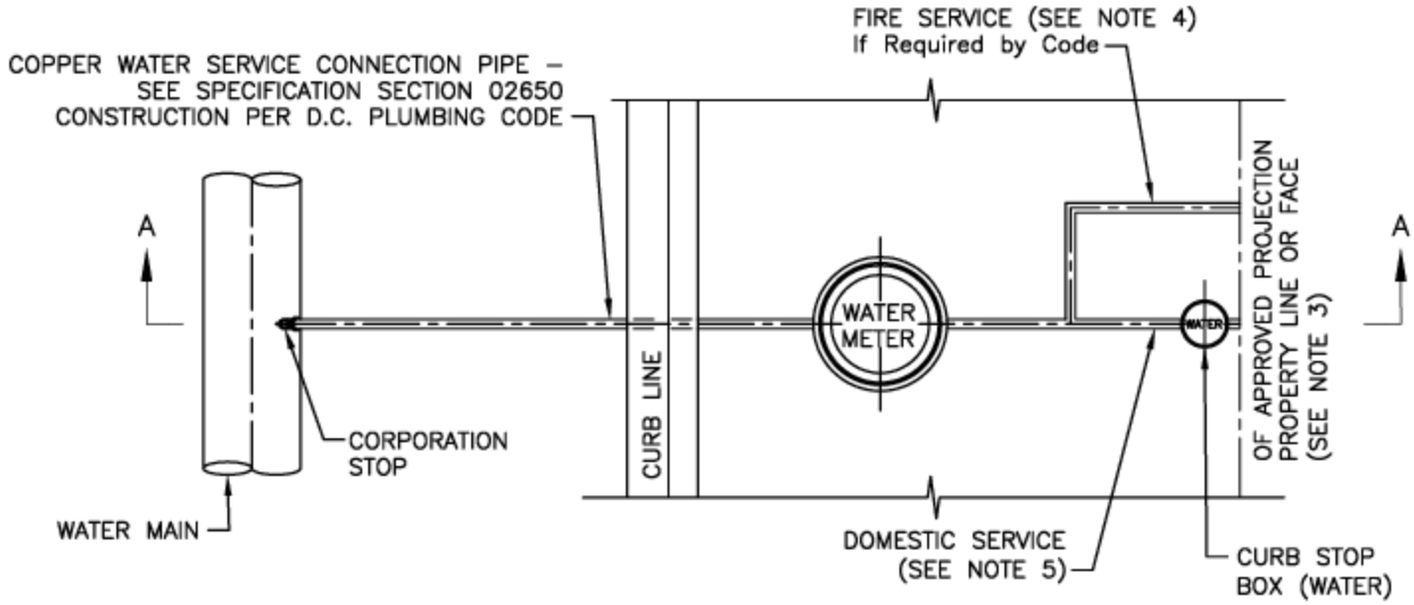
DISTRICT OF COLUMBIA WATER AND SEWER AUTHORITY	W–80.01 1 OF 1



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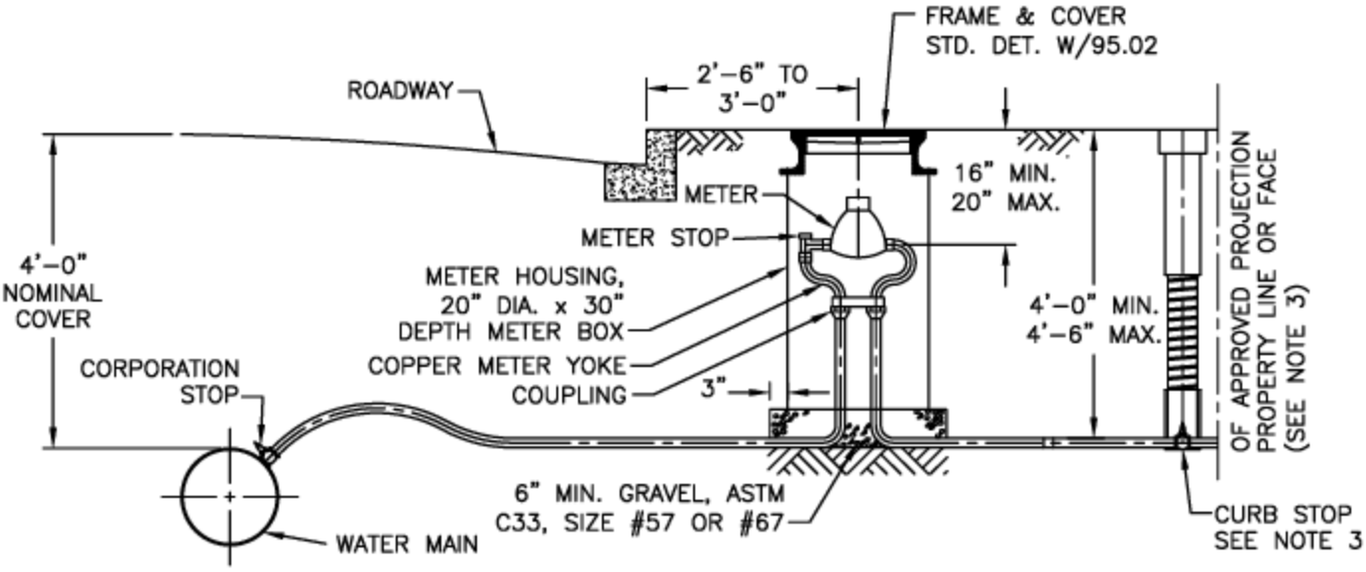

SECTION A–A

NOTES:

1. 1" DOMESTIC METER SETTER AS SHOWN.
2. 1 1/2" – 2" METER SETTER REQUIRES A METER VALVE ON EACH SIDE (NOT SHOWN ON DETAIL)
3. IF THE BUILDING OR APPROVED PROJECTION IS AT OR EXTENDS BEYOND THE PROPERTY LINE, THE CURB STOP SHALL BE PLACED 18 INCHES FROM FACE OF BUILDING OR APPROVED PROJECTION.
4. FOR NEW BUILDING CONSTRUCTION ONLY (IF REQUIRED): THE FIRE SERVICE LINE SHALL INCLUDE A SHUT–OFF VALVE INSTALLED INSIDE THE BUILDING.
5. FOR NEW BUILDING CONSTRUCTION ONLY (IF REQUIRED): THE DOMESTIC SERVICE LINE SHALL INCLUDE A PRESSURE REDUCING VALVE AND SHUT–OFF VALVE INSTALLED INSIDE THE BUILDING.

APPROVED DATE: January 2, 2004 DIRECTOR, DEPARTMENT OF ENGINEERING AND TECHNICAL SERVICES	REVISION NO.: 1 DATE: 6/20/03 PREPARED BY: J. Shabelski CHECKED BY: W.DARROW	STANDARD DETAIL WATER SERVICE CONNECTIONS 1" THRU 2" DIAMETER

ATTACHMENT

J

dc water is life®

IMPORTANT CONSTRUCTION INFORMATION FOR RESIDENTS

DC Water is Improving Water Infrastructure in Your Neighborhood

Replace Lead and Galvanized Iron Pipes for **FREE**

LEAD FREE DC

During upcoming infrastructure improvements on your block, DC Water will replace your lead or galvanized iron service pipe for FREE.

Please read this important information about what you should expect before, during and after construction.

For more information, contact:

DC Water Customer Service: 202-354-3600

24-Hour Command Center: 202-612-3400

Si usted necesita la versión en Español de este panfleto por favor llamar al 202-354-3600.

DC Water also provides translation assistance with 150 languages.

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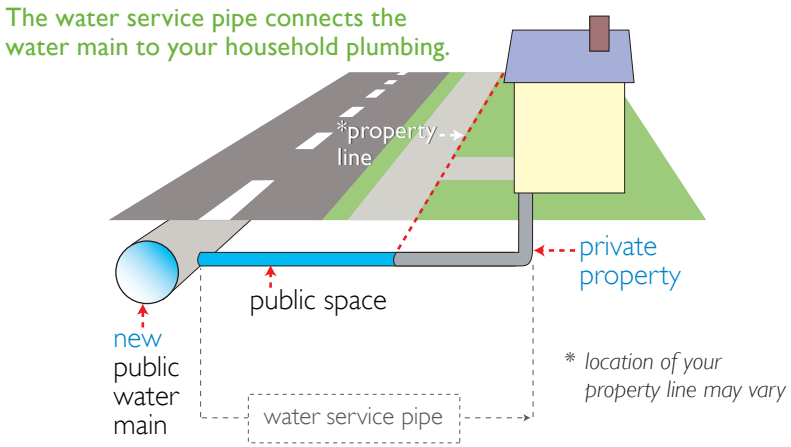
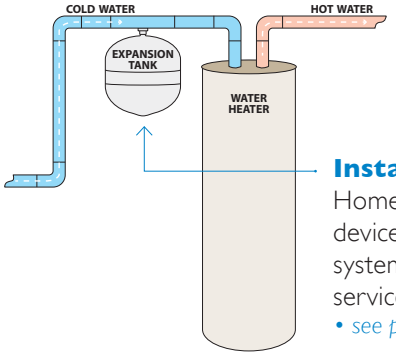
IMPORTANT INFORMATION

Understanding your property line and water service pipe

Your home's property line is likely somewhere between the sidewalk and house (you can view property lines on DC Water's Service Line Map at **dcwater.com/servicemap**). The homeowner owns the entire water service pipe and DC Water is responsible to maintain the portion in public space. The material of a water service pipe can vary from home to home in the District and some households still have lead service pipes.





Installing a thermal expansion device

Homeowners must ensure a thermal expansion device is installed on the household plumbing system, after DC Water replaces your water service pipe.

• *see page 4*

Lead pipe replacement

During construction, DC Water will replace service lines in public space, and the lead or galvanized iron service line on your property if you agree to have it replaced. After a lead pipe replacement, a temporary increase in lead will likely occur in household tap water. We will flush your line outside and provide you instructions to flush inside your home and water filters to minimize exposure to any lead. • *see page 6-8*

BEFORE, DURING AND AFTER CONSTRUCTION

Read what you can expect from this process.

DC Water's responsibility ■ Homeowner's responsibility ■

BEFORE CONSTRUCTION

Marking utilities with paint

To prevent hitting underground utility lines, the law requires Miss Utility (**missutility.net**) to find and mark utilities with temporary paint before digging projects. You will see these paint markings on your lawn, sidewalk and street up to two weeks before construction.

Relocating plants and shrubs

You should temporarily move any favorite plants within five feet of the Miss Utility blue markings. Typically, the water service pipe should follow a straight line from the Miss Utility blue marking to the house. DC Water is not responsible for damaged plants.

Locate and mark underground items

Locate and mark underground items, such as electronic dog fences or irrigation systems that may interfere with the service pipe replacement, and be sure to notify the contractor. DC Water is not responsible for damage to these objects if they are not identified by the homeowner prior to construction.

No parking notification

"No Parking" signs will be posted on your street 72 hours before construction begins. Signs will provide the dates and times for no parking in designated areas. In most cases, there will be restrictions on parking spaces. DC Water works closely with the District Department of Transportation (DDOT) to minimize street closures and traffic disruptions.

Water service shutoff

DC Water will provide a 48-hour notification prior to water service shutoff at your home. We recommend you collect a supply of water in advance for drinking and cooking purposes.

Access to your outside faucet

On the day of replacement, open the valve to an outside faucet and make the faucet available for use. This valve is usually located in your basement. After we replace or reconnect your water service, we will need to flush your water service pipe by opening the outside faucet.

Protecting your household plumbing

You should contact a licensed plumber if you are concerned about your plumbing system or thermal expansion. The licensed plumber can inspect your plumbing system to determine your options for meeting the D.C. Plumbing Code's requirements regarding thermal expansion. Household galvanized plumbing can also cause water quality issues, such as low pressure and discolored water.

DURING CONSTRUCTION

Digging in front of your household

During construction, we will be working in public space, but depending on the location of the property line, we may need to dig in your yard. The contractor may need to dig through lawns, sidewalks and streets. To minimize digging and avoid tree and root damage, the contractor will use a trenchless technology wherever possible. DC Water contractors take photographs of the repair area prior to construction to ensure it is properly restored. In most cases, your fence, retaining wall, porch or hedges will not be disturbed. In special circumstances, DC Water will work with a DDOT tree expert to develop a plan and work around major roots.

Installing a backflow prevention device

The DCRA Construction Codes Supplement of 2013 (2012 International Plumbing Code) requires the public water system to be designed, installed and maintained to prevent contamination from non-potable liquids, solids or gases being introduced into the public water supply. To comply with the D.C. Plumbing Code, DC Water will install a backflow prevention device in the outside water meter pit, during your water service pipe replacement. This device helps prevent contamination due to backflow into the public water system.

Temporary interruptions in street and sidewalk traffic

Street and sidewalk traffic will be temporarily detoured during construction. All holes will be filled or covered with a plate at the end of each day.

Avoid flushing toilet when water is shut off

When the contractor disconnects your water service, the interruption to your water supply is typically less than two hours. During this time, avoid flushing your toilet – this prevents the toilet valve from clogging with debris.

AFTER CONSTRUCTION

Flushing from your outside faucet

After construction, the contractor will flush your water service pipe through an outside faucet to remove pipe particles and other sediment. Sediment can dislodge from your plumbing during the pipe replacement process and reduce the flow of water in your home, particularly if you have older plumbing.

Restoring the work area

DC Water contractors will restore areas behind the curb after pipe replacement (assuming no weather delays), including the sidewalk and your yard. DC Water contractors will re-seed lawns and tree spaces, and restore sidewalks.

continued next page: After Construction

Street restoration

Streets that are disturbed during construction will be patched and typically restored within 60 days. Some streets may require more than 60 days if additional work is scheduled and is dependent on weather conditions. DC Water is responsible for final repaving at completion of water main or street restoration work.

Installing a thermal expansion device

What is thermal expansion?
Thermal expansion is an increase in water pressure that occurs when water is heated. This increase in pressure can cause leaks in household pipes and faucets, damage the water heater, and other plumbing problems. A thermal expansion device can prevent these issues.

What is a thermal expansion device?
A thermal expansion device safely manages changes in pressure caused by thermal expansion. This device helps prevent leaks and damage to a household plumbing system.

What is backflow prevention?
Backflow is the reverse flow of contaminants into the public water system. DCRA Construction Codes Supplement of 2013 (2012 International Plumbing Code) requires the public water system to be designed, installed and maintained to prevent contamination from non-potable liquids, solids or gases being introduced into the public water supply. To comply with the D.C. Plumbing Code, DC Water installs a backflow prevention device in the outside water meter pit during water service pipe replacement to prevent the reverse flow of water from your home into the public water system. This device creates a closed water system in your household and protects the public water supply from contamination.

When is a thermal expansion device required?
The DCRA Construction Codes Supplement of 2013 (2012 International Plumbing Code) requires homeowners to have a thermal expansion device installed on their household plumbing system, when a backflow prevention device is installed on the water service pipe. As a result, all homeowners must ensure a thermal expansion device is installed on their plumbing system, after DC Water replaces their water service pipe.

Some household plumbing systems already have a thermal expansion device installed. The most common device is a thermal expansion tank located near the water heater. If you are unsure a thermal expansion device is installed on your plumbing system, contact a licensed plumber to discuss their options.

More Info
For questions related to thermal expansion or backflow prevention, contact the DC Water Cross Connection Control Program at 202-612-3440 or crossconnection@dcwater.com.

HOUSEHOLD PLUMBING ISSUES

The homeowner is responsible for all plumbing on private property and in the home.

Discolored water

If older pipes are disturbed or sediment is dislodged during construction, you may experience discolored water. Run the cold water tap for according to detailed flushing instructions on page 7. Removing and cleaning faucet aerators will assist in flushing the sediment from your plumbing.

Household plumbing noises

If air becomes trapped in the pipes, you may experience knocking, banging sounds or sudden bursts of water when you turn on the faucet. Run water through all your faucets and make sure valves under all your sinks are fully open.

Low water pressure

After construction, you may experience low water pressure if air or sediment becomes trapped in the pipe. If you have old household pipes, especially galvanized pipes, sediment build up can cause low or no water flow. In addition, a greater flow may cause older pipes to leak or even burst. After flushing the cold water tap, clean faucet aerators. You may need to contact a plumber to clean a blocked faucet. Contact a plumber to determine if you need to replace old pipes inside your home, especially galvanized pipes. If there is no water pressure throughout the entire house, please contact the DC Water 24-Hour Command Center at 202-612-3400.

Water heater drips or leaks

If you experience pressure surges or high pressure, your water heater may leak after construction. Be sure the water heater thermostat, temperature and pressure valve are working properly by consulting with your owner's manual or contacting a licensed plumber.

Galvanized pipes

Galvanized pipes are old, iron pipes that were installed inside many homes built before the 1960s. These pipes can release lead in water if you have, or once had, a lead service pipe. When lead is released from a lead service pipe and passes through indoor galvanized plumbing (particularly over decades of use), lead can accumulate on the inside, corroded walls of this plumbing. Lead release from galvanized pipes can vary from home to home and can continue to occur even after the lead service pipe is replaced. Galvanized pipes can cause other water quality problems, such as low water pressure and discolored water.

You should consider replacing galvanized plumbing with another plumbing material. Contact a licensed plumber about replacing household plumbing. If pipe replacement is not an option, use a water filter until all sources of lead have been removed. To learn more about galvanized plumbing, contact the Drinking Water Division at 202-612-3440.

District funds will cover 100% of the costs to replace the lead or galvanized iron service pipe with copper pipe.

The property owner has 120 days to agree to permit DC Water to replace the lead service line on their property for FREE. If they agree, they should fill out and sign the agreement previously provided by DC Water. Alternatively, the property owner can provide written authorization (email) for a tenant to sign the agreement.

If we confirm your water service pipe is lead or galvanized iron and you have completed and signed the agreement to replace the portion on your property, please read this important information.

Scheduling pipe replacement on private property

If you have returned a signed agreement, the DC Water contractor will contact you to schedule a date for the lead pipe replacement.

Access to inside water connection

The contractor will need access inside your home where the existing service pipe enters the building. You will need to move any items including boxes, furniture, washers and dryers that block pipes inside or outside your home where the existing service pipe enters the building.

You must be home during pipe replacement on private property

You must be home on the date and at the time of lead pipe replacement on private property. It is the homeowner's responsibility to provide access to the plumbing connection inside your home. The replacement work at your house should take less than one day.

Mail the completed agreement in the prepaid envelope provided, or email a copy to **lead@dcwater.com**. If you need assistance with completing or returning the agreement call us at (202) 787-4044.

After a lead pipe replacement, lead particles may remain in your plumbing and a temporary increase in lead will likely occur in your tap water. Lead levels can potentially remain elevated for a few months after a lead pipe is replaced. Follow these instructions to flush the lead particles out.

Immediately flush your household plumbing

1. Flush tub and laundry room sink faucets for 10 minutes each with cold water, moving from the lowest floors to the upper floors. The faucet must be fully open to move the particles out with the water.
2. Flush all faucets used for drinking or cooking for 10 minutes.
   a. Remove the aerator (the screen traps particles!).
   b. Open the cold water faucet to maximum flow (the water might spray, you can drape a towel over the faucet neck to minimize the spray).
   c. Clean the aerator and screw back onto faucet.

Do not open a hot water faucet until the system is completely flushed. If an aerator is in poor condition, install a new aerator (available at local hardware stores).

Use filtered water

If your lead service pipe is replaced, DC Water will provide you with a water filter certified for lead removal and replacement cartridges. For at least six months after lead pipe replacement, use filtered tap water for drinking and cooking, including water used for making ice, beverages and infant formula. If water isn't used for more than six hours (including overnight), flush cold water tap until you notice a temperature change, then run for an additional 2 minutes before filtering it for drinking and cooking.

- Once a week for a month following the lead pipe replacement, follow Step #2 above and flush all faucets used for drinking and cooking.
- If the house is vacant for more than a week following the lead pipe replacement, repeat Step #1 above.
- Do not use hot tap water for drinking and cooking. Always use cold water including water used for making ice, beverages and infant formula.

For six months after construction

- Use filtered cold tap water for cooking and drinking. Be sure to replace the filter cartridge as recommended by the manufacturer.
- If water is not used for more than six hours (including overnight), flush the cold water tap for two minutes prior to drinking and cooking.
- Periodically, remove and clean all faucet aerators.

After six months

- Continue to always remove and clean aerators every 3 months to remove any particles that may be captured. Replace aerators annually.
- If you are pregnant or have children under age six, you should use filtered tap water for drinking and cooking until all sources of lead have been removed. This includes water used for making ice, beverages and infant formula.

– continued on page 8

LEAD PIPE REPLACEMENT continued

- Do not use hot tap water for drinking and cooking. Always use cold tap water.
- If water is not used for more than six hours, flush the cold water tap for two minutes prior to drinking and cooking.
- If you have household galvanized plumbing, continue to use filtered tap water for all drinking and cooking purposes until these pipes are removed. These pipes can continue to release lead in drinking water after the lead pipe is replaced.
- If you continue to use a filter, contact the manufacturer for replacement cartridges or be sure to purchase a filter that is labeled and certified to meet NSF Standard 53 for lead removal.

Free lead test kit

If your lead or galvanized iron service line is replaced, DC Water will deliver a lead test kit to your home approximately three to four months after pipe replacement. The lead test will provide information on lead levels in your household drinking water after pipe replacement.

Learn more at **dcwater.com/reducelead**.

LEAD, WATER AND YOUR HEALTH

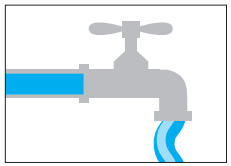
Exposure to lead in drinking water can cause serious health effects in all age groups.

Infants and children can have decreases in IQ and attention span. Lead exposure can lead to new learning and behavior problems or exacerbate existing learning and behavior problems. The children of women who are exposed to lead before or during pregnancy can have increased risk of these adverse health effects. Adults can have increased risks of heart disease, high blood pressure, kidney or nervous system problems.

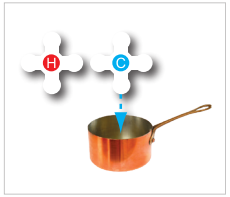
The cutting or other physical disturbance of the lead pipe during service line work causes a spike in lead released into your water. Therefore, we strongly encourage homeowners to agree to replace the private side and public side of the service line at the same time. Also, for the homeowner's awareness, the water service line pipe material must be disclosed when the home is sold and to all renters.

Learn more at **dcwater.com/lead**.

GENERAL TIPS TO REDUCE LEAD IN DRINKING WATER



Run your cold water tap for two minutes before using it for drinking or cooking. Lead and other metals can dissolve in water when it sits in pipes for a few hours.



Do not use hot tap water for drinking or cooking. Hot tap water can cause a greater amount of lead to release from plumbing. Always use cold tap water, including water used for making ice, beverages and infant formula.

Remove and clean faucet aerators every month. Particles can collect in the aerator screen located at the tip of your faucet. Aerators should also be replaced every year.

If have a known or suspected source of lead, use cold, filtered tap water. Use filtered tap water for drinking and cooking, including water used for making ice, beverages and infant formula. Routinely replace filter cartridges. Over time, filters can accumulate metals and bacteria.

DISTRICT OF COLUMBIA WATER AND SEWER AUTHORITY
1385 Canal Street, SE
Washington, DC 20003

DCWATER.COM

fpo. please place the FSC logo here (PMS 369 if possible) and space with others evenly. thanks

PRINTED WITH SOY INK
Environmentally Responsible Ink Product
Manufacturer tested and recommended

For assistance, contact:
(202) 787-4044 or lead@dcwater.com

David L. Gadis, Chief Executive Officer

DISTRICT OF COLUMBIA WATER AND SEWER AUTHORITY | 1385 CANAL STREET, SE | WASHINGTON, DC 20003

PRIVATE PROPERTY LEAD/GALVANIZED SERVICE LINE REPLACEMENT AGREEMENT

By signing below, I understand and agree that:

1. I/we own or represent the owner(s) of the Property located at:_____.
2. DC Water or its contractor will replace the portion of the lead or galvanized service line (L/G SL) with copper pipe located at the above identified Property when the portion of the service line located in public space is replaced. **DC Water will replace the L/G SL at no cost to me.**
3. The **only** plumbing work DC Water or its contractor will perform at above address will be the replacement of any lead or galvanized water service pipe with a new copper service pipe from the water main to the first plumbing connection inside the building structure. One-inch diameter copper pipe will be used for replacement, unless the existing lead or galvanized service pipe is larger, in which case the same size replacement pipe or larger will be used. The work may be rescheduled if the pipe location is different than expected.
4. I understand, to comply with the D.C. Plumbing Code, the replacement of water service line will require me to install of a thermal expansion tank on a hot water heater tank system, which will not be included in the service line replacement work.
5. DC Water will cancel this Agreement and only replace the portion of the L/G SL in public space if: (1) the Property has any existing conditions which prevents the replacement of the L/G SL on private portion of the Property; (2) ownership of the Property has changed, (3) the owner denies DC Water or it's contractor access to the property, or (4) the owner is not present at the time scheduled date and time or fails to reschedule the appointment.
6. I authorize DC Water and its contractors to enter my property and inside the building structure to perform the required work. I will be present at the scheduled time or _____ [insert name] is my authorized representative who will be present while work is performed.
7. I am responsible for any negligence on my part, as well as for any negligence by a person living at or visiting the Property, in connection with this Agreement and agree that I and any visitors will remain at a safe distance from the contractors while they are performing the work.
8. DC Water and its contractors will be responsible for their own negligence in connection with this Agreement.
9. I will disclose on the lines below any hidden hazards or defects within my Property which may interfere with installation of the LSL, including but not limited to: A electrical or irrigation systems, or known buried items such as rubble or fencing. I understand that I will be responsible for all damages resulting from any undisclosed condition. (If you need additional room, please attach another page.)

   _____

   _____

   _____

10. I understand that to gain access to work areas, DC Water's contractor may need to remove or disturb drywall or other permanent structures, retaining walls, fences, shrubs, brick sidewalks or driveways or lawns. If disturbed by the DC Water contractor, stones, fences, shrubs, plants, bricks, sod, etc., will be left on the Property by the contractor to be reused at owner's option and costs. Limited drywall work will be performed.

    _____

    _____

    _____

11. DC Water and its contracts will take care to avoid trees, shrubs and living plant material, where possible. However, neither DC Water nor its contractor are responsible for the wellbeing of the plant material impacted by the construction work. Owner is encouraged to dig up living plant material prior to the start of the construction and provide necessary protection for plants during construction.
12. DC Water will contract with the L/G SL contractor or a separate contractor to perform limited drywall restoration (drywall and primer) to the extent removed to complete the L/G SL replacement. This work may be scheduled with the homeowner separately from the L/G SL replacement.
13. DC Water's contractor will not be allowed to assist the property owner with movement or relocation of any property owner belongings, neither prior to nor following installation of the service line.
14. I understand I may cancel this Agreement at any time prior to midnight of the third business day after the date of signing this Agreement. Notice of cancellation must be submitted in writing and mailed to the address below.
15. I understand the L/G SL replacement work will remove that source of lead, but additional lead sources may exist inside the home, and it is recommended that I consult a licensed plumber to identify other lead sources. DC Water will provide water test kits 3-4 months following pipe replacement to identify if the water has elevated lead levels.

Property Owner Name(s): _____ _____

First/Last First/Last

Mailing Address (if different from service address): _____

Please provide the best phone number to call to schedule installation: _____

Two copies of this **Agreement** are provided. If replying by e-mail (preferred method), **sign** one copy of the **Agreement** and email a scanned copy to lead@dcwater.com under the subject "**Private Lead/Galvanized Service Line Replacement Project**." If replying by mail, **sign** the two copies in the signature space provided below. Please keep one copy for your records, and return one copy of the completed **Agreement** in the envelope provided and addressed to:

District of Columbia Water and Sewer Authority
Lead Pipe Replacement Program
301 Bryant St NW
Washington, DC 20001

Only the property owner(s) is (are) entitled to authorize work on said property. The Agreement will be countersigned by DC Water and returned to you. **The terms of this Agreement are binding on all those signing this Agreement individually and jointly.**

Initial and sign in space provided below.

_____I/we Agree and accept the terms of this Agreement.

_____I/we **DO NOT** accept the terms of this **Agreement**, and I understand that lead exposure can cause serious health problems, especially for pregnant women and young children. Lead can damage the kidneys and brain and has been linked with deficiencies in neurodevelopment. I understand that adults with kidney problems and high blood pressure can be affected by low levels of lead more than healthy adults. Additionally, I understand that the cutting or other physical disturbance of the lead pipe during service line work causes a spike in lead released into my water. Therefore, although strongly encouraged, I **DO NOT** agree to replace the private side service line at the same time as the public replacement. Finally, I am aware that D.C. Law 22-0241 requires the disclosure of the water service line pipe material when my home is sold rented.

_____

Property Owner(s) signature or Legally Authorized Representative[1] Date

_____

Property Owner(s) signature or Legally Authorized Representative[1] Date

_____

Email Address

[1] The Representative (tenant or other party) must submit a notarized letter from the property owner or other legal documentation identifying their legal designation to represent the owner.

Attachment No. 1

water is life

DISTRICT OF COLUMBIA WATER AND SEWER AUTHORITY

IMPORTANT HEALTH NOTICE

DC Water replaced your lead service pipe with copper pipe in:

☐ Public space and connected to a _____ pipe on your private property.

☐ Public and private property.

FILTER YOUR TAP WATER FOR COOKING AND DRINKING FOR SIX MONTHS

DC Water is providing you with a filter certified for lead removal. Please read the important health information provided with your water filter.

FLUSH YOUR TAPS

Following a lead pipe replacement, a temporary increase in lead will likely occur in your tap water. Lead levels can potentially remain elevated for a few months after a lead pipe is replaced.

We recommend you take the following steps:

Immediately flush your plumbing for approximately 60 minutes total – During this period, you should flush water throughout the house by opening cold water faucets one at a time, working from the lowest level (preferably the basement) to the highest level in your house. Do not open a hot water faucet until the system is completely flushed.

For 30 Days – Each day, flush your plumbing by opening at least one cold water faucet for 10 minutes. After flushing, remove and clean faucet aerators.

If you are pregnant or have children under age six, you should use filtered tap water for drinking and cooking until all sources of lead have been removed. This includes water used for making ice, beverages and infant formula.

(see reverse side for more information)

DCWATER.COM

water is life

DISTRICT OF COLUMBIA WATER AND SEWER AUTHORITY

DEALING WITH HOUSEHOLD PLUMBING ISSUES

If you experience household water quality or plumbing issues, please refer to the tips below. The homeowner is responsible for all plumbing on private property and in the home.

Discolored water –If older pipes are disturbed or sediment is dislodged during construction, you may experience discolored water. Run the cold water tap for 15 minutes from the outside hose faucet or the lowest point in your home. Removing and cleaning faucet aerators will assist in flushing the sediment from your plumbing.

Household plumbing noises – If air becomes trapped in the pipes, you may hear knocking or banging sounds when you turn on the water. Run water through all your faucets and make sure valves under all your sinks are fully open.

Low water pressure – After construction, you may experience low water pressure if air or sediment becomes trapped in the pipe. If you have old household pipes, especially galvanized pipes, sediment buildup can cause low or no water flow. In addition, a greater flow may cause older pipes to leak or even burst. After flushing the cold water tap, clean faucet aerators. You may need to contact a plumber to clean a blocked faucet. If there is no water pressure throughout the entire house and the problem is not resolved by flushing your cold water taps, call us at: _____.
Outside business hours, please call the DC Water 24-Hour Command Center.

For more information, please contact:

DC Water Customer Service: **202-354-3600**
DC Water 24-Hour Command Center: **202-612-3400**
Email: **lead@dcwater.com**

DCWATER.COM

ATTACHMENT

K

STOP

IMPORTANT INFORMATION

If you had a lead service line replacement, please read and follow ALL instructions before using your water.

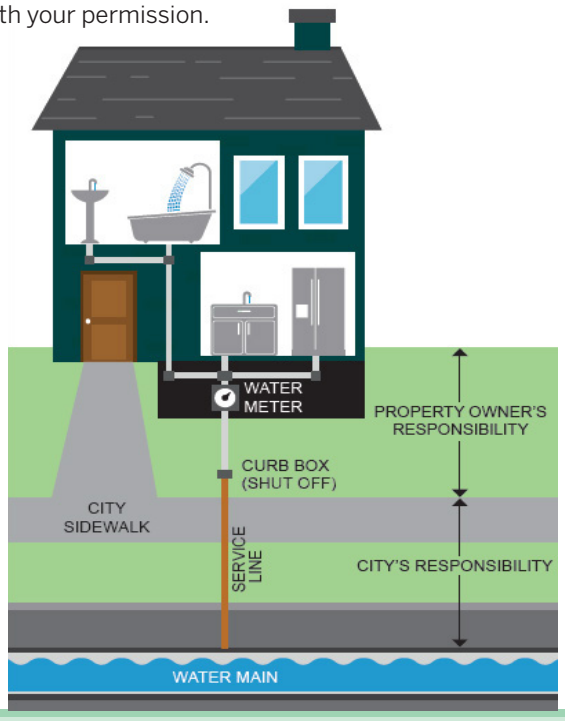
YOUR DRINKING WATER

The City of Detroit's water is clean and safe to drink and it meets all federal and state regulatory standards under the Safe Drinking Water Act. The water leaving the treatment plants does not contain lead, but lead can be released into drinking water from corrosion in lead service lines and household plumbing that contains lead. The water provided to Detroit Water and Sewerage Department customers contains a corrosion inhibitor to reduce corrosion of lead and other pipe materials into drinking water. If present, elevated levels of lead can cause serious health and development problems, especially for pregnant women and young children.

YOUR WATER SERVICE

A new water main has been installed on your street. Referring to the image below, the service line providing water to your home was connected to the water main in the following way:

- ☐ The original water service line was connected to the new water main as-is since the pipe material is copper.
- ☐ The City's portion of the service line was replaced with copper because lead piping was connected to the old water main; your portion of the service line remains the same.
- ☐ Your portion of the service line was replaced with copper at DWSD's expense and with your permission, because it was made of lead; the City's portion of the service line remains the same.
- ☐ The full service line was discovered to be lead piping, and both portions were replaced with copper at DWSD's expense and with your permission.



FLUSH YOUR PIPES

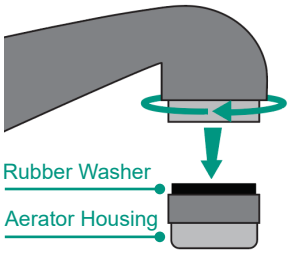
The Detroit Water and Sewerage Department (DWSD) recommends flushing your water taps after construction is complete in your neighborhood. DO NOT consume tap water, open hot water faucets, use your icemaker or filtered water dispenser until the flushing steps listed below are complete.

1. Remove faucet aerators from all water taps in your home.
2. Beginning in the lowest level of your home, open all the cold water taps in the house.
3. If you had your lead service line replaced, let the water run 30 minutes to remove the lead particles before using any water. (Otherwise let the water run for 5-10 minutes at the last tap you opened on the top floor.)
4. Turn off each tap starting with the first faucet you opened (bottom floor). Clean and install aerators.

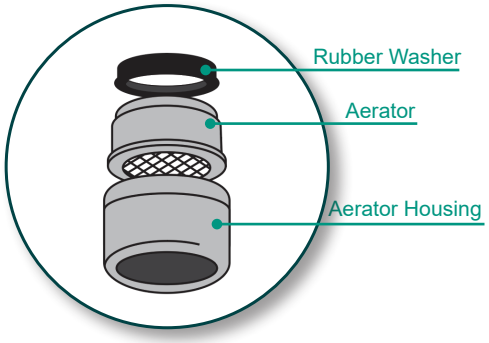
As a precaution, DWSD delivered to your home **one pitcher filter and replacement cartridges** that remove 99% of lead from tap water. Please continue to use the pitcher to filter your drinking and cooking water, replacing the cartridges as instructed by the manufacturer on the package.

WHAT IS A FAUCET AERATOR?

The aerator on the end of your faucet is a screen that will catch debris.



The aerators screw off from the end of your faucets by hand; you may need to use a wrench the first time. Brush and rinse the aerators before putting them back on.



USE THE WATER FILTER PROVIDED BY DWSD

As a precautionary measure, DWSD has delivered a filter that removes lead from water for you to use. If you were not home to receive the supplies, please call 313-964-9300 to schedule a delivery time.

TESTING YOUR WATER

Do you have a lead service line and want your drinking water sampled?

Visit detroitmi.gov/leadsafe or call us at 313-964-9300 to learn more.

For more information on health issues related to lead, contact the Detroit Health Department at 313-876-4000.

HEALTHY WATER TIPS

Always use cold filtered or flushed water for drinking, cooking and brushing teeth. If you are preparing formula for an infant, use a NSF/ANSI Standard 53 certified filter or bottled water.

Remove and clean faucet aerators (screens) monthly.

If your water has not been used for several hours, turn the water on from your faucet until it is cold, and continue to run for an **additional two minutes** – **three to five minutes if you have a lead service line** – to get fresh water from the water main.

Do **NOT** run hot water through your water filter.

After you run the water, consider filling a pitcher with the fresh water to keep in your refrigerator for drinking.

DWSD recommends you purchase a faucet filter that meets NSF/ANSI Standard 53 for lead reduction if you have a lead service line and either a pregnant woman and/or children under the age of six in the home. During water main replacement construction, DWSD provides homes on the block of the construction with a pitcher filter and replacement cartridges as a precautionary measure.

Do you see discoloration in your water? Flush using the tips in the two-minute instructions listed above. If you continue to see discoloration, stop using your water and call DWSD at 313-267-8000.

CONTACT US

detroitmi.gov/dwsd

313-964-9300 Lead Resource Line

DWSD Customer Alert

DO YOU HAVE A LEAD SERVICE LINE?

While the Detroit Water & Sewerage Department (DWSD) is on your street replacing the water main, if our workers discover you have a lead service line (the line from the water main to your house), **DWSD will replace the pipe with copper with your permission, at DWSD's expense.**

Read the information in this packet, sign the agreement and return it in the enclosed envelope.

DWSD will not replace your portion of the service line (from the curb box to your house) without your permission. Lead levels in your home may increase if you refuse to replace your portion of the lead service line. DWSD cannot reconnect your lead service line to the new water main. If you choose to not replace your lead service line, you will have a water service interruption.

DWSD Lead Service Line Hotline:

313•964•9300

The lead service line replacement will only be done while DWSD's contractor is on your street. This offer will not be available after construction is complete. This notice applies only to the houses which received the flier on their doors in the designated project area.

CITY OF DETROIT
Water & Sewerage Department

WORKING HARD FOR YOU.

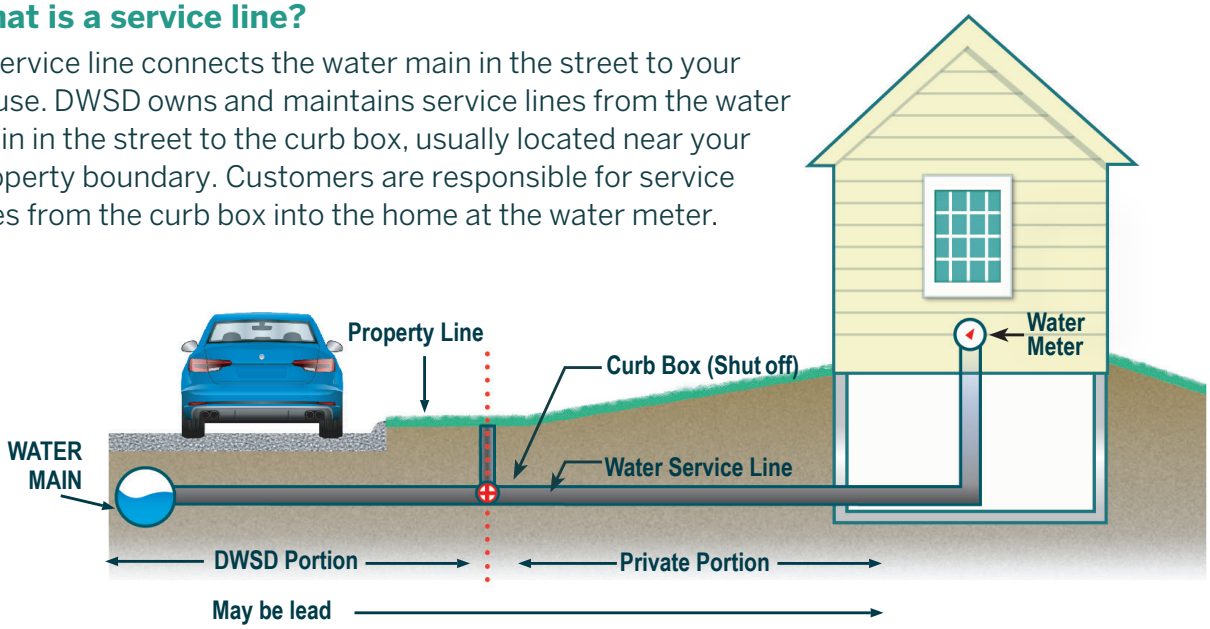
FOR MORE INFORMATION, CALL
313•964•9300
www.detroitmi.gov/DWSD

LEAD SERVICE LINE REPLACEMENT PROGRAM - FAQ

Water & Sewerage Department

Q. **What is a service line?**

A. A service line connects the water main in the street to your house. DWSD owns and maintains service lines from the water main in the street to the curb box, usually located near your property boundary. Customers are responsible for service lines from the curb box into the home at the water meter.



Q. **What homes typically have lead service lines?**

A. If your Detroit home was built prior to 1950, your service line may be made of lead and need to be replaced. DWSD stopped using lead on the DWSD portion of the service line around 1945.

Q. **How do I know if I have a lead service line?**

A. Service lines can be made of plastic, copper, lead or galvanized steel. Get a magnet and a coin, and then follow these steps to find out which you have:

1. Locate where the service line comes into your home, near the water meter and your shut-off valve. Look for the pipe running between your shut-off valve and either the wall or the floor.
2. If the magnet sticks to the pipe, it's galvanized steel and **does not** need to be replaced.
3. Gently scratch the surface of the pipe with the coin. If the scraped area is shiny, is silver in color and the magnet doesn't stick, it's made of lead. It may have a bulge near the valve. If so, it is a lead pipe and **does** need to be replaced.
4. If it is copper in color and the magnet doesn't stick, it's copper and **does not** need to be replaced.
5. If the pipe is white or grey and the piping is joined with a clamp, screw or glue, it's plastic and **does not** need to be replaced.

If you have a lead service line inside your home, call 313-964-9300 to start your replacement process. The material buried in your yard may be different from the material you can see inside your home. Even if you do not have lead inside the house, the contractor will still excavate the curb box in your front yard.

Q. Why did I receive a pitcher and filters? Is something wrong with my water?

A. The pitcher and filters are provided as a precautionary measure to stop any sediment or particles that may shake loose in your pipes during construction. During the construction work, use the filter for all drinking and cooking water, and replace the filter cartridges according to the manufacturer's instructions. The filters meet NSF standard 53 for lead removal. Water is safe for showering and other uses. Follow DWSD's flushing instructions.

Q. Will you restore my property?

A. Yes, property disturbed during construction will be replaced including seeding of grass, sidewalk and driveway repair, and restoring interior portions of the house. DWSD requires its contractors to maintain adequate insurance in the event damage occurs. DWSD will not be responsible for any damage to trees, flowers and shrubs resulting from the replacement of the service line.

Q. Do you have to come into my home?

A. Yes, if the contractor confirms a lead service line serves your home or if a lead service line is expected, a contractor will schedule a time to inspect your water service material and meter. Someone 18 years or older must be home the entire time the water service line replacement is taking place.

Q. Will this cost me anything?

A. The work is being done at the expense of DWSD.

Q. How long will the replacement take? How long will my water service be interrupted?

A. It takes about 4 hours for the replacement of the service line unless some unforeseen issues occur. Your water will be interrupted for approximately 2 hours on the day the service line is being connected to the water main. The contractor is not allowed to leave a customer without water overnight.

Q. Can I have my water tested? Is it free?

A. Yes. To request for your water to be tested, please visit detroitmi.gov/DWSD and search "lead and copper sample request form." If you do not have Internet access, please call 313-964-9300 for further assistance.

Q. What will happen if I decline?

A. The State of Michigan recently revised its Lead and Copper Rule, which now requires all lead service lines to be replaced within the next 20 years. Lead levels in your home may increase if you refuse to replace your portion of the lead service line. DWSD cannot reconnect your lead service line to the new water main. If you choose to not replace your lead service line, you will have a water service interruption. Once DWSD leaves your neighborhood, you will need to replace the lead service line at your expense to bring your house up to code and resume water service.

Q. How long will this project last on my street?

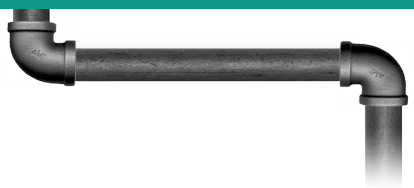
A. Each street is different and timing varies. However, when residents turn in signed agreements as soon as they are able, it makes the process faster.

STEP-BY-STEP PROCESS FOR REPLACING LEAD SERVICE LINES

Water & Sewerage Department

DWSD CONTRACTORS WILL DIG A 4' x 4' SQUARE IN YOUR FRONT YARD TO DETERMINE WHAT MATERIAL YOUR SERVICE LINE IS MADE OF.

1. **IF THE LINE IS COPPER,** the contractor will connect your service to the new water main.
2. Contractor will restore property.
3. No other action is required.



1. **IF THE LINE IS LEAD,** the contractor will inform you and schedule an appointment for an interior inspection of the service line and meter.
2. A copper service line will be installed from the new water main to your water meter.
3. Your water meter will be reinstalled or replaced.
4. The contractor will restore property.
5. You will continue to own and be responsible for the replaced water service line from the curb stop into the home. DWSD will guarantee the water service line for one year from the date of replacement.

- **You are encouraged to sign and submit your Lead Service Line Replacement Agreement as soon as possible.**
- **You can check the service line inside your house at any time during this process (see the DWSD FAQ brochure for details) and call us at 313-964-9300 to schedule your replacement sooner.**
- **You may request to have your water tested at any time. Visit detroitmi.gov/DWSD and search "lead and copper sample request form." If you do not have internet access, please call 313-964-9300 for further assistance.**

Water & Sewerage Department

WORKING HARD FOR YOU.

FOR MORE INFORMATION, CALL

313•964•9300

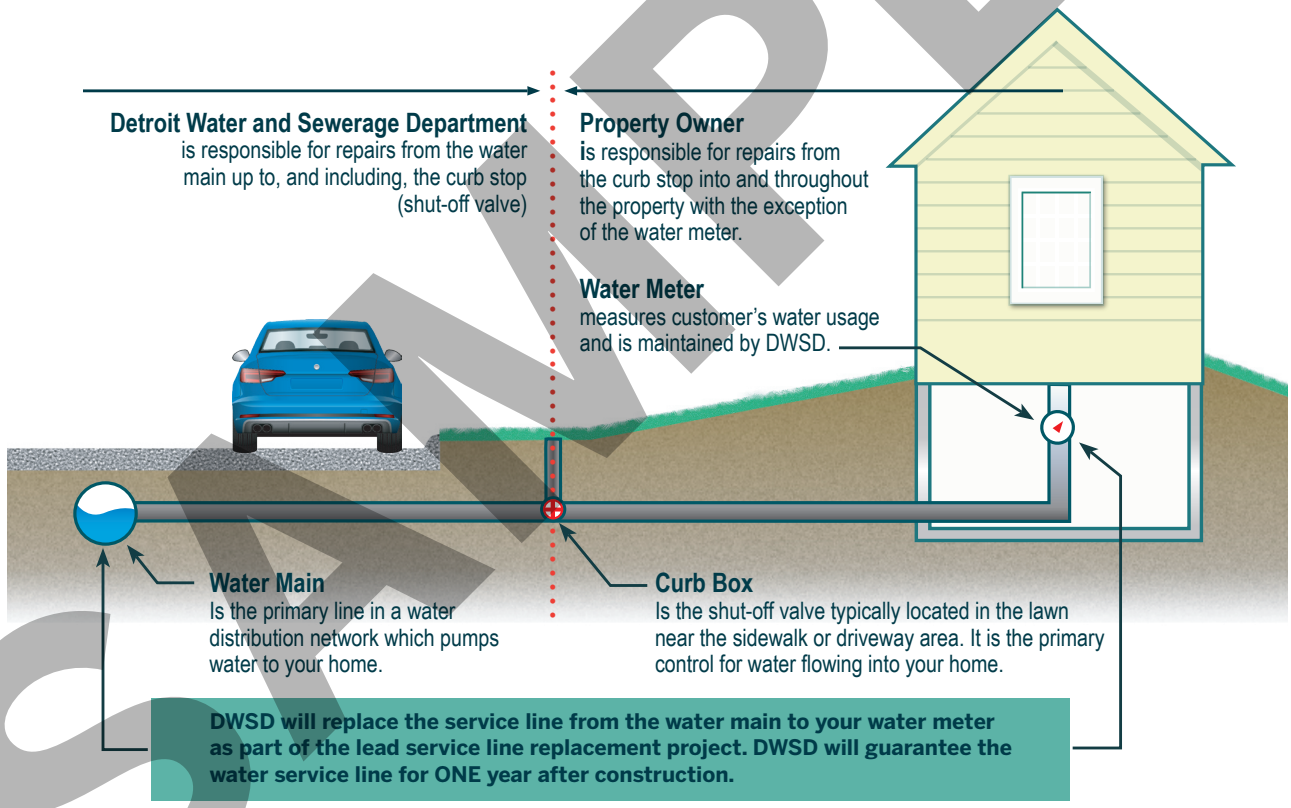
www.detroitmi.gov/DWSD

Please read this agreement. If a lead service line is confirmed, a DWSD Inspector or contractor representative will contact you directly to request you to sign an official copy of the agreement prior to replacing the lead service line with copper pipe, at DWSD's cost.

Water & Sewerage Department

LEAD SERVICE LINE REPLACEMENT AGREEMENT

Several contractors are working in neighborhoods across the City of Detroit to remove lead service lines as part of DWSD's Lead Service Line Replacement Program. Under this program, if your home has a lead water service line, you are eligible to have it replaced, at DWSD's expense.



SAMPLE

The following terms and conditions apply:

1. The lead portions of the service line from the water main to your meter will be replaced at DWSD's expense. You must have an active water account to receive water access after lead service line replacement.
2. Your signature on this form gives DWSD permission to replace the service line. DWSD will require its contractors to maintain adequate insurance in the event they cause any damage while performing the work described in this Agreement.

Continued on next page

LEAD SERVICE LINE REPLACEMENT AGREEMENT (CONTINUED)

3. Someone 18 years or older must be home while the lead service line replacement is taking place.
4. As part of this program, your water can be tested before and after the service line is replaced. You must request water testing and give separate permission. Please contact the Lead Service Line Hotline at 313-964-9300.
5. Please maintain a clear path to the water meter and clear material away from the water meter so that the contractors can complete their work.
6. All standard landscaping disturbed by the service line replacement will be seeded and mulched as soon as practicable. Pavement areas that are disturbed will be replaced with similar pavement surfaces. DWSD will not be responsible for any damage to trees, flowers and shrubs resulting from the replacement of the service line.
7. You will be required to "flush" the water in your home. Specific instructions will be given to you on how to complete this task.
8. Piping inside the home will not be replaced.
9. You will continue to be the owner and responsible party of the replaced water service line from the curb stop and into the home. DWSD will guarantee the water service line for one year from the date of replacement.

[This space intentionally left blank. Signature only required on official agreement.]

SAMPLE

Water & Sewerage Department

WATER MAIN REPLACEMENT PROGRAM
FLUSHING INSTRUCTIONS

As a precaution, DWSD is providing residents with a free water filter that will remove any lead and sediment from water during and after construction.

You will receive your free water filter one week prior to construction.

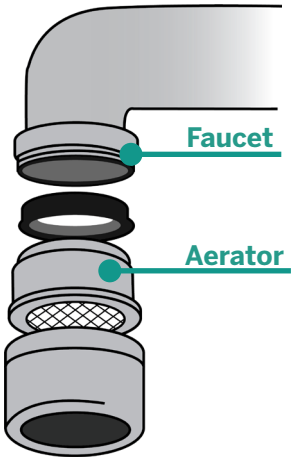
DWSD is replacing the water main that serves your home. The pipe connecting your home to the water main may be made of lead. The water provided to Detroit Water and Sewerage Department (DWSD) customers is treated to reduce corrosion of lead and other pipe materials in drinking water. Construction on your service line may cause sediment to loosen, which may contain lead particulates. Use the filter for all drinking and cooking water. Water is safe for showering and other uses. Follow the manufacturer's guidelines for using and maintaining the filter.

Flush your pipes before drinking.

During the construction period, take the following actions once a week:

Do not consume tap water, open hot water faucets or use icemakers or filtered water dispensers until you complete these steps:

1. Remove the faucet aerator (screens) from a faucet in the lowest level in your home. Fully open the cold water tap.
2. Continue removing the aerators at each faucet and turning on all cold water taps as you move to the top floor of your house.
3. Let the water run for at least 5 minutes at the last tap you opened (top floor).
4. Turn off each tap starting with the first tap you opened (bottom floor), then rinse and re-install the aerators at each tap.



Clean your aerators.

The aerator on the end of your faucet is a screen that catches sediment or particles. The aerators screw off from the end of your faucets by hand; you may need to use a wrench the first time. Brush and rinse the aerators before putting them back on your faucets.

(Turn page over for more details.)

Healthy Water Tips

- Always use cold water for drinking and cooking.
- Remove and clean the aerators (screens) on your faucets monthly.
- If water has not been used in your home for six hours or more, run the water from the tap until it is cold and continue to run for an additional 2 minutes to get fresh water at your tap. (Make sure to capture this water in your sink or a pail to use for watering plants.)
- Use a filter that meets NSF 53 for lead removal or bottled water if preparing formula for an infant.
- You will receive your free water filter one week prior to construction.
- **If you see discoloration in your water after flushing, stop using your water and call DWSD's emergency line at 313-267-8000.**

DWSD Lead Service Line Hotline:

313•964•9300

This notification is only intended for residents who live on the street of the water main replacement.

CITY OF DETROIT
Water & Sewerage Department

WORKING HARD FOR YOU.

FOR MORE INFORMATION, CALL
313•964•9300
www.detroitmi.gov/DWSD

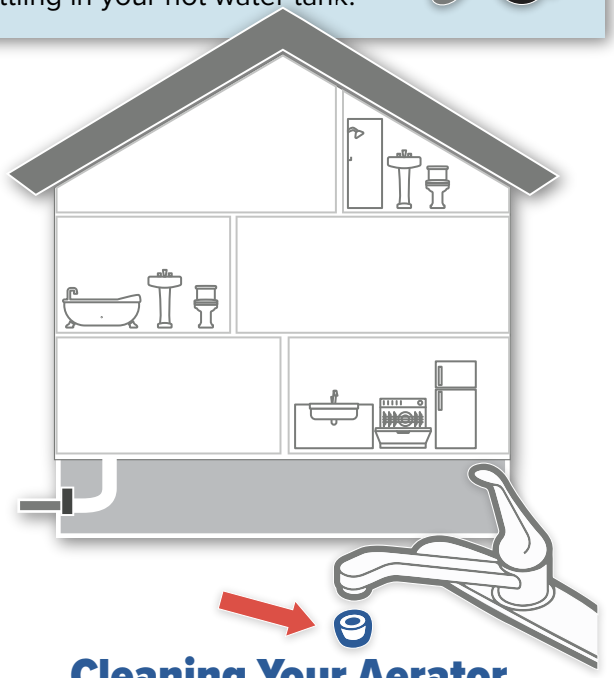
CITY OF NEWARK GET THE Lead Out

IMPORTANT HEALTH NOTICE

CITY OF NEWARK, NEW JERSEY
Lead Service Line Replacement Program

Flushing After your Lead Service Line Replacement

After your lead service line has been replaced, it is important to flush all of the pipes in your house. Flushing will remove any lead that may have entered the pipes in your house during construction. You should flush all interior plumbing the same day or before the next time you use your water. **DO NOT USE** hot water until the initial flushing is completed to prevent lead particles from settling in your hot water tank.



Flushing Instructions

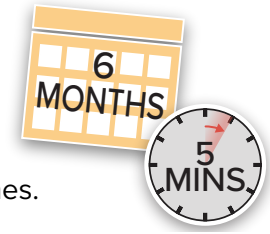
1. Find all the faucets that will drain, including the basement and all floors in your house.
2. Remove aerators and screens whenever possible, including the shower heads, from all faucets you plan to flush. Include the laundry tubs, hose-bibs, bathtubs, and showers as flushing points.
3. After all the aerators are off, open the faucets in the basement or lowest floor in the house. Leave all faucets running at highest rate possible, using cold water.
4. After the faucets are all open in lowest floor, open the faucets on next highest floor of the house. Continue until faucets are open on all floors.
5. After all faucets are opened, leave the water running for at least 30 minutes.
6. After 30 minutes, turn off the first faucet you opened and continue to turn off other faucets in the same order you turned them on.
7. Clean aerators/screens at each faucet. You may need to replace screens/ aerators if too old or worn. Conduct a 30 minute flush every other week for three months.

Cleaning Your Aerator

1. Remove faucet aerators and clean out any particles that may have accumulated there. The aerator is usually at the tip of the faucet and can be screwed off to clean.
2. After your lead service line is replaced, clean debris from aerators and screens once a month for six months. After six months, clean debris twice a year.

Daily Flushing

Daily flushes should continue for six months after your lead service line is replaced. Flush water through the plumbing in your house for 5 minutes each morning (or after an extended period of no water usage) before drinking.



NOTE: Taking a shower, running the dishwasher or flushing a toilet will flush your lines.

BENTON HARBOR
Port of Opportunities

RIGHT OF ENTRY & LEAD SERVICE LINE REPLACEMENT AGREEMENT

In consideration of the City of Benton Harbor's (the "City") efforts to remove lead water services, the property owner/current occupant has given permission per this signed agreement to the City and/or its officials, employees, or contractors to excavate, investigate, and replace non-copper water services

This permission involves: Allowing temporary access and right of entry to and upon the property to the City and the City's designated contractor(s) to perform investigation, inspection, construction and testing of the new private water service line and to enable any needed adjustments, maintenance, or repairs during the guarantee period

As Owner/current occupant, I understand and acknowledge that the work will be performed under the following provisions:

1. The service replacement is mandated by the State of Michigan Lead and Copper Rule. I understand the City is not permitted to re-establish water service to the water main until my lead/galvanized water service is completely replaced.

2. A new copper private water service line will be constructed at the City's expense, from the curb box in the public right-of-way to the water meter on the Owner's property including the meter setting and any necessary connections to reset the water meter. The existing service line will be disconnected and capped off.

3. All property disturbed by construction will be restored, including seeding of grass areas on the property and restore the interior portions of the building on the property disturbed by such work.

4. The contractor doing the work to provide adequate insurance to protect the Owner against any loss that may result from damage caused by negligent construction operations on the Owner's property, and require the contractor to provide the City with proof of such coverage.

5. The City guarantees that any work done shall be free from defects in material and workmanship for a period of one year from its completion.

THE PROPERTY OWNER'S/CURRENT OCCUPANT'S OBLIGATIONS.

1. Permit temporary access and right of entry to and upon the property to the City and the City's designated contractor(s) to perform construction and testing of the new private water service line and to enable any needed adjustments, maintenance, or repairs during the guarantee period;

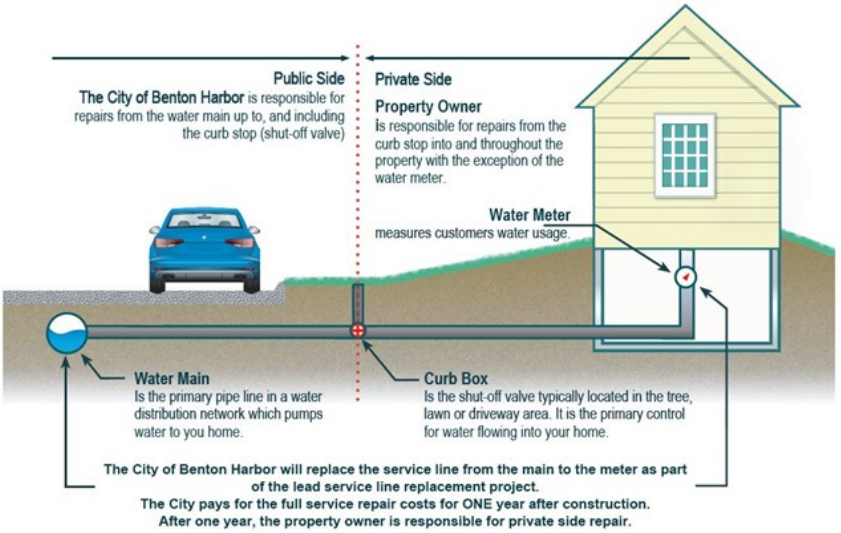
2. Property Owner will assume full responsibility for the maintenance, repair, and replacement of the private part of the water service line after one year from installation date.

3. Hold the City harmless and free from any claim or liability from any lawsuits, claims, injuries or damage done in performance of the water service line replacement work.

MISCELLANEOUS TERMS.

1. The responsibility of the maintenance, repair and the replacement of the water service located in the public right-of-way will be pursuant to City of Benton Harbor Water System Rules and Regulations.

2. This Agreement is a legally binding document and your signature will commit you to its terms. You acknowledge that you have been advised to discuss all aspects of this Agreement with an attorney, that you have carefully read and fully understand all of the provisions of this Agreement, and that you are voluntarily entering into this Agreement.



A copy of the completed agreement will be emailed to the email address you provide below.
If you have any questions about this agreement, please contact the City of Benton Harbor at 269-927-8457.

*** Owner/ Current Occupant Name:**

Email Address:

Optional – Add More Owners/Occupant

Property address (Landlords may add more properties under their ownership)

*** Address Line 1:**

Address Line 2:

City: Benton Harbor
State: MI

Optional – Add More Properties

Electronic Signature

*** Signing Owner/Current Occupant Name:**

*** Signing Owner/Current Occupant Phone#:**

* ☐
I certify that I am the owner/current occupant of the above listed property, and by signing this document fully understands and agrees to the listed clause and conditions stated in this agreement, and hereby declare that all information entered is true to my knowledge and submitted without any fraudulent intent.

Refresh

Input symbols

Submit

RIGHT OF ENTRY AND RELEASE
FOR LEAD SERVICE LINE REPLACEMENT

REASON FOR THE CITY'S REQUEST FOR A RIGHT OF ENTRY:

The City's records reflect that the water service line from the City's water main to your home, may be made of lead, or other materials containing lead such as brass or galvanized iron/steel. Although the lead service line is owned by you (as the property owner), the City believes that providing clean, lead-free drinking water to its residents is a public purpose beneficial to the City. For this reason, on September 18, 2019, the City enacted Ordinance No. 6PSF-M to implement the mandatory replacement of lead service lines within the City. Under the Ordinance, and with the monetary help of the County, the City has implemented a **Lead Service Line Replacement Program** where you can choose to have the City fully replace your obsolete lead service line with a new copper one *at no cost to you*. You also have the option to replace the obsolete lead service line at your own cost and expense. Whichever option you choose, under the Ordinance, the lead service line must be replaced.

If you desire to participate in the LEAD SERVICE LINE REPLACEMENT PROGRAM, then you must complete this form per the instructions provided below.

The City's Contractor and other Representatives will need access to your Property to perform the work associated with the Lead Service Line Replacement ("Replacement Work"). This Replacement Work includes access to the water meter inside your home, and involves: shutting off your water service for approximately eight (8) hours; removing your existing lead service line; replacing the lead service line with a new copper service line (from the street to your home, and through your basement wall to the existing water meter); connecting the new service line to the City water main and flushing the new service line. Before beginning work, the City's Contractor will notify you when they will be on your Property to perform the work. It is your responsibility to provide reasonable access and a working area for the Contractor at the service line and water meter location as requested by the Contractor. The Contractor and City Representatives may continue to enter onto your Property until construction is completed, and both you and the City accept the work. The City's Contractor and Representatives will suitably identify themselves prior to entering the property.

RIGHT-OF-ENTRY

I _____ affirm that I am the lawful owner ("Owner") of the Property, which has the street address of _____ ("Property"), and hereby grant the City of Newark's contractors, agents, and employees the right to enter and access my Property, so that the City can perform and complete lead service line replacement work on the Property. I authorize the City its contractors, agents, and employees to: take photographs and videos of the interior and exterior of the Property in the area of the water service line before and after installation; bring workers, material, equipment, and supplies onto the Property, and; utilize the Property for the purpose of performing the work necessary to replace the lead service line.

If you are a tenant, then please provide a copy of this Right of Entry to your landlord to authorize and sign. If your Property is rental property, then please notify your tenant(s) of your participation in the Lead Service Line Replacement Program and the scheduled work.

Pursuant to City Ordinance No. 6PSF-M, the Owner of any dwelling, building or structure shall replace their lead service line by any of the following methods. By indicating your choice below, signing and returning this Right of Entry form you, as the Owner of the Property:

- ☐ grant the City, its Representatives and Contractor the right to enter your Property between the hours of 7:00 a.m. and 6:00 p.m. to replace of your lead or galvanized iron/steel service line.

OR

- ☐ agree to replace your lead service line on your own and at your own expense within 90 days and submit proof of the completed work to the Department of Water and Sewer Utilities.

IMPORTANT: You agree and understand that the Lead Service Line Replacement Work cannot begin until the City has received this signed Right of Entry and it is on file with the City.

It is the City's policy and standard contract provision to require the Contractor to restore your Property to its preconstruction condition or better.

IN CONSIDERATION OF AND AS A CONDITION TO THE PERFORMANCE OF THE LEAD SERVICE LINE REPLACEMENT, YOU, THE UNDERSIGNED, HEREBY RELEASE AND FOREVER DISCHARGE THE CITY, ITS EMPLOYEES, AND LEGAL REPRESENTATIVE (COLLECTIVELY THE "CITY") FROM ALL LIABILITY FOR INJURY, DEATH, DAMAGE, OR LOSS TO PERSONS, REAL PROPERTY, OR PERSONAL PROPERTY IN CONNECTION WITH THE PERFORMANCE OF THE LEAD SERVICE LINE REPLACEMENT. YOU AGREE TO HOLD ONLY THE CITY'S CONTRACTOR, ACTUALLY PERFORMING THE WORK, RESPONSIBLE TO PAY ANY CLAIM IN CONNECTION TO THIS RIGHT OF ENTRY FOR DAMAGE TO YOUR PROPERTY OR ASSETS ON YOUR PROPERTY.

SIGN BELOW:

Name (Property Owner/Authorized Tenant):

_____

Property Address (Street Number & Street Name):

_____

_____	_____	_____
Signature	**Date**	**Mailing Address (Street Number & Street Name)**
_____	_____	_____
Printed name	**City**	**State Zip**

_____ ☐ **Cell or** ☐ **Home** _____

Phone Number **Email Address**

REQUESTS & CLAIMS:

A. YOUR PRESENCE DURING WORK: Someone must be present while the Replacement Work is being performed, to provide the Contractor with access in the area where your water service line enters your home up to your meter.

B. CLAIM PROCEDURES: In order to make a claim against the City's Contractor for damage to your Property in connection to the Lead Service Line Replacement Program and this Right of Entry, please call (973) 733-6303 and have a copy of this Right-of-Entry form available.

Planned Full Lead Service Line Replacement SOP

	WATER AND SEWER DEPARTMENT	**Category**	Planned Full Lead Service Line Replacement to be completed with Water Main Replacement (WMR) Projects
	[ENGINEERING]	**SOP #**	[TBD]
		Revision #	000
		Review Frequency	[Annually]
Division	Water	**Reviewed By**	
SOP Owner		**Last Reviewed / Update Date**	December 27, 2018
Implementation Date		**Approval**	

Design Phase

1. When streets and limits of a new water main replacement are identified, DWSD Engineering enters the street and limits in the Construction Project List Update "Design" tab at \\glwa-isilon.glwater.org\data\DWSD Field Service\CIP DataBase. DWSD Engineering adds the planned water main to the Planned Water Mains GIS layer. DWSD Engineering uses the Service Lines Analysis App to select all parcels adjacent to the planned water main replacement and generates an Excel report and sends to the DWSD Lead Team and Public Affairs. This report becomes the Water Main Replacement (WMR) Tracking Smart Sheet for the street.

2. DWSD Engineering identifies those WMRs that are nearest the procurement phase so the DWSD Lead Team can prioritize block meeting schedules.

3. DWSD Public Affairs (PA) schedules a design phase block meeting for the planned water main replacement. DWSD PA delivers the FLSLR meeting package to all homes on the WMR segment (not just expected lead service lines). The Package includes:

    a. Folder
    b. "Do You Have a Lead Service Line?"
    c. Block Meeting Invitation
    d. Lead Service Line Replacement Program FAQs
    e. Step-by-step lead service line replacement process
    f. Lead Service Line Replacement Agreement
    g. "Do You Know Your Pipes?"

4. DWSD PA holds the block meeting while the main is still in design. DWSD Engineering attends the meeting. Feedback from the affected residents is incorporated into the WMR design.

5. DWSD PA collects signed Water Service Line Replacement Agreements. The Agreements are tracked in the Collector App and WMR Tracking Smart Sheet.

Procurement Phase

1. Procurement staff schedules the pre-construction meeting with the Contractor, inviting DWSD Engineering and the DWSD Lead Team. Lead Team will provide a brief summary of lead hazards and purpose of lead risk mitigation measures at the meeting. The Contractor provides the preliminary WMR schedule identifying the sequence of streets in the project. Once approved at the meeting, the sequence of streets cannot be modified.

2. The DWSD Lead Team prepares a FLSLR implementation schedule for the WMR based on the Contractor's schedule.

Construction Phase

1. Every December, DWSD Engineering provides the DWSD Lead Team a draft schedule for the upcoming construction season that identifies all WMRs that will happen during the following construction season (approx. March – November). If a Contractor plans to work during the winter shutdown, DWSD Engineering will inform the DWSD Lead Team as early as possible but no later than the day the Contractor is given approval to work.

2. DWSD Lead Team ensures enough filters are in stock or ordered to cover the upcoming construction season.

3. The DWSD Lead Team verifies that advance block meetings have been held for each WMR planned for the upcoming construction season. Meetings are held for those WMRs for which meetings have not yet taken place.

4. DWSD Engineering provides WMR schedule updates to the DWSD Lead Team every Friday. The Lead Team and Public Affairs must be notified at least 30 days prior to mobilization to the WMR site by the Contractor. Once the DWSD Lead Team has been given 30 days' notice, the Contractor cannot move the mobilization date by more than 2 weeks except for cases of extreme weather or staffing emergencies.

5. DWSD Lead Team pulls updated Enquesta and Tax record data to update the contact information in the WMR Tracking Smart Sheet from the Design Phase at least 25 days prior to mobilization to the site. This list of addresses and contact information will be used for tracking purposes for the duration of the project and contact information will be updated as the work progresses.
    a. The WMR Tracking Smart Sheet will include the following information, if available:

i. Property address
ii. Tenant name and phone number
iii. Property owner name, address and phone number
iv. Identify if property owner is same as resident for each property
v. Date of initial service and expected service line material.
vi. Whether a Water Service Replacement Agreement has been received for the property.

b. The WMR Tracking Smart Sheet will be used as a tracking sheet at the block club meeting.
c. DWSD Lead Team informs DWSD Customer Service of the WMR schedule and provides the WMR Tracking Smart Sheet to stop shut-offs due to non-payment during construction. DWSD Customer Service flags accounts in Enquesta.
d. DWSD Lead Team shares the WMR Tracking Smart Sheet with Meter Ops to flag accounts with known meter issues.

6. Contractor prepares for full lead service line replacement:
   a. Performs background checks on all personnel, including subcontractors, who will be performing work inside customer homes. Background checks shall be submitted DWSD for review and approval prior to beginning work.
   b. Secures a licensed plumber to complete the meter connection on the private side of the service line.
   c. Contacts Miss Dig to mark stop box excavations

7. DWSD Meter Ops reviews all addresses in the WMR Tracking Smart Sheet to identify any known meter issues in homes with expected lead services that must be addressed during construction 20 days prior to mobilization to the WMR site by the contractor.

8. DWSD PA contacts Department of Neighborhoods representative, council member, and neighborhood leadership to make them aware of the upcoming project 30 days prior to mobilization to the WMR site by the contractor. Schedules a block club meeting to discuss the WMR with people who live in affected neighborhood.

9. DWSD PA and DWSD Lead Team deliver the Lead Service Line Replacement Program meeting package to all homes on the WMR Tracking Smart Sheet (not just expected lead service lines) 20 days prior to mobilization to the WMR site by the contractor that invites the residents to the block club meeting. This notification must come no less than 45 days before lead service line replacement is anticipated to begin on the project. The Package includes:

   a. Folder
   b. “Do You Have a Lead Service Line?”
   c. Block Meeting Invitation
   d. Lead Service Line Replacement Program FAQs
   e. Step-by-step lead service line replacement process
   f. Lead Service Line Replacement Agreement

g. Water Main Replacement Program Flushing Instructions
h. "Do You Know Your Pipes?"
i. Filter and replacement cartridges

10. DWSD Lead Team and DWSD PA convenes the block club meeting about 10 days prior to mobilization to the WMR site by the contractor. DWSD PA, Lead Team, Inspector, and Contractor attend the meeting. The meeting covers the agenda and details in the LSLR Block Meeting Template.
    a. DWSD Lead Team uses WMR Tracking Smart Sheet to update contact information, track sampling volunteers, and track filter distribution.
    b. DWSD Lead Team uploads all collected contact information to Enquesta within five days of the meeting.
    c. DWSD PA and Lead Team collects and tracks the signed agreements from people in attendance in the Collector App, and collects signed agreements that arrive in the mail. Mailed agreements tracked in the WMR Tracking Smart Sheet will be batch uploaded to the Collector App once a week.

11. DWSD Lead Team schedules water sampling appointments and collects samples from all homes that volunteer for water sampling. The ideal schedule for sampling is before construction begins on the WMR.

12. DWSD Inspector delivers "WMR Notice from DWSD Inspector" seven days prior to mobilization to the WMR site by the contractor.

13. Contractor completes the WMR and excavates every stop box.
    a. Contractor and/or inspector enters a service line inspection in the Collector App for every address, identifying the service line material on the private and the public side and uploading pictures. The collector app conveniently indicates which addresses have provided a signed Water Service Replacement Agreement.
    b. Where lead service lines are identified, Contractor installs a new stop box and copper line to the new water main. The lead service line is not disconnected until it can be fully replaced from the meter to the main.

Skip items 14 and 15 for addresses where a Water Service Replacement Agreement has already been received

14. For lead service line homes that have not provided a signed Water Service Replacement Agreement, the DWSD Inspector and/or Contractor tries to contact the resident if they are home and leaves a copy of the Agreement at the home. DWSD Inspector contacts the Lead Team regarding any lead service line home that does not provide a signed Water Service Replacement Agreement after multiple documented attempts.

15. DWSD Lead Team contacts each home with a confirmed lead service line (either inside or outside the house) that has not already provided a signed Water Service Replacement Agreement to obtain a signed agreement.

a. Lead Team will make 2 attempts at telephone contact on different days and at different times and at least 1 in-person attempt. The day, time, and method of contact will be documented each time in the Smart Sheet. If resident is not home, a door hanger with a summary will be left to contact DWSD.
b. If the DWSD Inspector determines the house is abandoned or a public hazard, the DWSD Inspector will check to see if the house is on the demolition list. No connection will be made for any home that is determined to be a hazard or on the demolition list.
c. If there is no response after three attempts and the DWSD Inspector determines the property is vacant, Contractor will replace the service line only from water main to the stop box, the new DWSD side service line and stop box will not be connected to the private side. Leave emergency number door hangar for any properties left without water due to failure to sign agreement.
d. If the tenant or owner refuses to sign the agreements, DWSD Lead Team will ask them to sign the Declination Form. If they refuse to sign the Declination Form, DWSD Lead Team will document the visit, write "refused to sign" on the Form and store in the Collector App with the affected address. The address is referred to DWSD Legal to handle on a case-by-case basis.
e. If no response is received:
    i. DWSD Lead Team sends a "Letter for Unresponsive Homes" by registered mail to the resident and the owner notifying their water may be shut off if they do not sign the agreement. "Water Service Replacement Agreement" and "Phase I Summary for WMR Homes" are enclosed.
    ii. If 5 days after the Letter the Agreement is not received, DWSD Lead Team <u>may</u> create a Non- Responsive Shut work order.
    iii. Depending on circumstances, the customer's service <u>may</u> be shut. DWSD Lead Team will obtain Director/CEO approval prior to non-responsive shutoffs.
    iv. If the tenant or owner provides a signed Water Service Replacement Agreement the contractor will replace the lead service line per the SOP such that water service is restored.

16. The Contractor schedules appointments at each house with a confirmed lead service line, a minimum of 7 days in advance of service transfer or as agreed to by the customer. All scheduled appointments will be tracked in the WMR Tracking Smart Sheet. Contractor will coordinate with DWSD to ensure the DWSD Lead Team attends all scheduled appointments, and homes with meter issues identified in item 7 have a Meter Ops Field Service Technician (FST) scheduled to attend. If the Contractor must cancel or reschedule an appointment, the Contractor must notify the customer and the DWSD Lead Team in writing or successful telephone call at least 48 hours before the scheduled appointment.

    i. Contractor, DWSD Lead Team, and Meter Ops (Meter Ops only attends if the meter or meter interface unit (MIU) needs to be replaced/repaired) attend the appointments scheduled in item 15.

ii. DWSD Inspector, Lead Team and/or Meter Ops will inspect and record the following in the Service Lines Collector App:
    1. Service size and material entering building
    2. Meter location
    3. Meter condition

iii. If the meter is missing, the meter is more than 8 years old, or if the AMR is not functioning, the DWSD Inspector calls Meter Ops immediately. A Meter Ops FST will be onsite within 1.5 hours. The DWSD Inspector and Contractor will remain onsite until the Meter Ops FST has installed a new meter.

iv. Contractor assesses the worksite and meter setting to prepare for lead service line replacement.

v. Prior to work, DWSD inspector takes photos of meter setting and water service entering building and stores photos in Collector App.

vi. At participating locations, DWSD Lead Team collects water samples.

vii. DWSD Lead Team answers all questions the resident has regarding DWSD service at their home.

viii. The WMR contractor assumes responsibility for communication with the tenant/property owner at this time.

17. If the customer fails to provide access at the time of the appointment, the Contractor will document the missed appointment and reschedule. If a customer has rescheduled the appointment more than three times, the Contractor may refuse further rescheduling and document for the project file.

18. During WMR construction, DWSD Inspector keeps filters onsite to deliver to any residents that did not receive them. DWSD Inspector notifies the DWSD Lead Team if any customer on the WMR segment has water shut off due to nonpayment during construction so that water can be temporarily turned back on for flushing purposes.

19. Contractor will contact the owner/tenant via phone or email to confirm the service replacement schedule and access to the property no less than 48 hours before the service is scheduled to be replaced. The Contractor will coordinate with residents who are not available during normal business hours to schedule a service replacement when access to the premises is available.

20. Contractor updates the WMR Tracking Smart Sheet with specific home service connection schedule. The WMR Tracking Smart Sheet identifies those homes that require meter repair or replacement. Meter Ops will be onsite at all appointments that require a meter or MIU repair or replacement. .

21. Day of replacement, Contractor
    a. Notifies resident that work is about to start and shuts off water so that customer does not accidently use water during replacement that will contaminate interior plumbing

b. Replaces full lead service line with copper service,
c. Provides proper meter setting, and reinstalls meter if no repair or replacement is required. The DWSD Inspector seals the meter if there are no known meter issues.
    i. If a meter issue has not previously been identified and the meter is missing, broken, or the AMR is not functioning, the DWSD Inspector calls Meter Ops immediately. A Meter Ops FST will be onsite within 1.5 hours. The DWSD Inspector and Contractor will remain onsite until the Meter Ops FST has installed a new meter.
    ii. If a meter repair or replacement is needed, the work will be completed by a Meter Ops FST. No property will be left with a straight pipe.
d. If the replacement cannot be completed on the workday, the Contractor will be prepared to provide a temporary connection to the water service to ensure the customer will not be without water overnight.
e. Contractor and licensed plumber will inspect newly installed service to ensure there are no signs of leaks, all adjustments have been made, and work is complete before leaving the customer premises.

22. DWSD Inspector is onsite during service connections and completes the following:
    a. Delivers and discusses the “WMR FLSLR Flushing Flier” at each home, contacting the resident before the water is turned back on.
    b. Adds a new (second) inspection in the Service Lines Collector App specifying the following:
        i. Replacement date
        ii. “Buried Customer Material” = Copper
        iii. “Buried DWSD Material” = Copper
        iv. “Service Line Material inside the home” = copper
        v. Pictures taken inside the home and in the yard after replacement is complete and interior restored.
    c. Records whether the contractor completes outdoor flushing
    d. If resident has no more filter cartridges, tell them how to get more.

23. The DWSD Lead Team schedules post-replacement water sampling appointment at sample volunteer homes.

24. Contractor restores
    a. Affected interior of the home including basement floor, wall, dry wall, block repair, paint, and
    b. Exterior including sidewalk, pavement, and grass at each property.
    c. Uploads post-construction pictures to Collector App

Post-Construction Phase

Planned Full Lead Service Line Replacement SOP

1. DWSD Inspector verifies service connection data in the Collector App and notifies DWSD Lead Team when the data are approved.

2. DWSD Lead Team mails “WMR Complete letter” to all homes providing warranty date, record of service line material, phone number to call if there is a problem.

3. DWSD maintains service line until one year after replacement date.

4. DWSD Lead Team informs Customer Service that properties that were put on the “no shut list” for construction can be taken off the “no shut list”.

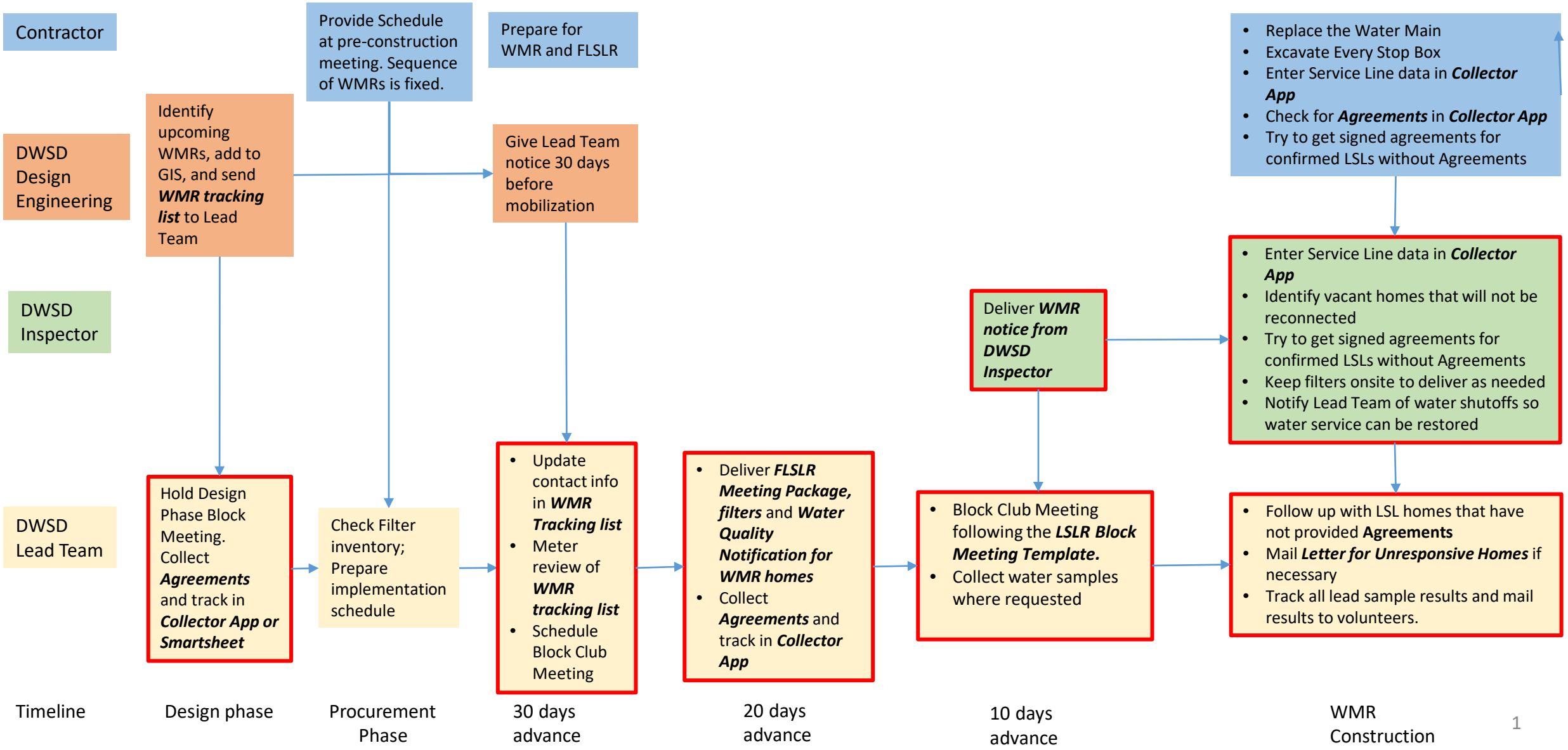
Planned Full Lead Service Line Replacement SOP

Notifications and Attachments for Implementation:

- Folder
- “Do You Have a Lead Service Line?”
- Block Meeting Invitation
- Lead Service Line Replacement Program FAQs
- Step-by-step lead service line replacement process
- Lead Service Line Replacement Agreement
- Water Main Replacement Program Flushing Instructions
- “Do You Know Your Pipes?”
- LSLR Community Meeting Template
- WMR Notice from DWSD Inspector
- Door Hanger
- Tenant Acknowledgement Form
- Declination Form
- Letter for Unresponsive Homes
- WMR FLSLR Flushing Flier
- WMR Complete Letter

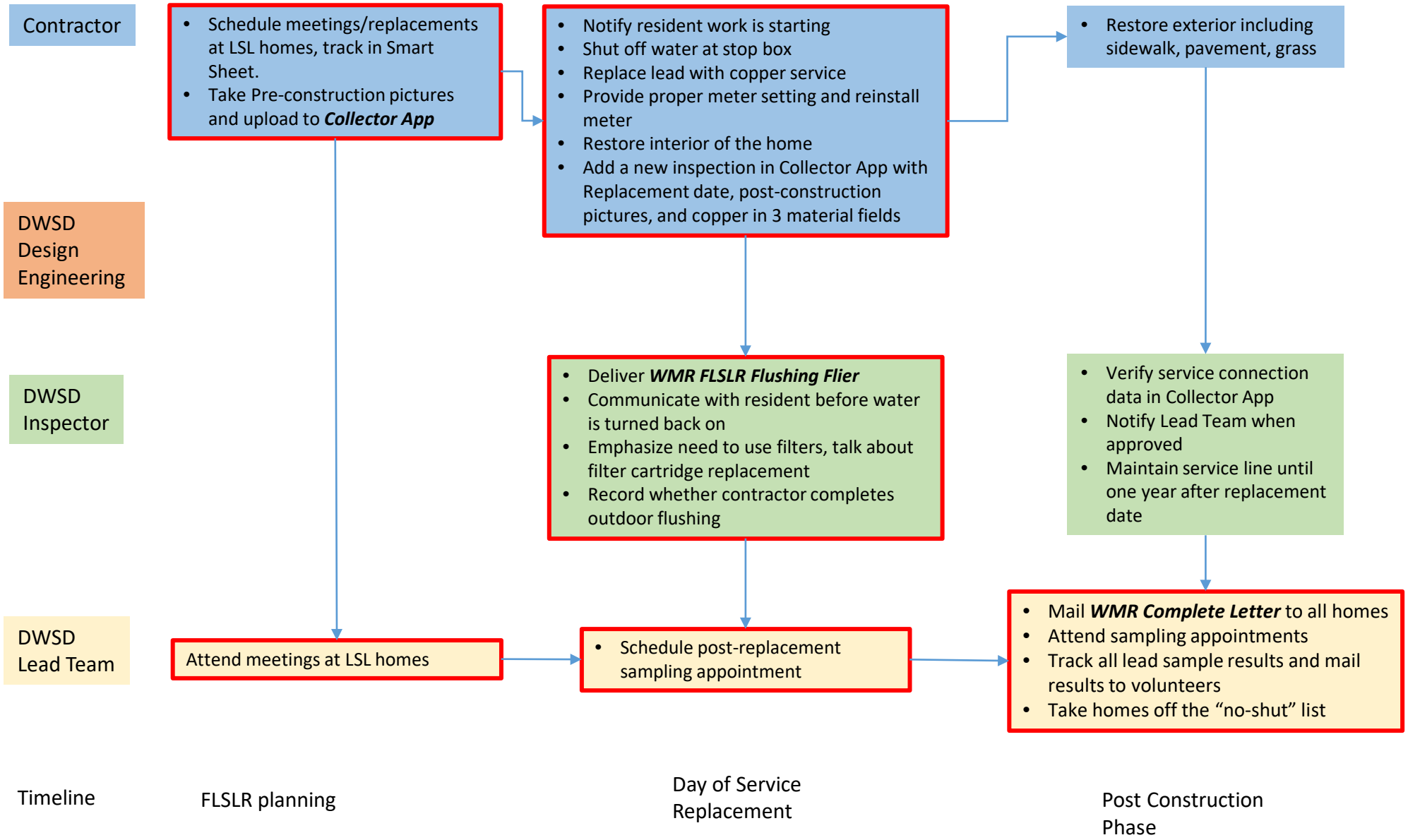
DWSD Planned FLSLR Program Process Flow Diagram

Represents customer interaction



DWSD Planned FLSLR Program Process Flow Diagram (cont.)

Represents customer interaction



SECTION 01 01 10
PROJECT SPECIFICATIONS

Part 1 - Summary

1. Section Includes

    a. Replacement of existing lead or galvanized steel service line with a new copper service line using trenchless technique from the curb stop and box at the right-of-way line to the customer shutoff valve**.**

    b. The removal and replacement of the existing lead service line from the water main to the curb box within the right-of-way will comply with all requirements of this specification and shall use a trenchless technique whenever possible.

    c. Where both sections of service line are made of lead or galvanized steel, the removal of both sections of lead service line shall be completed on the same date, thus completing a full lead service line replacement.

    d. This work includes the furnishing of all labor, equipment, and materials required for dewatering, excavation, installation, testing, backfilling, providing as-built plans, and all labor and related work necessary to complete the private water service installation.

    e. This work may include coordination with other entities before and after the lead service line replacement.

2. All water service work shall be completed in accordance with AWWA C810-17.

3. A standard operating procedure that defines all lead service line replacement tasks and interactions between the Owner, Engineer, Contractor, and any other supporting contractors, will be provided to the contractor at time of award.

4. Definitions

    a. Full Replacement – Full Replacement will include replacement of the water service from the existing water main to the curb stop shutoff (public) and from the curb stop shutoff to the shutoff valve or 18” inside the building, whichever is shorter (private).

    b. Partial Replacement – Partial Replacement will include replacement of the water service from the curb stop shutoff to the shutoff valve or 18” inside the building, whichever is shorter (private) or replacement of the water service from the water main to the curb stop shutoff if lead or galvanized steel is only found on the public side of the water service.

    c. None – Parcel that does not contain an existing service and will be reviewed by Owner during the project.

    d. Already Replaced – A service line that has been recently replaced with copper on both the public and private side of the curb shutoff. These locations shall be verified by potholing for visual inspection at the curb stop, as well as visual inspection inside the building.

If the existing water service contains lead in any component (i.e. gooseneck, service line, etc.) the following rules shall apply:

Pipe Material from Main to curb stop (Public Side)	Pipe Material from curb stop to home (Private Side)	Vacant or Active Property	Replacement Conditions*
Lead or Galvanized	Galvanized, Lead, Copper, or Plastic	Vacant	Partial Replacement on Public Side. Leave service line disconnected at Curb Stop
Lead or Galvanized	Galvanized or Lead, Copper, or Plastic	Active	Full Replacement
Copper or Plastic	Galvanized or Lead	Vacant	Cut and cap at existing curb stop and disconnect at Curb Stop
Copper or Plastic	Galvanized or Lead	Active	Partial Replacement on Private Side
Copper or Plastic	Copper or Plastic/HDPE	Active or Vacant	Curb Stop Pothole Only and visual inspection inside the house

**Note: According to the Michigan Safe Drinking Water Act administrative rule R 325.10604f (5) (c), upon restoration of service if any portion of the service line has lead or galvanized previously connected to lead (GPCL) remaining in the service line, service restoration is prohibited until all portions of the lead or GPCL are removed.*

Part 2 - Materials

1. Protection

    a. Protect materials from moisture and dust by storing in clean, dry location remote from construction operations areas.

    b. Keep materials in original packaging until immediately prior to use.

    c. Install a cap at the end of the copper coil to keep copper coil dust and insect free.

    d. Provide additional protection according to manufacture instructions

2. Furnish all pipe, fitting and appurtenance materials required for the contract in conformance with the requirements of the standard specifications, American National Standard Institute/American Water Works Association (ANSI/AWWA) specifications, and the Municipality's technical specifications for water mains and appurtenances.

3. Water Services. Provide materials to be incorporated into the work that meet the requirements outlined in section 923 of the MDOT Standard Specification for Construction and comply with the provisions of AWWA C800 as regards to composition and style of thread. Water service tube shall

be Type K copper, annealed soft temper in accordance with ASTM B-88. Ensure all brass meets National Sanitation Foundation (NSF)/ANSI 61 and Standard 372 of "lead free" alloy e-brass.

4. Service Joints. All fittings shall be flared end fittings except for 2 inch water services which may utilized compression fittings with locking devices. Where connections are made to existing service lines of differing materials, threaded or conductive compression pack joints, as applicable, may be provided. Connections between dissimilar metals should utilize dielectric unions to prevent galvanic corrosion. In all cases, ensure provisions for electrical conductivity are made at all joints and fittings.

5. Valves, Boxes and Appurtenance Items:

    a. Corporation Stops must meet NSF/ANSI 61. Corporation stops shall be McDonald #4701, Ford F-1000 or equal for 1 inch services and Ford FB-1000 or equal for 2 inch services. Stops shall be of all brass construction with the types of ends as required by the conditions of installation. Stops shall open counterclockwise.

    b. Curb Stops must meet NSF/ANSI 61. Curb stops shall be Ford B41-333, McDonald 76102-22, or equal for services up to 1 inch and Ford B41-333 or approved equal for 2 inch services.

    c. Service Saddles, Curb Boxes, and Copper Pipe fittings shall be in accordance with the Municipality's Standard Specifications.

Part 3 - Execution

1. Scheduling and Documentation

    a. Coordinate Construction Schedule and Operations with Owner a minimum of one (1) week prior to commencing lead service line replacements. Owner, Contractor Representative, and Engineer will convene in the field or in the office to discuss the Work Plan.

    b. Contractor shall review site conditions including all surface features and landscaping. Any landscaping that has a potential to be disturbed, shall be noted prior to work commencing. Any removed landscaping shall be replaced in equal or better condition, to include, but not limited to trees, bushes, grass and fences. The contractor shall document preexisting conditions by taking precondition photos and uploading to ArcGIS Field Maps or software equivalent provided by the owner.

    c. Contractor shall document both the pre-and post-construction of the lead service line replacement:

        i. Document the conditions within the right-of-way, the private property from the right-of way limit to the structure, and the point where the service connects to the meter (basement crawl space, other)

        ii. Provide photographs using ArcGIS Field Maps.

    d. The Contractor shall attend scheduled community meeting(s) regarding the lead service replacements.

e. The Contractor shall be responsible for scheduling appointments with tenant/property owner at each property in advance of excavation so the service line can be replaced at the same time it is verified to be made of lead or galvanized steel. The contractor shall provide a schedule for service replacement to the tenant and owner and be tracked in an excel spreadsheet and ArcGIS Field Maps and shall be submitted to the Engineer weekly.

f. If a customer cannot provide a time for accessing the internal connection within one (1) week, the Contractor will document the missed appointment and reschedule.

g. During the day of replacement, the Contractor shall complete the following:

    i. Notify the resident that the work is about to start and shut off water so that the customer will not use water during replacement that could contaminate interior plumbing.

    ii. Replace the entirety of lead line with copper service.

    iii. Complete and provide the following records in the ArcGIS Field Maps and in accordance with AWWA C810-17 and provide to OWNER and Engineer:

        a. Take a photo of the house with property number and completed service

        b. Take a photo of excavation pits, meter, and new and old pipes at meter.

        c. Record the length and material of new pipe installed

        d. Document the existing materials inside home and meter

        e. Document the method of installation

        f. Document the length and location of any abandoned or removed pipe materials. Complete House Plumbing Flushing and provide informational materials on flushing and filters and bottled water to resident. (see appendix for requirements and information materials) Document the delivery of materials to the resident. Updated information materials may be provided by the Owner or Engineer during the course of the work and should be substituted for the original materials as directed.

        g. Provide sampling kit with instructions of sampling at least 30 days after completion of service replacement per AWWA C810

        h. Provide a letter to the resident stating that the lead service line has been replaced with copper and their warranty is good for one year from the current date. A form letter will be provided for this purpose. If work cannot be completed during the workday due to conditions beyond contractors control, the water should remain off overnight and bottled water provided.

h. Water service replacement shall occur during daytime hours and not be shutoff overnight. All replacements are required to take place in one working day.

i. Lead or galvanized steel service line sections remaining in place on the private side to vacant properties shall be cut and capped and disconnected at the curb stop to reduce or eliminate the possibility of water leakage and to prevent future service restoration until all portions of the lead or GPCL are removed.

2. Maintaining Traffic

a. Maintain traffic according to the 2012 MDOT Standard Specifications for Construction.

b. Provide a traffic control plan developing the contractors work plan for review and approval by Owner and Engineer.

c. Work shall be isolated to one residential block unless approved by Owner and Engineer.

d. Perform work during daytime hours only. Allow night work only at the discretion of the Owner and Engineer. Any additional costs for maintaining traffic for night work will be borne by the Contractor.

e. Provide traffic control devices in accordance to the Michigan Manual of Uniform Traffic Control Devices (MMUTCD).

f. Traffic Control Devices

    i. Channelizing Devices

        1. Use plastic drums with high intensity sheeting as channelizing devices.

        2. Use eight-foot High Intensity Type III Barricades to block off streets.

3. Installation

a. Install all pipe materials required for the contract according to AWWA standards, Section 823 of the MDOT 2012 standard specifications and the Municipality's technical specifications for water mains, services, and appurtenances as applicable.

b. Locate services to be replaced prior to constructing replacements. Each water service crossed shall be first uncovered at the curb stop so the existing material can be determined. Existing material data shall also be documented inside the house between the foundation wall and interior water meter. Existing service data including address, material, location, and photos of each service encountered shall be logged using the ArcGIS Field Maps application as required in Part 3.1.g.iii and in accordance with AWWA C810-17.

c. Right of Entry Permission. Obtain right of entry permission from each homeowner prior to disturbing private property. Permission shall be obtained via a signed Right of Entry (ROE) agreement shown in Appendix D. Right of entries may be obtained and provided by Owner and Engineer and provided to the Contractor. If Right of Entry has been provided by owner, Contractor will not be paid for obtaining ROE.

d. Remove and replace existing pavement, curb and gutter, and sidewalk in accordance with MDOT 2012 Standard Specifications for Construction and this specification. Pavement, curb and gutter, and sidewalk removal and replacement shall be minimized to the smallest extent possible where trenchless methods of water service installation are utilized.

e. All lead services that are replaced shall be removed, meaning the existing corporation stop shall be turned off at the main, and the existing stop box shall be removed. All removed items shall become the property of the contractor and shall be disposed of properly.

f. All new water services shall be constructed of one piece of Type K copper, ¾ inch diameter, minimum bury 5 foot 6 inches. The copper shall be laid in a straight line from the stop box to the main. An additional 1 ft of slack copper shall be installed in a gooseneck configuration at the curb stop and also at the corporation stop.

g. All corporation stops shall tap into the main at 45 degrees from vertical, pointing in the direction of the stop box. Service saddles shall be installed on all 2 inch water services.

h. The contractor shall provide for each new service a new corporation stop, new curb stop, new curb stop box, and all fittings necessary to complete the connection to the existing service behind the curb stop at the right-of-way.

i. Curb Stop installation will be paid as **Curb Stop and Box**. Corporation Stops, Service Saddles, and fittings will be considered incidental to the cost to install the service line.

j. Water services within the Right-of-Way shall be placed and backfilled as detailed in MDOT Trench Detail G unless a trenchless method is used.

k. Public side service installation on public property (from the water main to the Right-of-Way) shall be installed by trenchless method and be paid as **Public Water Service, Trenchless** and is the preferred method to minimize pavement and other disruption. The Contractor may utilize horizontal directional drilling, impact moling (piercing/missile method), cabling/pulling or other trenchless installation acceptable to the engineer.

l. Water Service installation on private property (from the Right-of-Way to the structure) shall be installed by trenchless method and paid as **Private Water Service, Trenchless**. The Contractor may utilize horizontal directional drilling, impact moling (piercing/missile method), cabling/pulling or other trenchless installation acceptable to the engineer.

m. Connect new water service to the existing first shut off valve inside the building or 18 inches inside of building, whichever is shortest. New penetrations or amendment of existing penetrations into the structure shall be completed in accordance with the Michigan Plumbing and/or Building Code Plumbing shall be completed by a licensed plumber and in accordance with the Michigan Department of Licensing and Regulatory Affairs plumbing permit. The Contractor shall be responsible for obtaining a plumbing permit and scheduling inspections. Contractor shall provide the permit and final inspection to the Engineer. The City of Benton Harbor uses and requires the Michigan Department of Licensing and Regulatory Affairs (LARA) for Plumbing Inspections. The permit application and fee schedule can be found at https://www.michigan.gov/documents/lara/lara_bcc_327_plumbing_permit_application_1016_537607_7.pdf

n. Wall penetration, connection to interior plumbing, and final plumbing inspection will be paid as **Private Water Service, Connection to Residence**. All fittings and couplings required to make the connection shall be included in this item.

o. Restoration of pervious public side areas shall utilize appropriate seeding mixes and erosion control in accordance with sections 916 and 917 of the 2012 MDOT Standard Specification for Construction and the Special Provision for Slope Restoration, Type B.

p. It is the intent of trenchless water service installation to prevent or minimize disruption to private and public property. Remove and replace or otherwise amend existing landscaping and/or decorative hardscaping as directed by the Engineer. The cost for restoration of improvements shall be included with payment for the associated Private Water Service item of work. Restoration of pervious private side areas shall utilize appropriate seeding mixes and erosion control in accordance with sections 916 and 917 of the 2012 MDOT Standard Specification for Construction and the Special Provision for Slope Restoration, Type B.

q. The contractor is required to backfill and compact all excavations at the end of each day, or throughout the day if multiple services are being completed.

r. Pavement restoration must be completed within two (2) weeks upon service completion or unless otherwise approved by the Owner or Engineer. The contractor will be required to maintain all backfill, aggregate base materials, and replace and recompact as needed prior to paving. The contractor will be responsible for addressing all Soil Erosion and Control measures and keep each site clean and restored daily.

Part 4 - Measurement and Payment.

The completed work as described will be measured and paid for at the contract unit price using the following contract item(s):

Pay Item	**Pay Unit**
Maintaining Traffic	LSUM
Pavt, Rem	Syd
Public Water Service, Trenchless	Foot
Private Water Service, Trenchless	Foot
Curb Stop and Box	Each
Private Water Service, Connection to Residence	Each
Water Service, Complete	Each
Right of Entry	Each
Private Water Service, Cut and Cap	Each

1. **Maintaining Traffic** shall be paid at the contract unit price per Lump Sum (LSUM) and includes all temporary traffic control measures and flag control which are needed to maintain traffic in accordance with applicable laws and regulations. Includes supplying materials and maintenance throughout the during of the project. Includes installation and removal of any temporary gravel needed to maintain traffic.

2. **Pavt, Rem** shall be paid at the contract unit price per Square Yard (SYD) for pavement removal and includes removing pavement from driveways, HMA pavements, concrete pavements, roadways containing brick, and roadways containing both concrete and HMA regardless of depth of the existing pavement.

3. **Public Water Service, Trenchless** is to be measured in place along the centerline of the pipe. The price includes payment in full for furnishing all material, labor, and equipment required to perform the work specified herein, including dewatering, excavation and backfill, bracing or sheeting and blocking of excavated trench or piercing/missile pits, removal of the existing water service, service line couplings, service joints, and all other miscellaneous items necessary for the installation of pipe and connection to the curb stop. If a service line cannot be installed by trenchless methods, the contractor must be prepared to install service line by open excavation to complete the work. Price for installing the service line by open excavation will be the same pricing bid for **Public Water Service, Trenchless**. All the requirements listed in Part 3.1.g.iii and are required for this pay item in accordance with AWWA C810-17.

4. **Private Water Service, Trenchless** is to be measured in place along the centerline of the pipe. The price includes payment in full for furnishing all material, labor, and equipment required to perform the work specified herein, including dewatering, excavation and backfill, bracing or sheeting and blocking of piercing/missile pits, removal of the existing water service, service line couplings, service joints, and all other miscellaneous items necessary for the installation of pipe and connection to the curb stop. If a service line cannot be installed by trenchless methods, the contractor must be prepared to install service line by open excavation to complete the work. Price for installing the service line by open excavation will be the same pricing bid for **Private Water Service, Trenchless**. All the requirements listed in Part 3.1.g.iii and are required for this pay item in accordance with AWWA C810-17.

5. **Curb Stop and Box** shall be paid at the contract unit price per each and shall include installation of a curb stop, curb stop box, excavation, backfill, and disposal of waste.

6. **Private Water Service, Connection to Residence** is to be measured in place. The price includes payment in full for furnishing all material, labor, and equipment required to perform the work specified herein, including dewatering, excavation and backfill, bracing or sheeting, blocking, removal of the existing private water service, service line couplings, service joints, and all other miscellaneous items necessary for the installation of pipe and connection to the first shut off valve inside the building or 18 inches inside the building, whichever is shortest. This includes the penetration of a structure's foundation wall. Unit pricing shall also include all scheduling, coordination with LARA for Plumbing inspection, providing inspection documentation, and inspection costs based on LARA fee schedule for water service sizes including application and final inspection fees. All the requirements listed in Part 3.1.g.iii and are required for this pay item in accordance with AWWA C810-17.

7. **Water Service, Complete** is to be measured and paid for each. The price includes payment in full for completing the post replacement requirements per AWWA C810-17 for all replacement types. This completion of flushing the service before connecting, flushing the household plumbing after connection, and providing written notice to the home that their lead line has been replaced and their warranty is good for one year. All documentation will be provided by ArcGIS Field Maps upon completion of the pay item for **Water Service, Complete**.

8. **Water Service, Investigation** will only be paid at locations where the existing service line is confirmed to be non-lead at all inspection points including 3 feet on each side of the curb stop shutoff and the connection to the meter or 18" inside the building, whichever is shorter. The price includes payment in full for providing

notice to each property, accessing the property to investigate the existing service materials, and to provide an inventory to the Engineer via the ArcGIS Field Maps application. The Contractor will be required to locate and confirm existing materials on both sides of the curb stop and in the home. Documented inventory and photos shall be provided to the Engineer. Provide written notice that the entire service line has been confirmed to be made of [material identified], is not made of lead, and does not need to be replaced. A form letter will be provided. All the requirements listed in Part 3.1.g.iii and are required for this pay item in accordance with AWWA C810-17.

9. **Right of Entry** shall be paid at the contract unit price per each. If the Owner has obtained Right of Entry for an address, the Contractor will not get paid for the Right of Entry pay item for that address.

10. **Water Meter Replacement** shall be paid and the unit price bid from the supplemental items. This item will only be required when the existing meter is defective and requires replacement. The price shall include the contractor replacing a meter or shutoff valve inside the house within accordance of the Michigan plumbing code to return the property to service. The Owner will provide the water meter to the contractor for replacement.

11. **Private Water Service, Cut and Cap** is to be paid per each. This price includes payment in full for cutting a capping an existing lead or galvanized steel connection on the private side to a vacant property.

The following work items as described will be measured and paid in accordance with the 2012 MDOT Standard Specifications for Construction:

Pay Item	**Pay Unit**
Mobilization, Max	LSUM
Sidewalk, Rem	Syd
Curb and Gutter, Rem	Ft
Subbase, CIP	Cyd
Aggregate Base, 8 inch	Syd
Hand Patching	Ton
Conc Pavt, Misc, Nonrienf, 6 inch	Syd
Curb and Gutter, Conc, Det C4	Ft
Driveway, Nonreinf, Conc, 6 inch	Syd
Sidewalk, 4 inch	Sft

Model Ordinance for the Replacement of Lead Service Lines

[based on Newark, NJ ordinance]

Note: an ordinance may require state enabling legislation

§ 1. Definitions - For the purposes of this Chapter:
CITY — Shall mean the [City].
CONTRACTOR — Shall mean a licensed vendor that contracts with the [City] to replace lead service lines.
DEPARTMENT — Shall mean the [Water Department of the City]
DWELLING — Shall mean a building or structure or part thereof containing one or more dwelling units. This chapter shall also apply to buildings and structures that are not used for residential purposes.
DWELLING UNIT — Shall mean any room or groups of rooms or any part thereof located within a building and forming a single habitable unit with facilities that are used or designed to be used for living, sleeping, cooking, eating, or bathing.
LEAD SAFE — Shall mean any condition that does not allow access or exposure to lead, in any form, to the extent that adverse human health effects are possible.
LEAD SERVICE LINE — Shall mean a water line that is not lead-free (including a galvanized pipe that is or has been connected to any lead pipe upstream) and that runs from the water main into the structure or building.
OCCUPANT — Shall mean a person or persons in actual possession of and living in the building or dwelling unit.
OWNER — Shall mean any person who has legal title to any dwelling, with or without accompanying actual possession thereof; or, who has equitable title and is either in actual possession or collects rents therefrom; or, who is executor, executrix, trustee, guardian, or receiver of the estate of the owner; or as mortgagee; or as vendee in possession either by virtue of a Court order or by agreement or voluntary surrender of the premises by the person holding the legal title; or as collector of rents has charge, care, or control of any dwelling or rooming house.

§ 2. Prohibition of Lead Service Lines – It is hereby established that the existence of lead service lines is prohibited in the [City].

§ 3. Exclusion – A property owner may be excluded from the Mandatory Replacement of its lead service line by providing the [Water Department], within 90 days of the effective date of this ordinance, with written proof from a licensed and certified plumber that it does not have a lead service line on its property, and/or that the lead service line was previously removed and replaced.

§ 4. Property Owner Responsibility to Replace Lead Service Line –

a. The owner of any dwelling, building, or structure serviced by a lead service line is required to replace the lead service line on their property. The replacement of the lead service line must be completed within 90 days of the effective date of this ordinance. An extension of time may be granted where the owner can demonstrate, to the [Water Department] designee, that a good faith effort has been made to comply with the ordinance.

b. The owner of a dwelling, building, or structure shall replace their lead service line by any of the following methods:

1. Signing up for the Lead Service Line Replacement Program offered by the [City] at the expense of the [City/water system] and allowing contractors to access their property to conduct the replacement. The Contractor will provide the owner with a Right of Entry form for completion. The Right of Entry form will provide the contractor with access to the property to verify the existence of a lead service line; or

2. Replacing the lead service line on their own and at their own expense. If an owner selects this option, then replacement must be completed within 90 days of the effective date of this ordinance. An extension of time may be granted where the owner can demonstrate, to the [Water Department] designee, that a good faith effort has been made to comply with the ordinance. An owner is required to provide the [Water Department] with proof that the lead service line has been replaced. Proof must include at a minimum: (i) a permit issued by the [Water Department] to a licensed plumber authorized to do the work; (ii) an invoice from the contractor who completed the work; (iii) a copy of the estimate along with any report of the work completed; and (iv) an inspection report [by the Water Department or the Buildings Department] verifying the removal.

§ 5. City Responsibility to Replace Lead Service Lines – Notwithstanding section 4, if an owner of the dwelling, building, or structure does not sign up for the Lead Service Line Replacement Program or does not replace its lead service line within 90 days of the effective date of this ordinance (or within the time frame provided in an extension) or is inaccessible or otherwise denies access to the property to enable the replacement of the line, then the following procedure shall be followed:

a. The City shall secure entrance to the property from the owner or current occupant of the dwelling, building, or structure, and the City shall incur no liability from the owner. The contractor will provide the owner or occupant with a Right of Entry form for completion. The Right of Entry form will provide the Contractor with access to the property to verify the existence of a lead service line. The City shall restore the property to its original condition, or as close as possible to its original condition; and

b. If access is granted by the occupant of the dwelling, building, or structure, the occupant shall be held harmless and no liability shall incur to the City or occupant due to the replacement of the lead service line by the [City]; and

c. If access is denied by the current occupant or owner, then the City shall commence procedures, including filing a Court action, to conduct the replacement of the lead service line.

§ 6. Owner and Buyer Responsibilities –

a. Upon the sale or transfer of ownership of any dwelling, building, or structure, the owner must provide proof that the lead service line has been replaced in order to secure a Certificate of Occupancy, Certificate of Code Compliance, [and Smoke & Carbon Monoxide Detector Certificates].

b. Upon the sale of any City-owned property, within 90 days of the closing, the buyer is responsible for replacing the lead service line, by either enrolling in the Lead Service Line Replacement Program or in accordance with section 4(b)(2) above.

§ 7. Enforcement – The [City/water system] may shut off water to any property for which access has been denied to replace a lead service line. The [City/water system] shall record in property records for such property that it has a lead service line and that access to replace that line was denied.

Enclosure 1

Denver Water's Lead Reduction Program Plan

Denver Water Variance From Optimal Corrosion Control Treatment Requirements Under the Safe Drinking Water Act's Lead and Copper Rule

LEAD REDUCTION PROGRAM PLAN

Submitted to EPA, September 2019

DENVER WATER

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EXECUTIVE SUMMARY

Introduction

Denver Water is committed to delivering safe water to 1.4 million people in the metro area, which is why Denver Water is working to significantly reduce lead exposure risks for customers with lead service lines and plumbing. The water we deliver to homes and businesses is lead-free, but lead can get into the water as it moves through customer-owned service lines and lead-containing plumbing.

This Lead Reduction Program Plan has been prepared in support of Denver Water's request to the Environmental Protection Agency for a variance from the optimal corrosion control treatment requirements under the Safe Drinking Water Act's Lead and Copper Rule.

Currently, Denver Water maintains a pH of 7.8 to reduce corrosion of lead service lines and plumbing. Denver Water conducted a study on multiple treatment options to reduce the potential for lead to enter drinking water from lead service lines and household plumbing. Based on the results, the Colorado Department of Public Health and Environment, the state regulatory agency that oversees drinking water regulations, required Denver Water to begin adding orthophosphate by March 2020, in accordance with regulatory requirements.

Despite its benefits, orthophosphate added to drinking water can increase phosphorus levels in wastewater and stormwater, resulting in adverse impacts to wastewater treatment plants and downstream reservoirs, streams and rivers. Once started, orthophosphate cannot easily be discontinued without causing an increase in corrosion, making orthophosphate a potentially permanent treatment method.

Due to these concerns, Denver Water, along with the Colorado Department of Public Health and Environment and other stakeholders, convened working groups in 2018 to further evaluate the benefits and risks of orthophosphate alongside other options to reduce lead exposure. As part of this process, Denver Water investigated whether a lower dose of orthophosphate, a higher pH of 9.2 with alkalinity adjustment or a multi-faceted approach including pH/alkalinity adjustment to 8.8 combined with the accelerated replacement of lead service lines and the provision of filters to customers could achieve the same or greater reduction in lead exposure risk. Based on this analysis, and as highlighted in Figure 1, Denver Water seeks to implement the multi-faceted Lead Reduction Program in place of adding orthophosphate to drinking water because the Lead Reduction Program provides the greatest benefit to public health and the environment.

FIGURE 1: LEAD REDUCTION PROGRAM PLAN BENEFITS

Protects Future Generations
The Lead Reduction Program permanently removes the largest source of lead within 15 years through accelerated lead service line replacement versus more than 50 years of using orthophosphate.

Focuses on Health Equity and Environmental Justice
The components of the Lead Reduction Program provide equal access for everyone to benefit from reducing overall lead exposure.

Provides Better Water Quality
For customers with lead service lines, Denver Water will provide filters that reduce lead by 97% until their lead service line can be replaced.

Creates a Regional Solution
The Lead Reduction Program prevents additional phosphorous loading at regional wastewater treatment plants, which is costly to remove.

Protects Infants and Children
The Lead Reduction Program prioritizes filter distribution and lead service line replacement in areas at greatest risk to lead exposure, namely areas with young families, child care providers and schools.

Protects Environmental Health
Upon implementation, the Lead Reduction Program will prevent introduction of a new source of phosphorous into reservoirs, rivers and streams. Nutrients can impair water for aquatic life as well as downstream wastewater and water utilities.

The Lead Reduction Program includes multiple elements, the most essential of which involve:

- Development of a lead service line inventory to identify and track lead service line replacement.
- A filter program.
- An accelerated lead service line replacement program.
- Corrosion control treatment with pH/alkalinity adjustment.
- Communications, outreach and education plans.

Overall, as compared to orthophosphate, the Lead Reduction Program provides a holistic and permanent lead reduction approach that is as effective at protecting public health, more efficient in reducing lead exposure, less harmful to the environment, more equitable in its public health benefits and more cost-effective with fewer regional risks.

History

How does lead enter drinking water?

Lead exposure, whether from paint, soil, air or water, is a significant public health concern because it has the potential to adversely affect some of our most vulnerable populations, especially children. When it comes to lead in drinking water, no levels are considered safe. That is why Denver Water is working with the Colorado Department of Public Health and Environment, the Environmental Protection Agency and Denver Water's customers to reduce the risks of lead exposure as drinking water moves through homes and businesses with lead service lines and lead plumbing.

While Denver Water delivers safe, lead-free water to customers' homes, lead can enter the water through three sources: (1) a customer's lead service line, which conveys water from the water main in the street to the customer's home, (2) a customer's household plumbing that contains lead solder and (3) a customer's plumbing fixtures that contain lead (e.g., faucets, valves). Figure 2 highlights the sources of lead in drinking water.

Denver Water studies show that lead service lines, typically found in homes built before 1951 within the Denver Water service area, are the primary source of lead in drinking water.

What has Denver Water done historically to control lead and reduce lead exposure?

For decades, Denver Water has been working to reduce lead in drinking water. Figure 3 highlights the history of lead in drinking water and provides an overview of Denver Water's activities to reduce lead exposure. Since 1992, Denver Water has tested water from inside customer homes with known lead service lines or lead solder as part of the Safe Drinking Water Act's Lead and Copper Rule. Additionally, Denver Water has provided corrosion control treatment in the form of pH adjustment of the water delivered to customers' homes to minimize the corrosion of customer-owned lead service lines and plumbing.

FIGURE 2: SOURCES OF LEAD IN DRINKING WATER

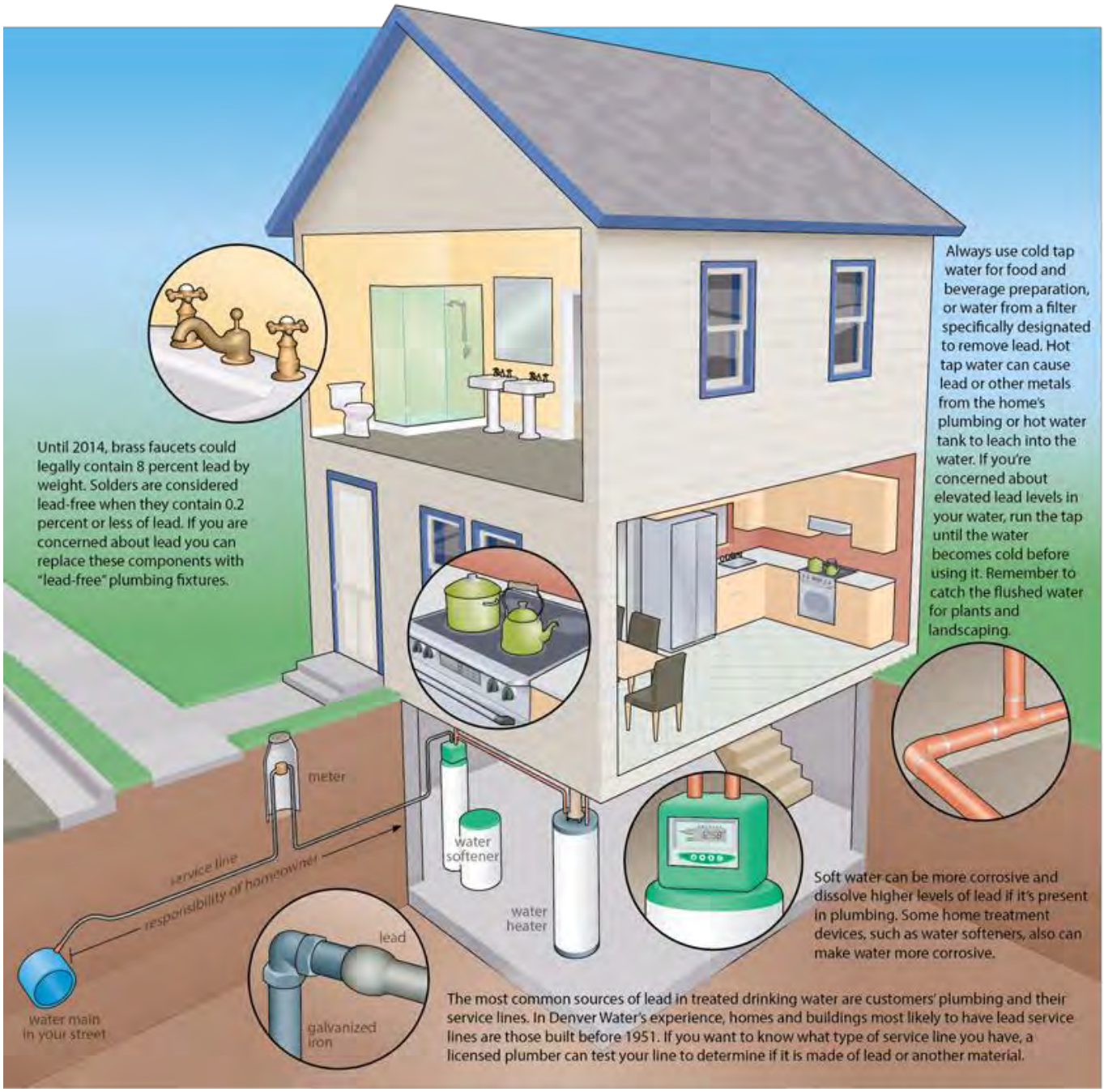


FIGURE 3: HISTORY OF LEAD IN DRINKING WATER

Since 1994, Denver Water has been authorized to maintain a minimum pH/alkalinity of 7.5. In accordance with this authorization, in recent years, Denver Water has sought to consistently maintain a pH of 7.8. This approach has resulted in the following lead concentrations measured from Tier 1 homes as defined in the Lead and Copper Rule. A Tier 1 home is a sample site that is a single-family structure built between 1983 and 1987 that (1) contains copper pipes with lead solder, (2) contains lead pipes and/or (3) is supplied by a lead service line.

Category	Lead Concentration Range (1997-2019 data) (expressed in units of ppb – parts per billion)
Average lead concentrations for Tier 1 homes	4 to 8
90th percentile lead concentrations for Tier 1 homes	7 to 17*

* Lead and Copper Rule action level is 0.015 mg/L = 15 ppb; 17 ppb was reported once in 2012.

Although these treatment efforts were largely effective for many years, in 2012, the 90th percentile value for sample results of lead concentrations in tap water was 17 ppb, exceeding the Lead and Copper Rule action level of 15 ppb. Since the Lead and Copper Rule was adopted in 1992, the 2012 exceedance of the lead action level was Denver Water's first and only exceedance.

As a result of this one exceedance, Denver Water was required to investigate the cause and evaluate alternative treatment solutions. These studies included a lead service line pipe rack study that required the harvesting of lead service lines from homes in the distribution system. These studies, especially the pipe rack study, required a significant investment of time and resources by Denver Water and resulted in the submittal of an Optimal Corrosion Control Treatment Report in late 2017. Based on the data in the report, in March 2018, the Colorado Department of Public Health and Environment designated orthophosphate be added to drinking water as the optimal corrosion control treatment and directed Denver Water to prepare to implement orthophosphate treatment by March 2020.

Corrosion Control

What is corrosion control?

When water interacts with metal, the metal can oxidize, resulting in corrosion. By adjusting the chemistry of the water, it is possible to cause a buildup or coating on pipe walls, which reduces the amount of lead released from lead-containing pipes and fixtures. This protective coating, however, requires the maintenance of a delicate chemistry in the water. To reduce corrosion and maintain the coating, the Lead and Copper Rule requires drinking water systems to maintain "optimal corrosion control treatment," which means a corrosion control treatment that minimizes the lead and copper concentrations at customers' taps. This can be done through orthophosphate addition, pH/alkalinity adjustment or calcium hardness adjustment. Depending on the chemistry of the water, some corrosion control treatment methods can be more effective than others.

What is orthophosphate?

Orthophosphate is a phosphate-based corrosion control inhibitor that changes the chemistry of water to create a protective coating on service lines and plumbing that, in turn, reduces the corrosion that causes lead releases. Although orthophosphate is effective at reducing lead exposure, it can increase phosphorus levels in wastewater and add excessive nutrients to surface water, adversely affecting rivers, streams and lakes in our region. To remove phosphorus, wastewater treatment plants would need to invest in facility upgrades. In addition, once Denver Water begins to treat with orthophosphate, it will likely need to continue treatment indefinitely to avoid upsetting the delicate chemistry of the water that maintains the protective coating on service lines and plumbing.

Are there effective alternatives to orthophosphate?

Because of concerns about the negative impact of orthophosphate on wastewater treatment plants and the environment, Denver Water engaged stakeholders to assess alternatives to using orthophosphate that may provide even greater protection to Denver Water customers.

These studies investigated two treatment approaches: (1) the lowest effective dose of orthophosphate (3, 2 or 1 mg/L as orthophosphate) required to minimize lead at drinking water taps in Denver Water's system and (2) the effects of a higher pH of 9.2 as a corrosion control treatment method on lead releases. Denver Water and stakeholders also analyzed the costs to remove phosphorus from the watershed as well as the costs to counter the potential effects of increasing pH. In addition, Denver Water developed a lead control model, demonstrating the efficiency of replacing lead service lines in combination with both use of lead removal filters and pH/alkalinity adjustment, as compared with orthophosphate corrosion control treatment alone.

Based upon these studies, Denver Water is proposing an alternative, holistic approach that directly tackles the biggest issue, customer-owned lead service lines, at its source by accelerating the replacement of those lines through a Lead Reduction Program. The Lead Reduction Program would reduce the risk of public exposure to lead beyond what can be achieved by adding orthophosphate to the drinking water by:

- Developing a lead service line inventory so our customers can investigate the likelihood of having a lead service line.
- Implementing the Filter Program, a program that would distribute filters to all homes with a known, suspected or possible lead service line, reducing lead by 97% or more.
- Implementing an accelerated lead service line replacement program that would replace the major source of lead decades ahead of the current rate of replacement: approximately 63,955 lead service lines would be replaced within 15 years versus 50 years or more under current practices.
- Adjusting pH from 7.8 to 8.8 and maintaining alkalinity above 30 mg/L as $CaCO_3$ for corrosion control treatment to reduce corrosion of lead service lines, household plumbing

and fixtures (note: treatment objectives for pH/alkalinity adjustment will be approved by the Colorado Department of Public Health and Environment).

- Enhancing the communications, outreach and education program to help customers understand the Lead Reduction Program and ways that they can reduce their exposure to lead.

How will this change my water quality?

The proposed pH/alkalinity adjustment to improve corrosion control will have little-to-no noticeable impacts to Denver Water customers, their plumbing, and appliances. Results from internal and external taste tests show that changes in taste and odor are not anticipated to be an issue with either proposed corrosion control treatment alternatives. Further, there is no evidence that the effectiveness of fluoride would be impacted.

For customers with chemistry dependent uses (pools, fish tanks, breweries, etc.), the customers will be informed of the change and prepare accordingly. Proper maintenance of appliances to prevent excessive scale build-up should be part of general maintenance practices regardless of the water quality that enters premise plumbing.

Variance Request and Lead Reduction Program

How does the Environmental Protection Agency determine whether an alternative treatment method is as effective or better than orthophosphate?

To implement the Lead Reduction Program, Denver Water must apply for a variance from the Environmental Protection Agency. Under 42 U.S.C. § 300g-4(a)(3) and 40 C.F.R. § 142.46, the Environmental Protection Agency may grant a variance from the optimal corrosion control treatment requirements under the Safe Drinking Water Act's Lead and Copper Rule *"upon a showing from any person that an alternative treatment technique not included in such requirement is at least as efficient in lowering the level of the contaminant with respect to which such requirements was prescribed."*

Is Denver Water proposing the Lead Reduction Program on a voluntary basis?

Denver Water is proposing the Lead Reduction Program on a voluntary basis as an alternative to orthophosphate treatment under the Lead and Copper Rule. Denver Water cares about the 1.4 million people it serves and the safety of the water at their taps. Denver Water wants to provide the best short- and long-term solution to prevent lead exposure. In addition, Denver Water is concerned about the adverse impact that orthophosphate could have on the downstream reservoirs, rivers and streams, the quality of the source of supply and the costs wastewater treatment and stormwater management providers would incur to remove phosphorus. For these reasons, Denver Water is proposing the Lead Reduction Program as a proactive measure to permanently replace lead service lines from its service area as efficiently as possible, provide additional public health protection that cannot be achieved through orthophosphate treatment alone, protect the watersheds and help reduce regional costs that would be incurred to remove phosphorus from wastewater.

What commitments is Denver Water making?

Denver Water will actively engage its customers within the City and County of Denver and the service areas of its distributors that collectively make up Denver Water's "integrated system." The Lead Reduction Program will aim to reduce lead concentrations by distributing filters to customers with known, suspected or possible lead service lines, replacing 7.0% of the lead service lines annually and replacing all lead service lines within 15 years. Denver Water's commitments are described in more detail in Table 1.

TABLE 1: DENVER WATER'S PROPOSED LEAD REDUCTION PROGRAM COMMITMENTS

Communications, Outreach and Education
Denver Water is committing to: • Educate and engage with residents, customers, distributors, local public health agencies and government stakeholders about lead awareness and reduction efforts. • Educate the public on measures they can take to reduce their exposure to lead in water used for drinking, cooking and infant formula preparation. • Tailor and support a communications, outreach and education program focused on expecting and existing families with formula-fed infants/children up to age 2, at homes with copper piping with lead solder, with special emphasis on homes built 1983-1987. • Seek feedback from residents and other stakeholders to learn best practices and effective ways to implement program activities. • Strive for 100% participation in the Filter Program.
Lead Service Line Inventory
Denver Water is committing to: • Research, investigate and document the presence of customer-owned lead service lines. • Help customers identify if they have a lead service line. • Maintain a current lead inventory and map. • Confirm materials at properties with a suspected or possible lead service line. • Use the inventory to target communications, outreach and education efforts at areas with the greatest risk.
Filter Program
Denver Water is committing to: • Provide filters and filter cartridge replacements to properties with known, suspected and possible lead service lines for up to 15 years during the life of the Lead Reduction Program. • Educate and inform residents on the importance of using filters for drinking water. • Denver Water is striving for 100% adoption in the Filter Program; if filter adoption is less than 75%, Denver Water will increase outreach and education efforts in low adoption areas to improve filter use.
Accelerated Lead Service Line Replacement Program
Denver Water is committing to: • Replace all known lead service lines in 15 years. • Replace 7.0% of the lead service line inventory each program year, based on a cumulative annual average. • Use the predictive model to help prioritize lead service line replacements, taking into consideration public health/toxicology concerns, child care providers, primary schools, neighborhoods with a high density of young families and socioeconomic and environmental factors. • Follow up with residents and provide filters until the service line is confirmed as non-lead or until six months after the lead service line is replaced.
Corrosion Control Treatment
Denver Water is committing to: • Maintain water quality by implementing corrosion control treatment through pH/alkalinity adjustment. • For homes built from 1983 to 1987 with copper piping with lead solder where water quality tests exceed 3 ppb, provide equivalent treatment by offering free filters and replacement cartridges for expecting and existing families with formula-fed infants/children up to age 24 months, per CDPHE guidance.

Learning by Doing
Denver Water is committing to: • Evaluate the performance of the Lead Reduction Program to improve outcomes. • Establish an Advisory Committee to inform Denver Water on more efficient and effective ways to implement the Lead Reduction Program to achieve the variance goals.
Health Equity and Environmental Justice
Denver Water is committing to: • Create equitable access for all communities within the integrated system so that all residents will benefit from the reduction in lead exposure. • Prioritize the integration of health equity and environmental justice principles by measuring the community needs and tailoring outreach efforts to reach vulnerable populations. • Consult and collaborate with community organizations and members, health equity and environmental justice experts, stakeholders and customers to continually improve upon the Lead Reduction Program.

How will the performance of the Lead Reduction Program be evaluated?

Denver Water will use the criteria shown in Table 2 to evaluate the performance of the Lead Reduction Program. An annual report will detail the program's success and provide regulators with clear criteria to determine when to require correction or take enforcement action.

TABLE 2: LEAD REDUCTION PROGRAM EVALUATION FOR COMPLIANCE

Element	Definition of Compliance	Correction Active	Failure to Meet Condition
Lead Service Line Inventory	Must investigate a minimum of 1.4% of total LSLs in inventory per year.	• Achieve compliance by following year. • Provide notice of corrective action to customers with filters.	If less than 1.4% investigations occur for three program years: • Notice to all customers.
Filter COE	Outreach and education materials provided each year to at least 95% of households enrolled in the Filter Program.	• Must achieve compliance by following year. • Notice to customers with filters.	If Denver Water fails to provide outreach and education materials to at least 95% of households enrolled in the Filter Program for three years: • Notice to all customers.
Filter Program	Achieve minimum filter adoption rate of 65% per year.	• If filter adoption rate is less than 65% in a year, increase outreach and education efforts to improve filter use. • Notice of corrective action to customers with filters.	If failure to achieve 65% adoption rate for three years: • Termination of variance. • Notice to all customers.
Accelerated Lead Service Line Replacement	Must achieve 7.0% cumulative annual average replacement rate each year.	• Achieve compliance by following year. • Notice to customers with filters.	If less than 7.0% of lead service lines are replaced for three years: • Termination of variance. • Notice to all customers.
Corrosion Control Treatment	Lead and Copper Rule sampling results remain below action level for lead.	• Must adjust corrosion control and distribution management. • Customer education and notice.	If action level exceeded for two monitoring periods: • Must provide customer notice. • Termination of variance unless CDPHE requires otherwise.

What is the estimated cost of each alternative?

Denver Water estimated the life cycle cost for each alternative. This effort included incorporating cost data from other water and wastewater utilities, stormwater entities, watershed authorities and recreational entities. CDPHE requested a summary of costs to support the implementation of, or resulting from, the variance or orthophosphate alternatives, and excluding costs related to Denver Water's existing lead service line replacement work. Denver Water also calculated the costs including the costs for the existing lead service line replacement work because these efforts will continue under either alternative. As seen in Table 3, under either assumption, the variance alternative is more cost effective.

TABLE 3: LIFE CYCLE COSTS IN TERMS OF NET PRESENT VALUE

Assumption	Orthophosphate (at 2 mg/L as PO_4)	Variance
Excluding Existing Service Line Replacement Efforts	$322M to $506M	$265M to $362M
Including Existing Service Line Replacement Efforts	$376M to $582M	$319M to $439M

How will Denver Water fund the Lead Reduction Program?

Denver Water will fund the Lead Reduction Program through rates, loans, grants and donations. In addition, as a show of support for the Lead Reduction Program Plan, Metro Wastewater Reclamation District committed $22.5 million in funding in a resolution adopted on July 16, 2019.

"The Metro Wastewater Reclamation District strongly supports the Lead Reduction Program because it is a permanent and holistic solution that benefits both public health and the environment across the unique arid west region. In furtherance of its support, the Metro Wastewater Reclamation District Board of Directors has made a commitment of up to $22.5 million to the Lead Reduction Program if the variance is approved by Environmental Protection Agency."

What if the variance request is not approved or the variance criteria are not met?

Following the Colorado Department of Public Health and Environment's designation of orthophosphate for optimal corrosion control treatment, Denver Water initiated design and construction of chemical feed systems to dose orthophosphate at 3 mg/L at Denver Water's three treatment plants. If the variance request is not approved, these systems will begin introducing orthophosphate on March 20, 2020.

If the variance is granted and certain criteria in Table 2 are not met during the 15-year period of the Lead Reduction Program, Denver Water might also be required to implement orthophosphate using the chemical feed systems.

More details on the optimal corrosion control treatment designation of orthophosphate can be found at: www.colorado.gov/cdphe/lead-dw-treatment

Public comment period for the Lead Reduction Program Plan

Denver Water conducted a public comment period from July 12 to August 7, 2019 to gather feedback on the program benefits, filter input, communication preferences and overall support. The information was distributed through a variety of different engagement channels such as newsletters, targeted emails to stakeholders and customers who have expressed an interest in Denver Water's lead reduction efforts, TAP news site distribution, social media, distributors, neighborhood groups, etc. During this four-week period, 406 comments were received from unique IP addresses that have indicated that more than 98% of respondents support the Lead Reduction Program, emphasizing benefits for future generations, environmental health and protecting infants and children. Public feedback has been incorporated throughout the plan. Full results can be found in Appendix I.A.

Denver Water also received letters of support from various public health agencies, copies of which can be found in Appendix I.B.

How to navigate through this Lead Reduction Program Plan

This executive summary introduces the Lead Reduction Program Plan, the variance request and Denver Water's commitments if the variance is approved by the Environmental Protection Agency.

Section I presents the history of lead occurrence and control in the Denver Water system, from the single exceedance of the action level for lead in 2012 until the designation of orthophosphate for optimal corrosion control treatment by the Colorado Department of Public Health and Environment in March 2018.

Section II provides a summary of the investigations undertaken by Denver Water since March 2018 to demonstrate that the Lead Reduction Program is as effective as the alternative of orthophosphate at reducing lead concentrations in drinking water. An overview of the elements that together make up the Lead Reduction Program is presented.

Section III describes how Denver Water will implement all six elements of the Lead Reduction Program.

Section IV details how Denver Water will evaluate the performance of the Lead Reduction Program and ultimately maintain regulatory compliance with the Lead and Copper Rule.

Section V describes how Denver Water will address health equity and environmental justice needs through the Lead Reduction Program.

Section VI presents the implementation schedule for the Lead Reduction Program.

Section VII presents the estimated costs of the Lead Reduction Program.

A series of technical memoranda were prepared during the development of the Lead Reduction Program and are included in the appendices to this plan.

What is Denver Water asking of the customer?

- Understand that lead can get into water as it moves through customer-owned lead service lines and lead solder and what you can do to reduce lead exposure.
- Help us identify if you have a lead service line – learn more at denverwater.org/Lead
- If you have a lead service line:
  - Allow Denver Water to replace the lead service line at no cost to the property owner.
  - Use a filter until the lead service line can be replaced.
- If you have sources of lead in premise plumbing inside the home:
  - Replace faucets and indoor plumbing with lead-free components.

To minimize exposure to lead when using water for drinking, cooking and making beverages, ice and infant formula:

- Use a filter certified by NSF International to remove lead for drinking and cooking. Replace the filter cartridge according to the manufacturer's instructions.
- Use only cold water for drinking, cooking and making baby formula. Remember, boiling water does not remove lead from water and hot water often contains higher levels of lead than cold water.
- If water has not been used in the home for a few hours, such as first thing in the morning or when getting home from work or school, run the kitchen or any bathroom faucet for five minutes (remember to capture the water and reuse it!). You can also run the dishwasher, take a shower or do a load of laundry to help flush water in your internal plumbing before drinking or cooking.
- Regularly clean your faucet's screen (also known as an aerator).
- Consider replacing faucets and indoor plumbing with lead-free components.

I. DENVER WATER'S HISTORY OF LEAD OCCURRENCE AND CONTROL

From the late 1800s to the mid-1900s, lead service lines were installed in the Denver metro area to deliver water from the main into customers' homes. This was a common practice in the industry across North America, as lead service lines offered significant durability and protection from leaks and subsequent contamination of household water supplies. In 1949, Denver Water's engineering standards were amended to allow the use of other materials, such as copper, for service line installations. By 1986, the state of Colorado had banned lead in pipes, solder and other plumbing materials.

Lead in Denver Water's service area

Denver Water's service area consists of the City and County of Denver and its outlying distributors, as depicted in the map in Figure 4. The service area shown in the map includes adjacent distribution systems that are physically connected to and provided with water from Denver Water's system.[1]

Lead service lines are known to exist in Denver and in approximately half of the service areas of Denver Water's distributors.

Within Denver, customers own and have historically been responsible for their service lines. Since Denver Water did not install and does not own service lines, it has few records about the location or type of material (copper, lead or other) of service lines. However, the year of service line installation provides some indication of whether the service line is likely to be made of lead.

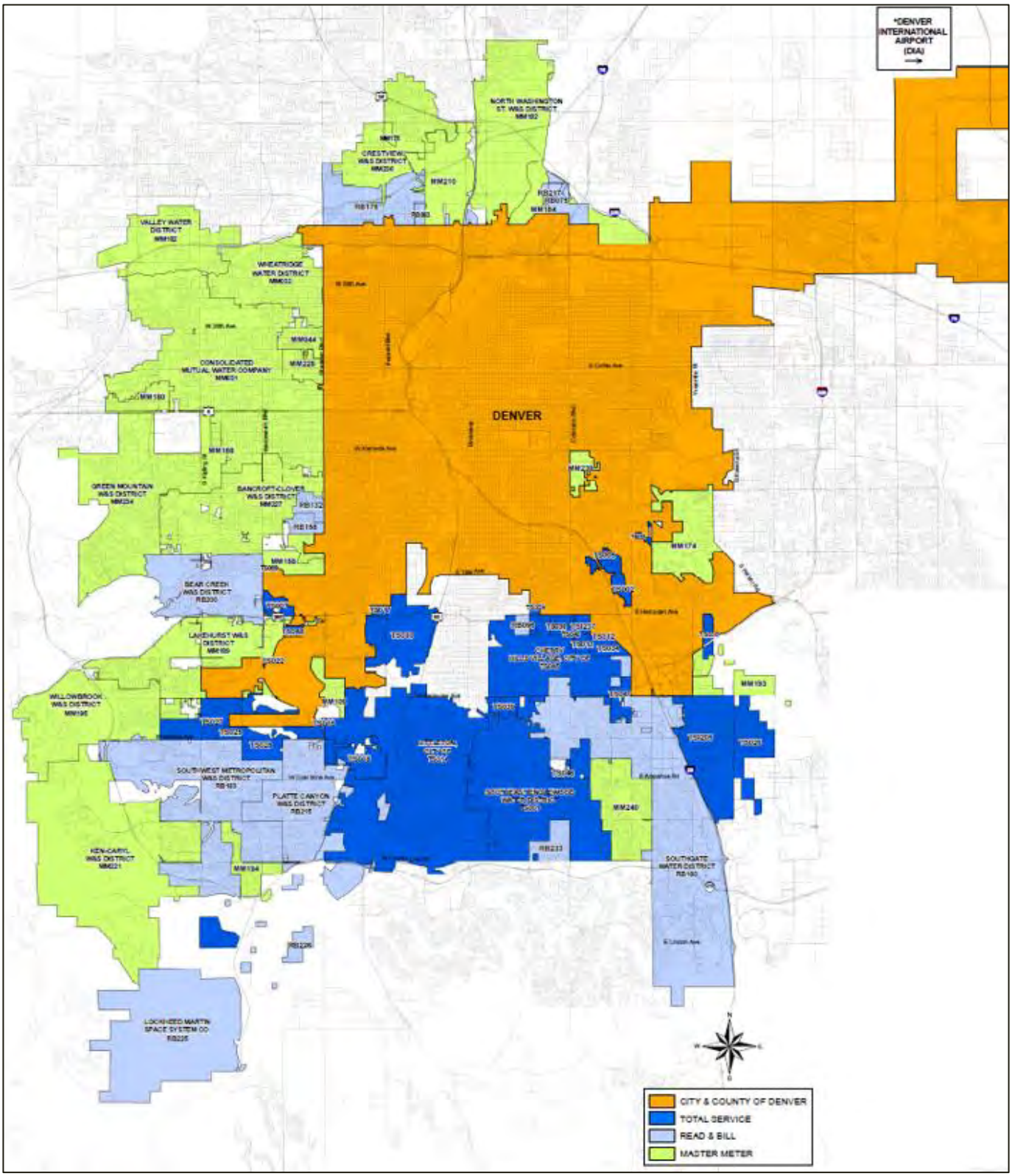
In 1949, the Denver Water Board added copper to its list of approved materials for service lines. Although Denver Water's engineering standards did not eliminate lead as an acceptable material for service lines until 1971, data collected during construction and repair work and from water quality tests for homes built after 1950 indicate that the use of lead as a service line material sharply decreased after 1950.

Actions taken by Denver Water to protect customers from lead in drinking water

Since 1992, Denver Water has tested water from customers' faucets per the Environmental Protection Agency's Lead and Copper Rule and the Colorado Department of Public Health and Environment's Primary Drinking Water Regulations. The results from the last twenty years are shown in Figure 5. Additionally, Denver Water has studied corrosion control and modified treatment processes to improve corrosion control.

[1] See Rule 11.42(1), 5 CCR 1002-11 and Appendix III.B.1.

FIGURE 4: DENVER WATER SERVICE AREA INCLUDING INTEGRATED SYSTEMS

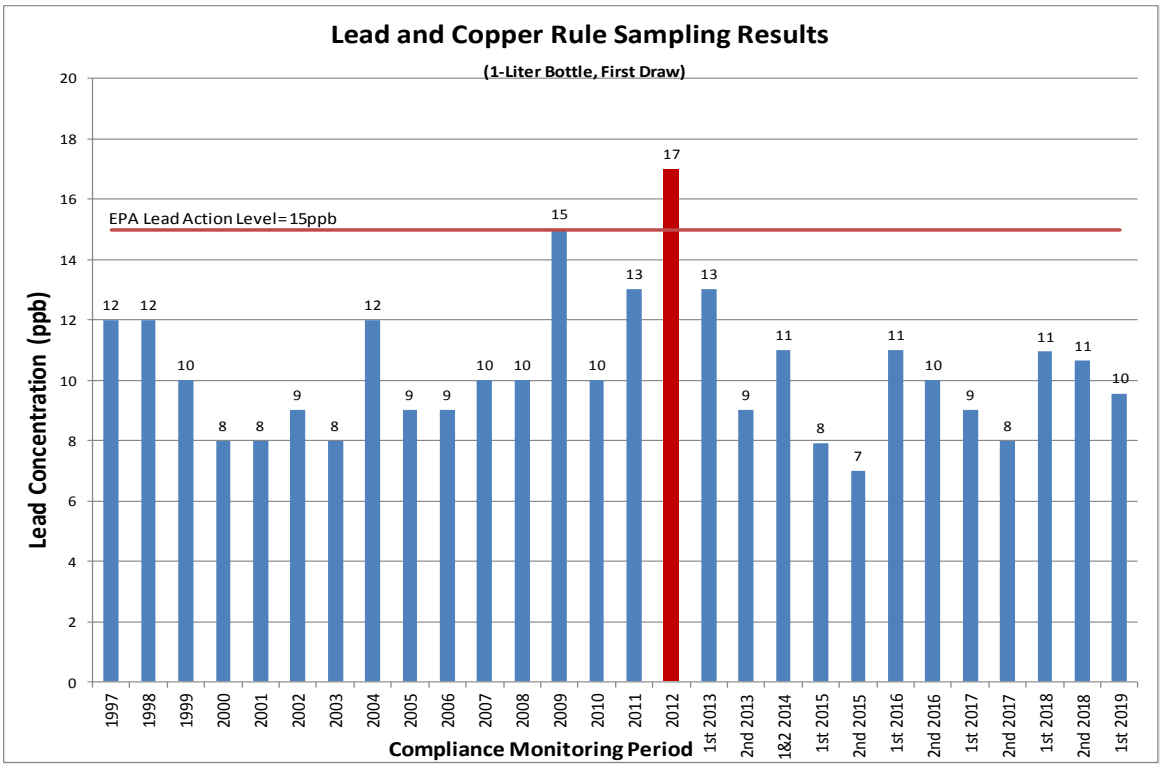


A corrosion control study completed in 1994 recommended that Denver Water adjust the pH of the water produced from its treatment plants to a range of 7.5 to 8.3 standard units. CDPHE issued a letter following the study indicating that to comply with the Lead and Copper Rule,

Denver Water must produce water with a minimum pH of 7.5 and minimum total alkalinity of 15 mg/L as $CaCO_3$ before the water enters the distribution system. In 1994, Denver Water implemented the changes to meet these regulatory requirements.

Through 2011, Denver Water's LCR sample results for Tier 1 lead service lines and Tier 1 copper piping with lead solder were under the lead action level of 15 parts per billion (ppb). In 2012, Denver Water's LCR sample results exceeded the lead action level. As seen in Figure 5, sample results from homes indicated a monitoring value of 17 ppb for the 90th percentile (meaning that the concentrations of lead were above 15 ppb in more than 10% of the homes tested). This exceedance prompted Denver Water to implement its largest public health education campaign and study options for improving corrosion control treatment. (Note that water testing has demonstrated that corrosion of copper has always been well under the action level for copper, which is 1.3 parts per million.)

FIGURE 5: 90TH PERCENTILE LEAD CONCENTRATIONS BETWEEN 1997 AND 2019



What steps did Denver Water take after exceeding the lead action level in 2012?

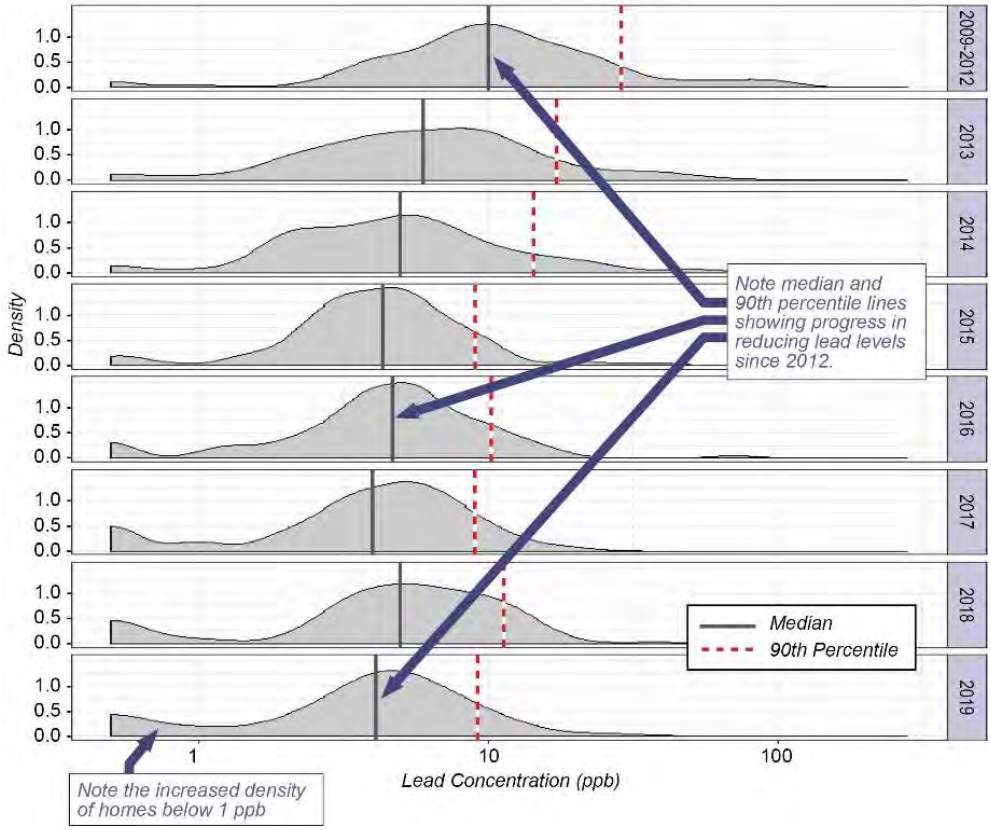
After the 2012 samples exceeded the lead action level, Denver Water implemented a multi-faceted approach to create awareness and protect customers from lead in drinking water, which included:

- Adoption of proactive and ever-adapting communications strategies that included direct customer mailings, bill inserts, sharing information at community gatherings, working with traditional media on coverage of lead issues and social media, including educational and call-to-action posts on Denver Water's Facebook page and messages via Twitter.
- Offer of free lead water quality testing kits to customers.
- A program to replace customer-owned lead service lines when encountered during water main or major road construction work.
- New policies enforcing replacement of lead service lines during building redevelopment.
- A partnership with the Denver Urban Renewal Authority on a pilot program to make low- or no-interest financing available to homeowners to replace their lead service lines.

These changes resulted in the replacement of approximately 1,200 lead service lines per year as compared to the previous rate of approximately 500 per year between 2000 and 2012.

Additionally, as seen in Figure 6, Denver Water has continued to optimize its existing corrosion control system through improved pH and alkalinity monitoring and adjustment at the treatment plants. Denver Water has also made chemical adjustments in the last year to maintain alkalinity levels above 40 mg/L as $CaCO_3$ at all plants and decrease the chloride-to-sulfate mass ratio to further improve corrosion control.

FIGURE 6: LEAD CONCENTRATION DISTRIBUTION FOR HOMES WITH LEAD SERVICE LINES (2009-2019)



Denver Water studied ways to improve corrosion control treatment

In 2013, Denver Water proceeded to examine all possible causes of the 2012 exceedance and was required to conduct a desktop study to identify potential corrosion control changes to plant operations including increasing pH and alkalinity or adding corrosion control inhibitors such as orthophosphate and silicates. The optimal corrosion control treatment from the study concluded that a pH/alkalinity adjustment could result in lead reductions of between 40% and 53%, while orthophosphate would likely reduce lead concentrations between 67% and 76%, depending on water source and temperature. However, the report suggested further studies were necessary to confirm that theoretical calculations could be replicated in a real-life scenario. The report also recommended additional studies to determine the best way to make a water quality change without causing a period of poor water quality and identify the time required for the scales to adapt to the new water quality.

The 2013 desktop study also concluded that:

- Adjusting pH/alkalinity would require higher pH levels, which might impact disinfection by-product formation in the distribution system or cause copper pitting. Copper pitting is not well understood, and Denver Water's chloride levels are on the low end of the range where pitting has shown to be an issue.
- Adding orthophosphate might contribute to increased biological growth in the distribution system and result in the precipitation of phosphate compounds that show up as turbidity in water heaters. Orthophosphate would increase the amount of phosphorus at regional wastewater treatment facilities (loading), which are tasked with removing residual phosphorus prior to discharge. Operating costs would increase not only for Denver Water but also for regional wastewater treatment plants.

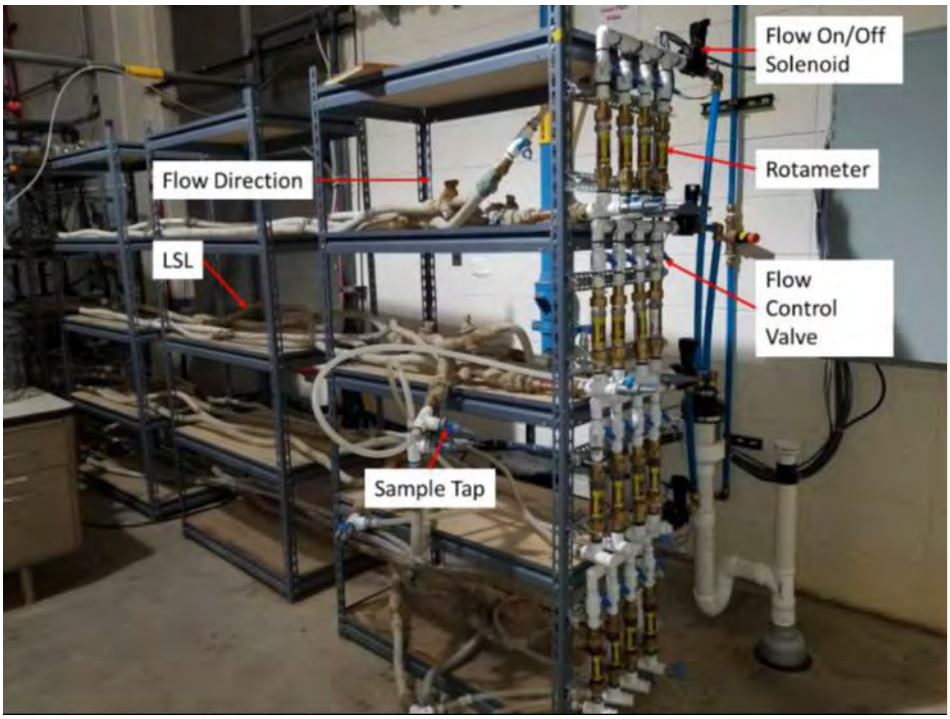
As a result of the 2013 desktop study, Denver Water was required to conduct a corrosion control study. Denver Water collected 32 lead service lines from customers' homes and initiated a pipe rack study using sections of the 32 lines. Figure 7 shows the lead pipe rack at the Marston Treatment Plant. The study included:

- Development of a CDPHE-approved pilot testing protocol.
- Construction and operation of two lead pipe rack pilot skids in 2015 and 2016 to accommodate the two different sources of supply that provide water to Denver Water customers.
- Testing of three forms of corrosion control additives: silicates, pH/alkalinity and orthophosphate.

Dosing for corrosion control began mid-2016 and continued through late 2017 to gather enough data to produce statistically meaningful results. Early in the study, silicates were dropped as an alternative because adding silicates failed to demonstrate significant reductions in lead

concentrations. Variability in the results for individual lead pipe racks would suggest that changes in corrosion control may disturb existing scales for either orthophosphate or pH/alkalinity adjustment; however, in both cases lead concentrations did decrease with time.

FIGURE 7: LEAD PIPE RACK AT THE MARSTON TREATMENT PLANT



The Optimal Corrosion Control Treatment Report was submitted to CDPHE in September 2017, and while the study found that orthophosphate provided greater lead reduction than pH/alkalinity adjustment, as seen in Table 4, Denver Water recommended pH/alkalinity corrosion control treatment due to concerns that orthophosphate would require improvements at downstream wastewater treatment plants to remove the additional phosphorus to meet discharge permit requirements. Furthermore, orthophosphate changes the scale composition on all pipelines in the distribution system, including service lines and household plumbing. Once the phosphate-based scales are formed, Denver Water would likely be committed to adding orthophosphate in perpetuity or until another treatment technique is proven to be as effective as orthophosphate at minimizing lead releases. Discontinuing orthophosphate would cause the pipe scales to dissolve, potentially releasing lead, iron and other metals that are both aesthetic and public health issues.

TABLE 4: SUMMARY OF RESULTS FROM LEAD PIPE RACK STUDY

Pilot Plant Location	pH 8.8	Orthophosphate
Marston Treatment Plant (representing 80% of Denver Water's supply)	Median Reduction: 35% to 51%*	Median Reduction: 66% to 72%*
Moffat Treatment Plant (representing 20% of Denver Water's supply)	Median Reduction: 57% to 72%*	Median Reduction: 64% to 81%*

*Three pipes were dedicated to each treatment type at each pilot plant. The range here represents the low and high results from the three pipes.

CDPHE designated orthophosphate for OCCT in March 2018

On March 20, 2018, CDPHE designated orthophosphate as the optimal corrosion control treatment based on evidence that orthophosphate would reduce lead concentrations at customers' faucets by up to 74%, as compared to 50% using pH/alkalinity adjustment. Per the Lead and Copper Rule as set forth in Regulation 11 of Colorado's Primary Drinking Water Regulations, Denver Water treatment plants must be equipped with and ready to implement orthophosphate by March 20, 2020.

Denver Water proceeded with the design and construction of additional chemical feed systems at each treatment plant to support corrosion control treatment using orthophosphate by March 2020. These systems can also support pH and alkalinity adjustment for corrosion control.

Denver Water pursues an alternative to corrosion control with orthophosphate

In response to concerns about introducing a new source of phosphorus into the watershed and the downstream impacts, Denver Water sought an alternative approach to reduce the risk of lead exposure for its customers. The development of the alternative lead reduction strategy is discussed in Section II.

II. LEAD REDUCTION ALTERNATIVES ANALYSIS

While Denver Water's 2017 study, along with results from other water utilities, demonstrated the effectiveness of orthophosphate in reducing lead exposure, Denver Water and other stakeholders raised concerns about relying on orthophosphate as a long-term treatment strategy, such as:

(1) Detrimental Impacts to the Watershed: orthophosphate would increase phosphorus loading in wastewater, stormwater and regional waterbodies. Phosphorus is a key food source for algae, especially blue-green algae, and these microorganisms compete for the same oxygen in water that other aquatic life, like fish, need to survive. Additionally, algae in large numbers release compounds that cause taste and odor problems in raw water, which are very difficult and expensive to remove and often make potable drinking water unpalatable. On occasion, blue-green algae can grow quickly and release toxins in what are known as harmful algal blooms, as seen in Salem, Toledo, the Great Lakes and the Gulf of Mexico. These toxins are detrimental to aquatic life and humans, impacting recreation and drinking water supplies if local potable water treatment plants are not equipped to remove them.

(2) Long Term Impacts to the Watershed: to avoid upsets in corrosion control, orthophosphate dosing must continue until all known lead service lines are replaced and Denver Water can prove that corrosion control is no longer needed. Denver Water estimates that at the existing rate of 1,200 replacements per year it will take 50 years or more to replace all lead service lines and stop orthophosphate dosing.

(3) Potential Impacts in Drinking Water: the protective coatings begin to dissolve when orthophosphate is turned off. Long-term disruptions (a month or longer) in the supply chain for orthophosphate could result in significant lead releases into the drinking water of homes with lead service lines. Orthophosphate can also increase the likelihood of nitrification occurring in the distribution system, which can lead to an increased formation of disinfection by-products.

Because of these concerns and a commitment to protect public health, Denver Water, along with CDPHE, EPA and other stakeholders, embarked on a process to explore whether alternative approaches might be as or more effective at reducing lead exposure while also reducing the potential adverse impacts associated with orthophosphate.

This section describes the stakeholder process, the alternative studies specific to reducing lead in drinking water and the conclusions derived therefrom. Studies related to the impact of orthophosphate on the environment are described in a white paper released by CDPHE.[2]

[2] See https://www.colorado.gov/pacific/cdphe/OCCT-Stakeholder-Information

The regulatory framework for alternative treatment approaches

The Lead and Copper Rule is based on a treatment technique consisting of four key pillars: public education, source water treatment, lead service line replacement and corrosion control - *Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper*, 56 F4 26460-01, P. 26477 (June 7, 1991). These pillars are highly prescriptive in the sense that the LCR defines specifically when each pillar is triggered and exactly what must be done to fulfill each pillar of the treatment technique. For example, once the lead action level is exceeded, a drinking water provider is required to engage in public education efforts for as long as the lead action level is exceeded. If the lead action level is exceeded after corrosion control treatment has been installed, and the drinking water provider owns the service line, then the drinking water provider is required to begin lead service line replacement in a prescriptive manner. Lead service line replacement activities must continue until the drinking water provider is able to meet the 90th percentile lead action level requirements for two consecutive monitoring periods. In addition, with regard to corrosion control treatment, specific treatment requirements must be studied and the optimal form of treatment must be implemented, with little opportunity to pursue alternative approaches.

For EPA to approve any "alternative treatment technique" under 42 U.S.C. § 300g-4(a)(3), the alternative approach must be "at least as efficient in lowering" lead concentrations:

> The [EPA] Administrator may grant a variance from any treatment technique requirement of a national primary drinking water regulation upon a showing by any person that an alternative treatment technique not included in such requirement *is at least as efficient in lowering the level of the contaminant* with respect to which such requirement was prescribed. A variance under this paragraph shall be conditioned on the use of the alternative treatment technique which is the basis of the variance.

See also 40 C.F.R. § 142.46.[3]

Because Denver Water does not own any part of customers' lead service lines, historically, it has focused on education and optimal corrosion control efforts and was not required to conduct lead service line replacement after the 2012 lead exceedance. The analyses described in the following sections explore alternatives to this approach.

Denver Water's role in the alternatives analysis

In July 2018, Denver Water, CDPHE and regional stakeholders entered into a memorandum of understanding to study alternative approaches to orthophosphate (at 3 mg/L) for lead reduction while assessing impacts to downstream watersheds and utilities. Stakeholders included

[3] Under 40 C.F.R. § 142.46, EPA may approve the variance "whether or not the public water system for which the variance is requested is located in a State which has primary enforcement responsibility…."

representatives from federal and state agencies, member municipalities, utilities, environmental and watershed advocacy groups and Denver Water distributors.

Stakeholders were tasked by executive leaders from CDPHE, Denver Water, Metro Wastewater, Aurora and the Greenway Foundation to "*work collaboratively to seek long-range regional solutions that maintain public trust and protect public health and the environment per the Safe Drinking Water Act and the Clean Water Act, while additionally minimizing impacts to water supplies, wastewater treatment plants, and watersheds.*" Specific areas of interest included:

- **Reducing impacts to downstream wastewater treatment plants.** Sixty percent of Denver Water's supply is reclaimed at Metro Wastewater, Broomfield, South Adams County, South Platte Water Renewal Partners (Littleton/Englewood) and at utilities in the Water Infrastructure and Supply Efficiency or WISE Program. The addition of orthophosphate increases the amount of phosphorus that must be removed during treatment and requires an investment in new infrastructure and/or increased chemical dosing to meet the discharge limits for phosphorus.
- **Reducing impacts to the watershed, stormwater and nearby waterbodies.** Forty percent of Denver Water's supply reaches irrigated areas from as far south as Littleton to as far north as Broomfield. Orthophosphate may require investment in new treatment infrastructure and/or increases in the number and types of management practices needed to reduce the additional phosphorus loading. Alternatives may also include phosphorus offsets, such as banning phosphorus fertilizers, to further reduce the amount of phosphorus in the watershed.
- **Mitigating water quality impacts in distribution systems.** Potential water quality impacts in the distribution system, such as higher disinfection by-product formation or the increased occurrence of nitrification, may be experienced in both Denver Water and its consecutive water systems (Broomfield, South Adams County and East Cherry Creek Valley) that blend Denver Water's treated water with their water supplies.
- **Understanding impacts of transitioning between corrosion control treatment techniques.** Transitioning from orthophosphate to pH/alkalinity and vice versa can disrupt the protective coatings and result in lead releases. Denver Water studied the impact of these transitions to determine the feasibility of implementing a different corrosion control treatment in the future.

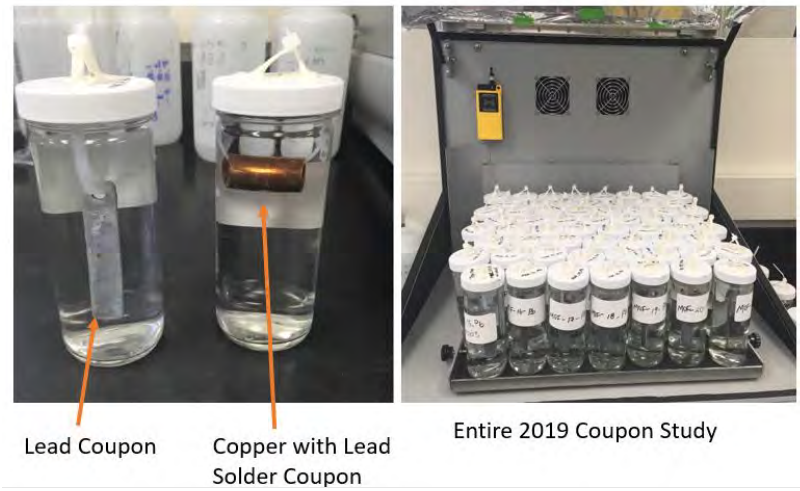
For its part in the alternatives analysis, Denver Water investigated the effects of the following alternative corrosion control strategies:

1) A lower dose of orthophosphate;
2) Higher pH adjustment; and
3) Combined alternatives including accelerating lead service line replacement, a filter program and pH adjustment.

The effects of lower doses of orthophosphate or higher targets for pH adjustment on lead release from lead service lines

As part of the alternatives analysis, Denver Water evaluated whether lower doses of orthophosphate, higher levels of pH or a combination of high pH and very low doses of orthophosphate could achieve an equivalent reduction in lead concentrations as the designated optimal corrosion control treatment (studied at 3 mg/L). To test effectiveness, Denver Water conducted additional pipe rack studies with harvested lead service lines[4] and initiated coupon studies to measure the effectiveness of different corrosion control strategies on lead release.[5] The coupon study arrangement is shown in Figure 8.

FIGURE 8: STUDY OF LEAD RELEASE USING A) LEAD COUPONS AND B) COPPER WITH LEAD SOLDER COUPONS



Denver Water tested lower doses of orthophosphate (2 mg/L, 1 mg/L and 0.5 mg/L) to determine if a lower dose could achieve the same level of lead reduction as the 3 mg/L dose used in the 2017 study. Both the lead pipe rack studies and lead coupon studies concluded that 2 mg/L was the lowest effective dose for orthophosphate, reducing lead concentrations by 74% over the existing corrosion control treatment method using a pH of 7.8 standard units. The 2 mg/L dose equates to a one-third reduction in the amount of phosphorus that would otherwise be contributed to the watershed under a 3 mg/L orthophosphate condition.

Denver Water also evaluated increasing pH to 9.2 standard units as an alternative corrosion control approach. The 2017 lead pipe rack study examined the effect of increasing pH to 8.8 standard units: lead concentrations were reduced 50% more than the existing corrosion control treatment using a pH of 7.8 standard units. At pH 9.2, lead concentrations increased and hard water deposition was observed on plumbing fixtures. Data from downstream utilities and stormwater entities suggested that a pH adjustment of 8.8 has less of a financial impact and does not impact the environment to the same degree as orthophosphate at doses of 1 mg/L or higher.

[4] See Appendix II.B for pilot testing results with the lead pipe racks.
[5] See Appendix III.E.2 for coupon testing results.

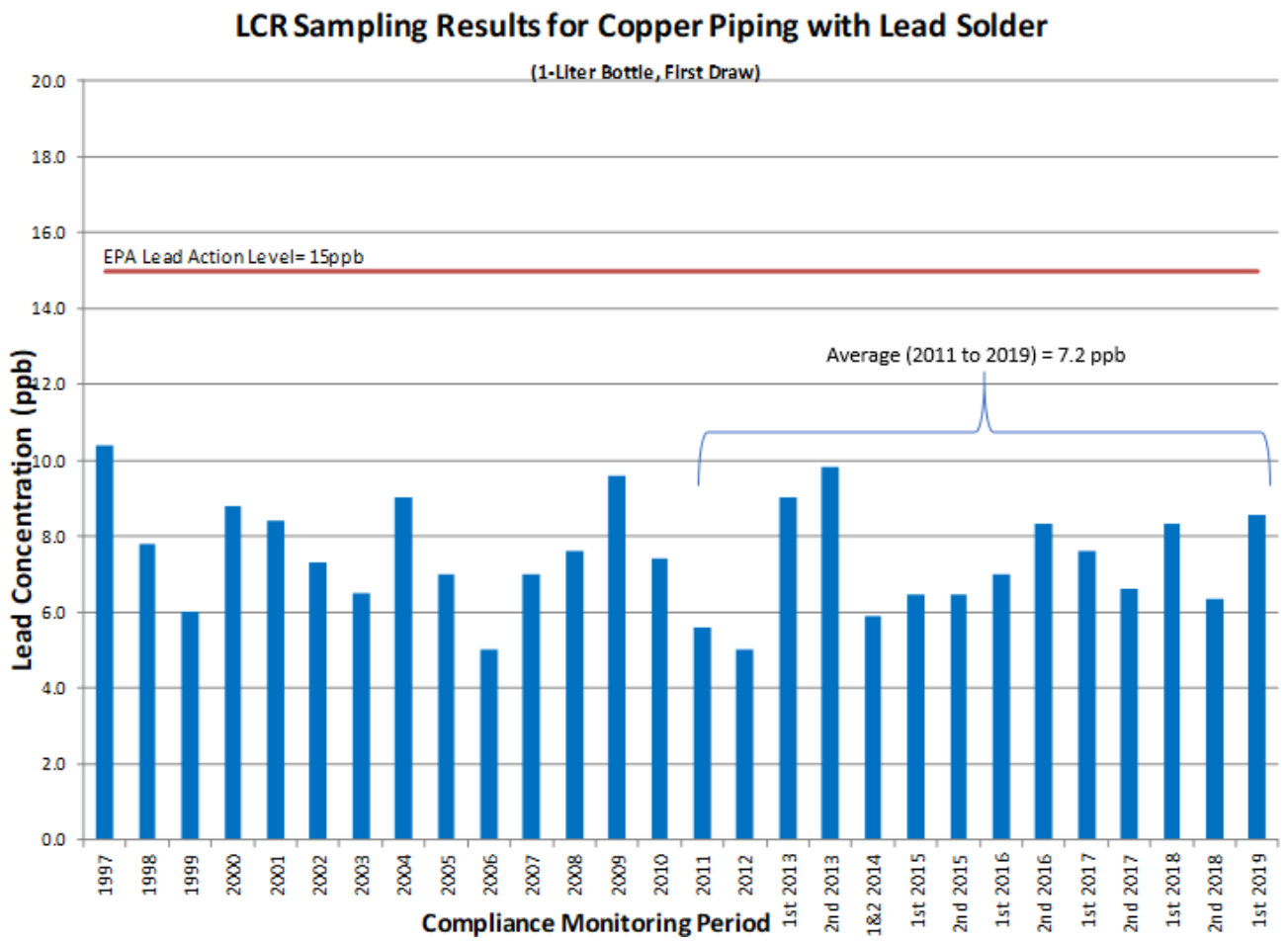
The results from a combined approach, using a high pH (8.8) and a low dose of orthophosphate (0.5 mg/L) also proved to be less effective than orthophosphate alone and was removed from further study. Of all the pH and orthophosphate doses tested, only the 2 mg/L dose proved to be as effective as the previously studied 3 mg/L dose.

The effects of 2 mg/L orthophosphate or pH of 8.8 standard units on copper piping with lead solder

CDPHE and EPA asked Denver Water to demonstrate the effectiveness of both pH/alkalinity adjustment and orthophosphate in reducing lead release from copper pipes with lead solder.

A review of LCR historical data shows that the average of the 90th percentiles for each monitoring period reported between 2011 and 2019 was 7.2 ppb, as shown in Figure 9. Denver Water has never exceeded the action level for copper piping with lead solder.

FIGURE 9: DENVER WATER'S 90TH PERCENTILE LEAD CONCENTRATIONS FOR TIER 1 HOMES (BUILT 1983-1987) WITH COPPER PIPING WITH LEAD SOLDER



Denver Water initiated copper with lead solder coupon testing in March 2019 using water from the supply feeds to the lead pipe racks at the Marston Treatment Plant and Moffat Treatment Plant. This testing was conducted to evaluate the effectiveness of the different corrosion control treatments. Table 5 shows the results from the coupon testing.[6]

TABLE 5: PERCENT REDUCTION IN LEAD AS OBSERVED FROM TESTING WITH COPPER COUPONS WITH LEAD SOLDER

Sample Location	pH 8.8	Orthophosphate (2 mg/L as PO_4)
Marston Treatment Plant (representing 80% of Denver Water's supply)	41% (32% - 61%)	70% (66% - 80%)
Moffat Treatment Plant (representing 20% of Denver Water's supply)	43% (29% - 71%)	68% (54% - 84%)

Using the percent reductions from Table 5 above, Denver Water calculated the following ranges of 90th percentile lead concentrations based on the initial average 90th percentile lead concentration of 7.2 ppb representative of homes built between 1983 and 1987:

- After treatment with orthophosphate: 2.2 to 2.3 ppb.
- After treatment with pH/alkalinity adjustment: 4.1 to 4.2 ppb.

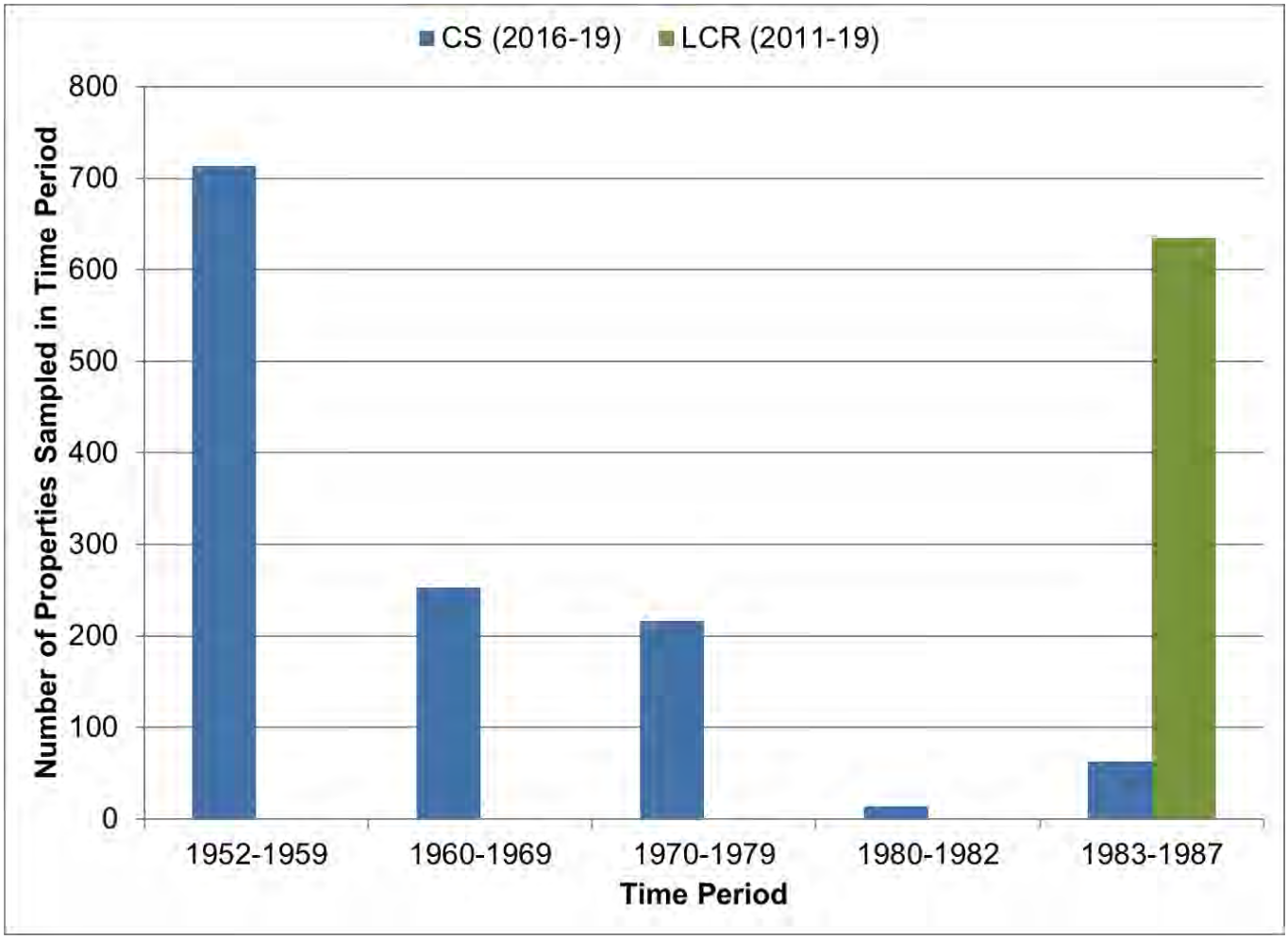
Although orthophosphate demonstrated better lead reduction than pH/alkalinity adjustment, the relative difference in reduction is small when applied to already low levels of lead coming from copper piping with lead solder (an approximately 2 ppb difference).

Is the difference between the two corrosion control treatments meaningful when applied to copper piping with lead solder?

Denver Water applied the percent lead reductions from Table 5 above to 1,831 water quality samples from homes served by copper piping with lead solder. Figure 10 represents the number of samples included in the analysis based on the build date, with blue bars representing customer requested samples and green bars representing LCR compliance samples.

[6] Based on median reduction (interquartile range) between the control and treated samples from the post conditioning phase (weeks 11-17 of the study). A detailed overview of the coupon testing, including results for lead coupons, is presented in Appendix III.E.2.

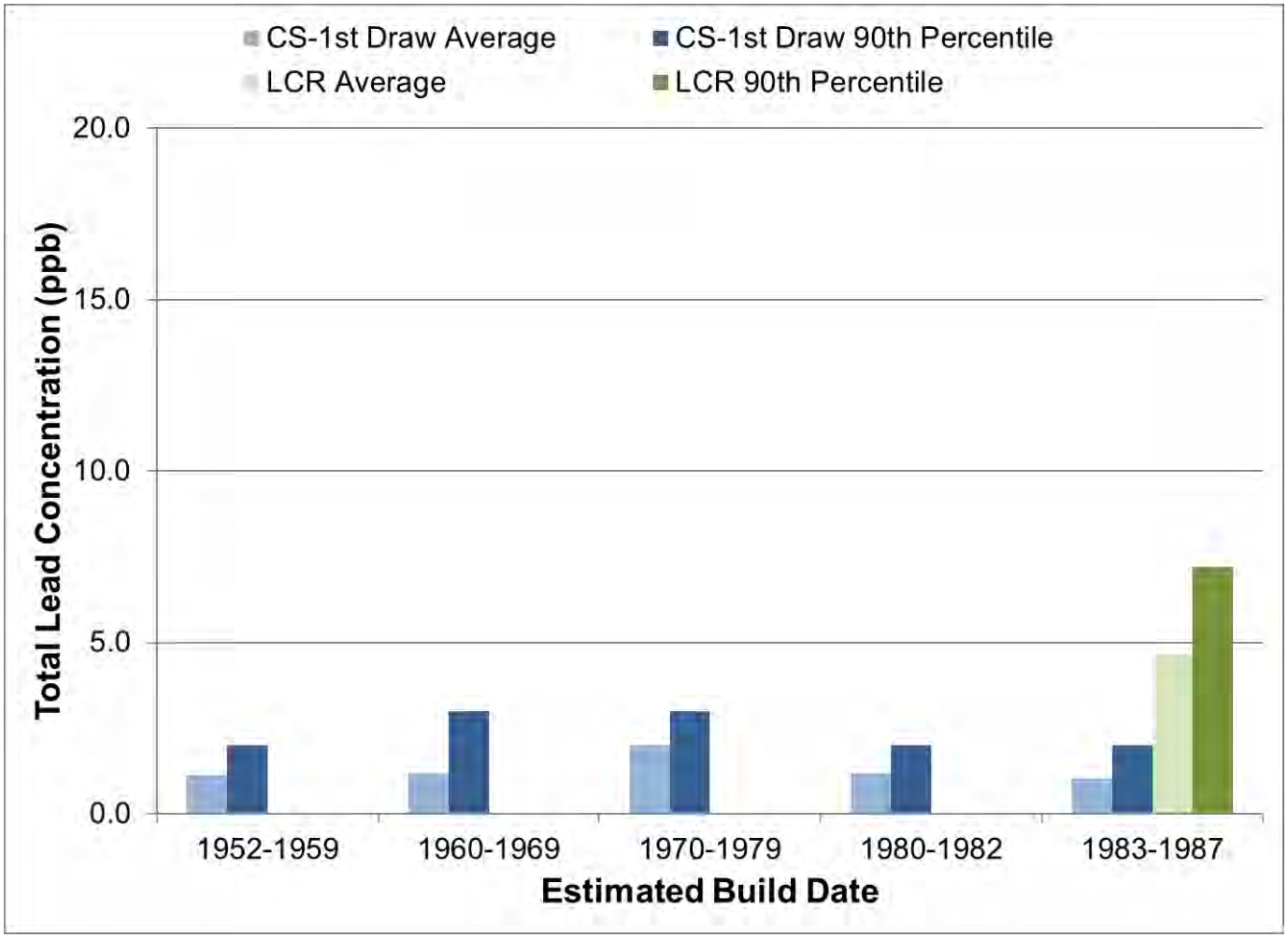
FIGURE 10: DISTRIBUTION OF AVAILABLE WATER QUALITY SAMPLES BY DECADE OF BUILD DATE (COPPER PIPING WITH LEAD SOLDER)



Although Denver Water has data from LCR compliance sampling dating back to 1997, only results from samples collected since 2011 were included in the analysis. Results from sampling prior to 2011 were considered to be less robust: Denver Water may have used different analytical methods with different detection limits, Denver Water's own procedures may have varied, and/or treatment objectives (and the resulting performance) at the three water treatment plants may have changed between 1997 and 2011.

The analysis by decade of lead concentrations measured at homes with copper piping with lead solder are presented in Figure 11. The majority of lead concentrations are relatively low and typically below 5 ppb, although higher lead release (7 ppb) is observed from homes constructed between 1983 and 1987.

FIGURE 11: DECADE ANALYSIS OF LEAD RELEASE FROM COPPER PIPING WITH LEAD SOLDER WITH EXISTING CORROSION TREATMENT



Note: Only results from the first draw from the 3-bottle test (blue bars) are used in Figure 11 due to its similarity with the Lead and Copper Rule sampling protocol for compliance sampling.

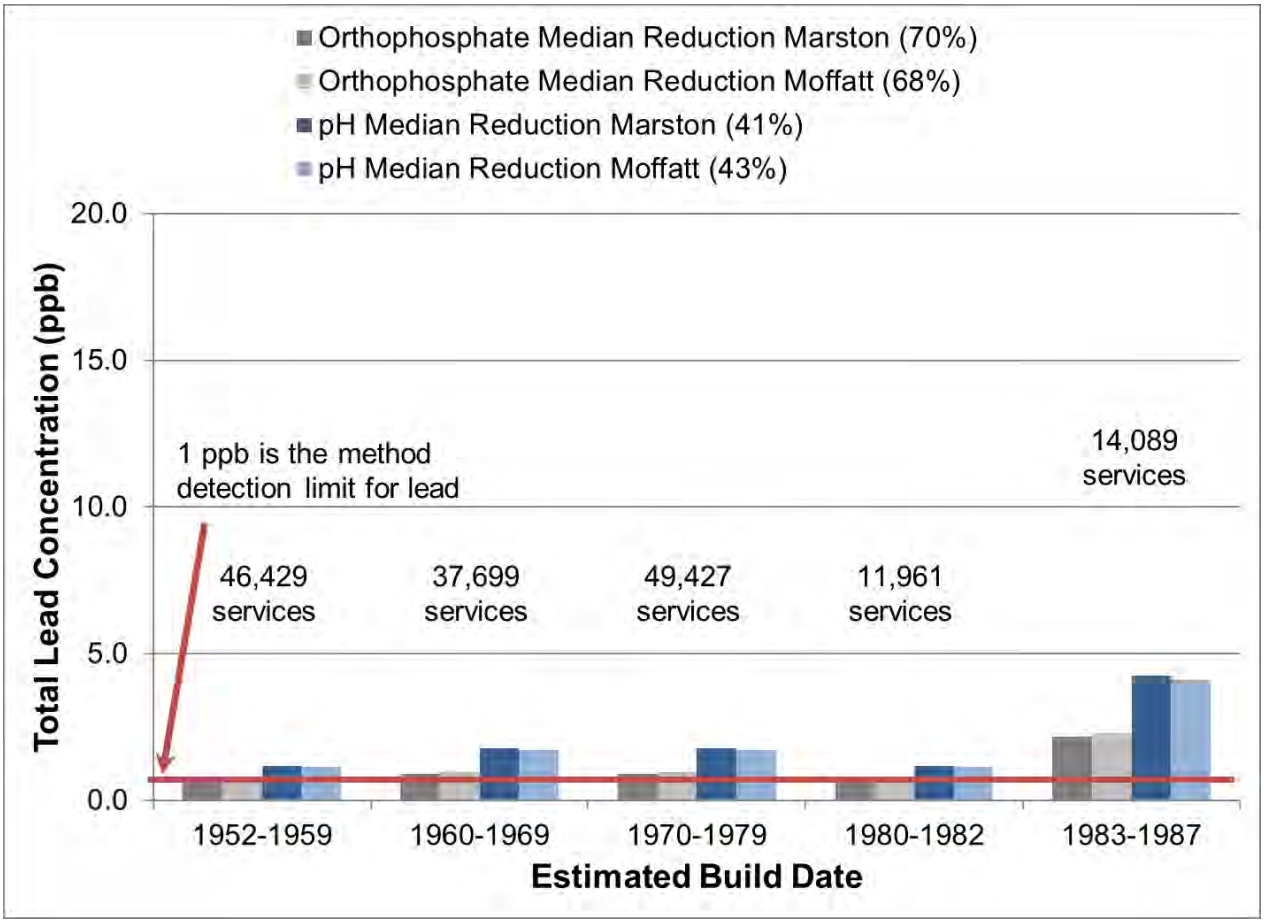
The data included in Figure 11 were reviewed to identify sites where lead concentrations were higher than would be expected from a property with copper piping with lead solder. Potential outliers were identified based on: i) lead above 5 ppb in at least five samples at a property included in the monitoring pool on multiple occasions; or ii) lead above 15 ppb in at last one sample.[7] Some results were clearly outliers (i.e., at one property, one value out of 15 was 100 times higher than all other results at the property) and some properties had results available both before and after lead service line replacement. Approximately 4% of the properties were identified as potential outliers and 1% were considered to have a lead service line and have been added to the lead service line inventory for replacement. Where no obvious explanation could be identified for variable lead results observed, additional field investigations were recommended to confirm the material of the service line (3% of properties).

[7] See Appendix II.C for details.

Regardless of whether a result was an outlier, all results from the 2011 to 2019 LCR compliance sampling set were included in the lead reduction analysis and therefore provide a conservative estimate of lead concentrations at homes constructed between 1983 and 1987.

The lead reduction percentages from the coupon tests from Table 5 were applied to the data included in the decade analysis of all homes with copper piping with lead solder, as seen in Figure 12. In some cases, the lead concentrations are below method detection limits (red line = 1 ppb). The decade analysis demonstrates that more than 45% of all of Denver Water's customers—and most customers served by copper piping with lead solder—will experience very similar lead concentrations whether Denver Water uses pH/alkalinity adjustment or orthophosphate. For the less than 5% of Denver Water properties built from 1983 to 1987, lead concentrations are projected to be less than 5 ppb and the difference in performance between pH adjustment and orthophosphate is approximately 2 ppb.

FIGURE 12: DECADE ANALYSIS OF LEAD RELEASE FROM COPPER PIPING WITH LEAD SOLDER AFTER TREATMENT



According to a Health Impact Partners report on policy making to achieve equity in lead poisoning prevention,[8] a difference of 2 ppb in lead concentration corresponds to a change in

[8] Adapted from the Human Impact Partner's "Achieving Equity in Lead Poisoning Prevention Policy Making: Proceedings from a Consensus Conference," May 2019. See HumanImpact.org/LeadPolicyEquity

blood lead level[9] of less than 0.1 ug/dL. For comparison, the Centers for Disease Control and Prevention defines elevated blood lead level at 5 ug/dL.

Based on the evidence above, Denver Water would assert that the difference in effectiveness of orthophosphate and pH adjustment is not meaningfully different for most customers served by copper piping with lead solder. Because the difference in lead concentrations is slightly greater for homes built from 1983 to 1987, Denver Water has proposed additional measures to reach equivalency, specifically targeted at existing and expecting families with formula-fed infants/children up to age 2. Details about these measures can be found in Sections III.

Effects of a comprehensive strategy to reduce lead concentrations in homes served by lead service lines

Because neither alternative corrosion control approach on its own (pH adjustment or orthophosphate) achieved the equivalency for reduction in lead concentrations while also reducing adverse impacts to downstream wastewater treatment plants and watersheds, Denver Water evaluated other strategies to achieve an equivalent or better reduction in lead exposure as the designated optimal corrosion control treatment.

This evaluation was prompted by CDPHE and EPA's request to provide an effective and comprehensive solution to protect individual customers as well as the population as a whole. Denver Water evaluated coupling pH adjustment with lead service line replacement, interim filter distribution and public education to meet this challenge. Below is a summary of the individual studies that supported the final recommendation and request for variance for the holistic approach.

Sources of lead

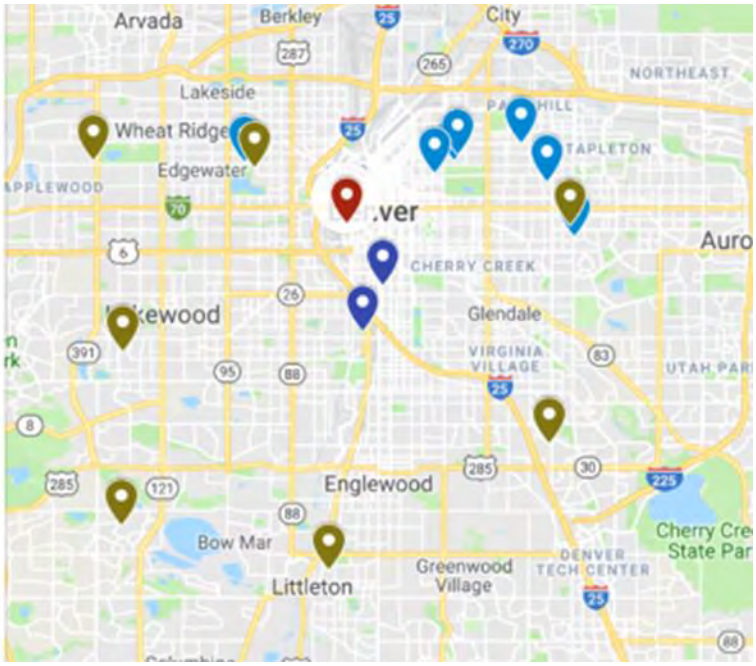
In conducting the studies, Denver Water had to determine the relative contributions of lead from lead service lines as compared with other sources, such as copper piping with lead solder and premise plumbing. In 2018 and 2019, Denver Water sampled water from volunteer Denver Water employee households to generate lead concentration profiles extending from the sink out to the water main in the street. Following EPA protocols, more than 20 sequential sample bottles of different sizes (from 125 mL to 1 L) were used in the sampling protocol.

In the initial round of sampling, Denver Water collected data from ten homes with known lead service lines; seven of these were sampled in subsequent rounds (see Figure 13). For comparison, lead profiles were also generated for eight homes with known copper piping with lead solder, with six homes being included in subsequent rounds of profiling. Customers self-selected whether to remain in the study for each subsequent sampling round. The water samples from these homes are representative of different neighborhoods within Denver Water's service area.

[9] The concentration of lead (in micrograms) in blood (deciliters), ug/dL, is used to quantify blood lead level.

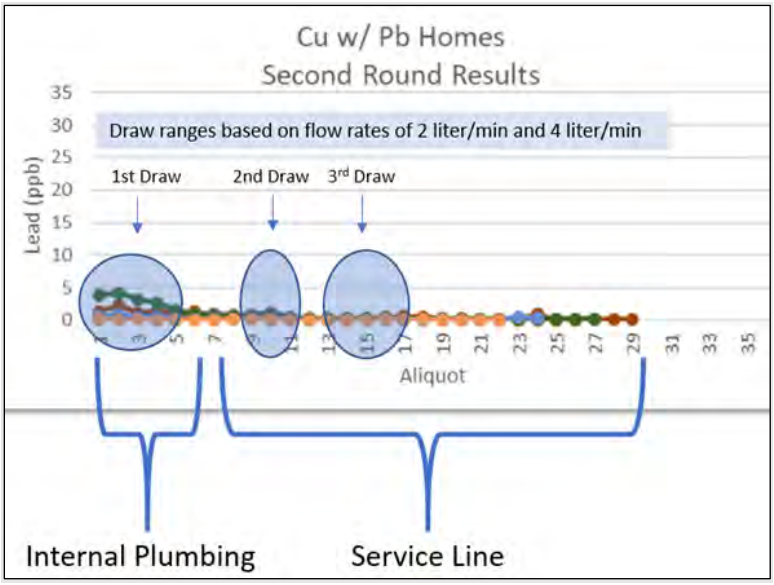
FIGURE 13: HOUSEHOLDS FROM ACROSS THE DENVER WATER SYSTEM INCLUDED IN PROFILE SAMPLING

(Blue denotes households with a known lead service line and green denotes households with a known copper piping with lead solder as included in the first round of sampling in 2019)



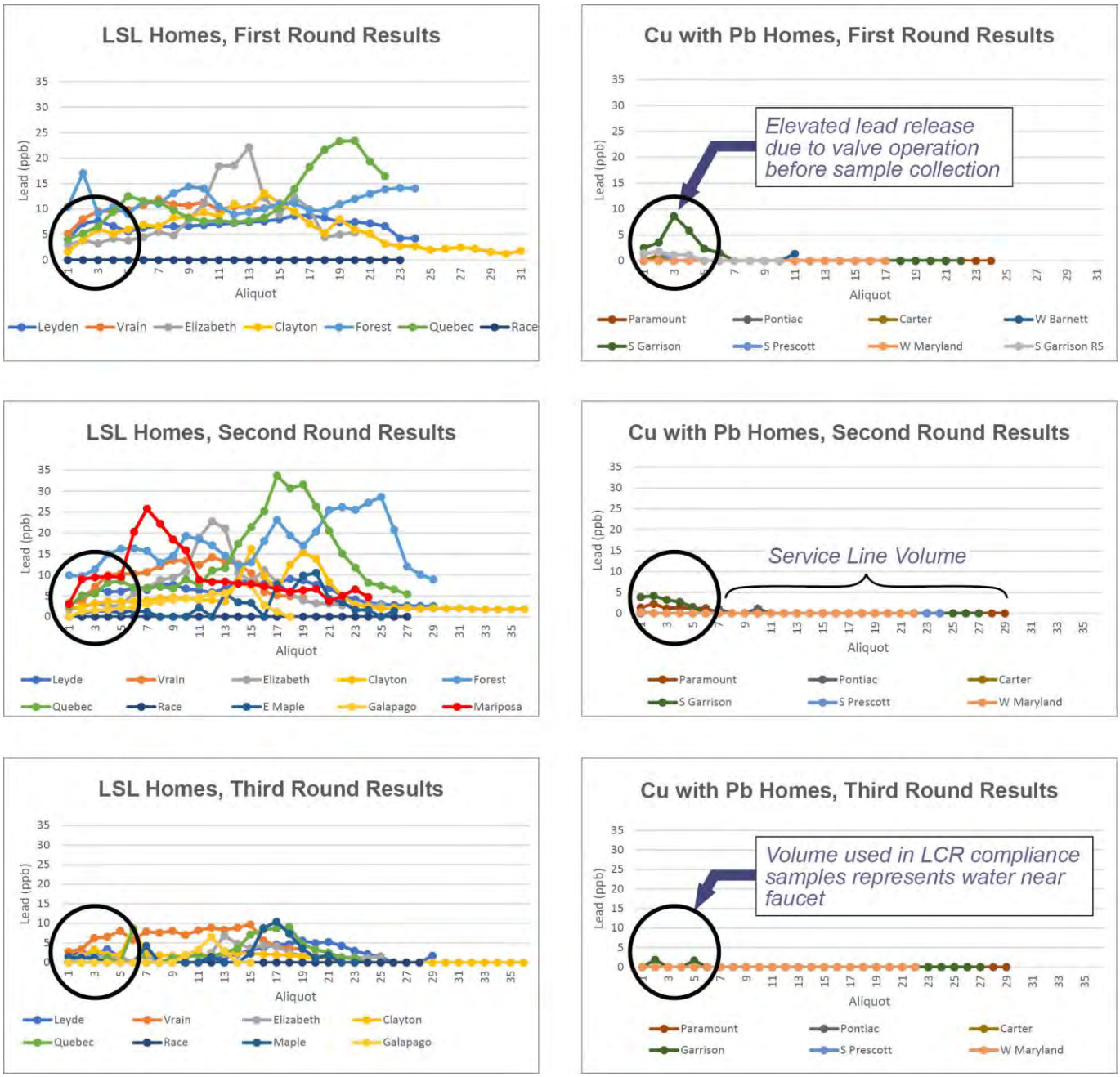
Results of this analysis show a higher concentration of lead in homes with lead service lines across the length of the profile (sink to water main). At households with verified copper piping with lead solder, lead release is typically characterized by a small increase in lead concentrations closest to the sink faucet, followed by a decrease to non-detect lead concentrations shortly thereafter, as shown in Figure 14.

FIGURE 14: LEAD PROFILE FROM SINK FAUCET TO WATER MAIN



Side-by-side results from the three rounds of lead profile sampling are shown in Figure 15; the lead concentration profiles of households with lead service lines are shown in the graphs on the left and the profiles of households with copper piping with lead solder are shown in the graphs on the right.

FIGURE 15: LEAD PROFILE RESULTS FROM VOLUNTEER DENVER WATER HOUSEHOLDS
(Lead service lines on the left, copper piping with lead solder on the right)



Results from profile testing at homes with copper piping with lead solder, as shown in the right column of Figure 15, demonstrate that lead concentrations are consistently maintained below 5 ppb and near non-detect levels with the existing corrosion control treatment. Simple flushing in the morning or after getting home from work or school would remove most of the lead captured during the sampling of water from these homes.[10]

Evaluation of the benefits of lead service line replacement

After the single exceedance of the action level for lead in 2012, Denver Water offered free water quality testing to all Denver Water users and more than 3,000 samples have been returned and analyzed since then. See Figure 16 for an overview of the 3-bottle sampling kit used by Denver Water.

FIGURE 16: DENVER WATER'S 3-BOTTLE SAMPLING KIT

Denver Water's 3-Bottle Sampling Protocol
Three 1 L water quality samples (i.e., 1st, 2nd and 3rd draw) were collected before and after lead service line replacement to provide insight into lead release from the faucet to the service line. Customers receive a sample kit with three 1 L bottles and are asked to sample from a cold-water faucet in a bathroom or sink that is not connected to a home water treatment system. Customers must avoid using water for a minimum 6-hour stagnation period before collecting samples. After the stagnation period, the customer turns on the cold water faucet and fills up the first bottle, allows the water to run for 30 seconds, fills up the second bottle, allows the water to run for 30 seconds and fills the third bottle. Results indicate the relative contribution to lead measured at the faucet from fixtures, in home plumbing and the service line. Per Figure 14, the first bottle captures water from internal plumbing and the second and third bottle capture water from the service line. Over 3,000 households have participated in the customer requested water quality sampling program. Denver Water offers water quality sampling for lead for free to all Denver Water households, visit: denverwater.org if you would like to participate.

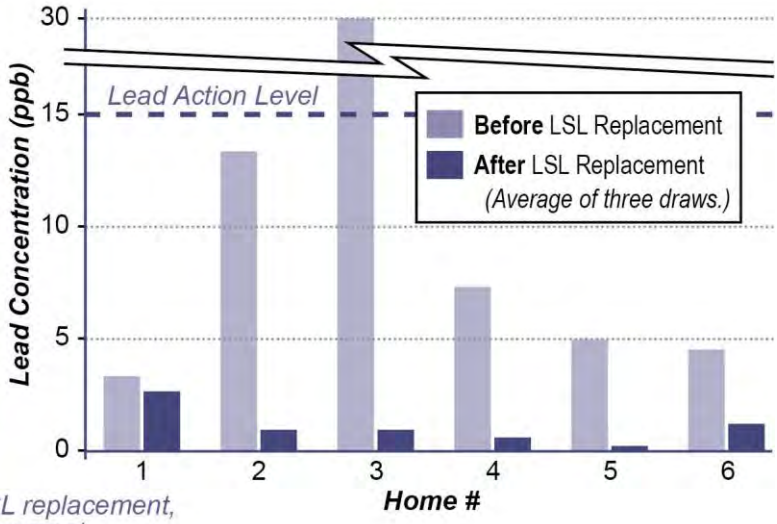
Six of the households who had previously sampled their water subsequently replaced their lead service lines between 2016 and 2018 with non-lead lines and followed up with recommended water sampling. A comparison of the before and after water quality results allowed Denver Water

[10] Information on the profiling study can be found in Appendix III.E.1.

to evaluate the impact of lead service line replacement on reducing lead concentrations. The results in Figure 17 demonstrate the potential public health benefit of permanently removing the dominant source of lead contributing to drinking water: lead was measured at 2.2 ppb or lower after lead service line replacement, regardless of the lead concentrations before replacement, which were measured as high as 30 ppb. These results align with the lead profile testing results in demonstrating the benefit of replacing lead service lines.

FIGURE 17: LEAD REDUCTION AFTER LSL REPLACEMENT MEASURED AT SIX HOUSEHOLDS

Home #	Before LSL Replacement			After LSL Replacement		
	1st Draw	2nd Draw	3rd Draw	1st Draw	2nd Draw	3rd Draw
1	5	0	5	5.1	1.3	0.2
2	9	14	30	3	0	0
3	29	31	30	1	1	1
4	8	12	2	2	0	0
5	2	2	11	1	0	0
6	3.5	5.3	5.7	2	2	0
Avg.	9.4	10.7	14.0	2.4	0.7	0.2



Lead is reduced to near non-detect levels after LSL replacement, regardless of the lead measured before LSL replacement.

Evaluation of a Filter Program

Although the replacement of lead service lines provides significant and permanent reductions in lead concentrations, it may take several years to remove all lead service lines. CDPHE was concerned about the customers who would not receive a lead service line replacement until year 10 or 15, for example. During that time, these customers would be subject to higher levels of lead with Denver Water's use of pH/alkalinity adjustment versus orthophosphate. Hence, filters were added to the LRP approach.

Filters can provide immediate protection from lead in drinking water when properly used and cartridges are replaced. They can also provide an interim barrier to remove lead from a customer's drinking water until the presence or absence of a lead service line can be confirmed. Pitcher filters can remove more than 97% of lead from drinking water.[11] At the same time, filters are only effective to the extent they are used.

To evaluate the potential filter adoption rate, Denver Water reviewed results from a past study of filter use by its customers. Based on a 2017 customer survey (1,432 responses) by Denver Water, 54% of customers reported that their households typically drink unfiltered tap water, 37% of respondents used filters (the type of filter used was not confirmed) and 9% drank bottled water regularly.

[11] See Appendix III.C.2.

More recently, in July 2019 Denver Water conducted a Filter Pilot Program of 300 customers with known or suspected lead service lines. Participants were surveyed two weeks after receiving a pitcher filter.[12] Based on lessons learned from the pilot, Denver Water will include the following steps as part of the full-scale Filter Program:

1. Provide advance targeted communications, outreach and education prior to filter distribution to introduce the Filter Program and explain the importance of filter use.
2. Reinforce the importance of using the filter for cooking and infant formula preparation, in addition to drinking water.
3. Inform participants that the filters and replacement cartridges are provided at no cost to the customer for the duration of the program.
4. Explore alternative filter types.

Participants of the Filter Pilot Program were randomly selected in seven neighborhoods that are representative of the general Denver Water customer population. The participants included a range of income levels and a mix of English-speaking and Spanish-speaking households. All household in the Filter Pilot Program were asked to complete a filter use survey and by August 13, 2019, 27% of all participants had completed the survey. Of the surveys completed, 13% were completed in Spanish. Filter use survey responses indicated a 91% filter adoption rate for drinking water and a 60% filter adoption rate for cooking.

Evaluation of comprehensive approach: pH/Alkalinity adjustment combined with accelerated lead service replacement and Filter Program

Based on the analysis of alternative corrosion control treatments and exploration of other strategies to reduce lead exposure, a multi-faceted approach that includes corrosion control using pH/alkalinity adjustment, the accelerated replacement of customer-owned lead service lines within 15 years and a Filter Program, which will provide immediate protection will offer the highest public health benefit in both the short and long term. This approach is the foundation for the Lead Reduction Program.

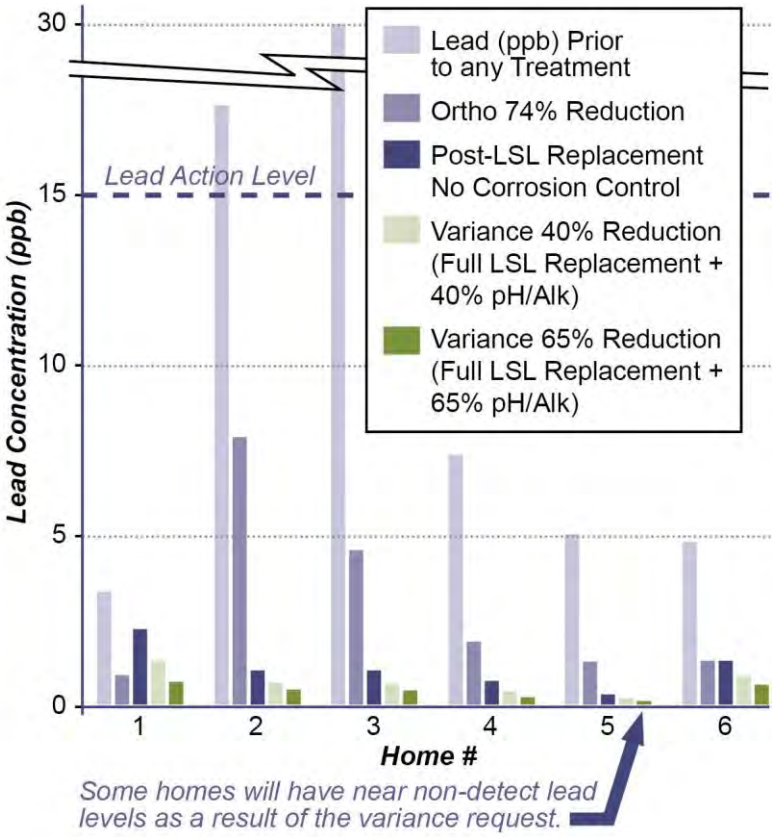
As shown in Figure 18, in the long-run, replacing lead service lines and adjusting the pH/alkalinity of the water will be far more effective at reducing lead exposure compared with continued treatment with orthophosphate. For the six households sampled, lead concentrations are predicted to be less than 5 ppb with the variance alternative.

[12] The Filter Pilot and survey are described in Appendix III.C.2

FIGURE 18: EXPECTED LEAD CONCENTRATIONS UNDER ORTHOPHOSPHATE AS COMPARED TO THE VARIANCE APPROACH AT SIX HOUSEHOLDS WITH A LEAD SERVICE LINE

Home #	Lead (ppb) Prior to any Treatment	Lead (ppb) After Treatment			
		Orthophosphate 74% Reduction	Post-LSL Replacement No Corrosion Control	Variance 40% Reduction (Full LSL Replacement + 40% pH/Alk)	Variance 65% Reduction (Full LSL Replacement + 65% pH/Alk)
1	3.3	0.9	2.2	1.3	0.8
2	17.7	4.6	1.0	0.6	0.4
3	30.0	7.8	1.0	0.6	0.4
4	7.3	1.9	0.7	0.4	0.2
5	5.0	1.3	0.3	0.2	0.1
6	4.8	1.3	1.3	0.8	0.5
Avg.	11.4	5.0	1.1	0.7	0.4

Based on actual sample test results pre- and post-LSL replacement, using the average of the three bottles collected from each home.



Evaluation of lead concentrations in water for households that do not adopt filters

Until the lead service line can be replaced, all customers with known, suspected or possible lead service lines will be given a filter that is NSF-certified to remove lead. If a household does not use a filter to remove lead for drinking and cooking, the household will still receive the benefit of a 40% to 65% reduction in lead concentrations from pH/alkalinity adjustment (yellow columns in Table 6) but will not benefit from the 97% reduction provided by the filters (purple column in Table 6). The success of the Lead Reduction Program depends on the cooperation of the customer, particularly during the period when all known lead service lines are being replaced. Without the interim use of filters until the lead service line can be replaced, the orthophosphate alternative will outperform the Lead Reduction Program for that home. The number of customers required to use filters to achieve equivalent performance to orthophosphate alone is discussed in Section III; however, Denver Water will strive for 100% filter adoption to reduce lead exposure for all customers with a known, suspected or possible lead service line.

TABLE 6: COMPARISON BETWEEN FILTER USE AND PH/ALKALINITY ADJUSTMENT DURING THE VARIANCE TERM (2020 TO 2034) AT SIX HOUSEHOLDS

Homes that use a filter (purple column) and homes that do not use a filter (yellow columns)
(The lead service line has not been replaced in either scenario)

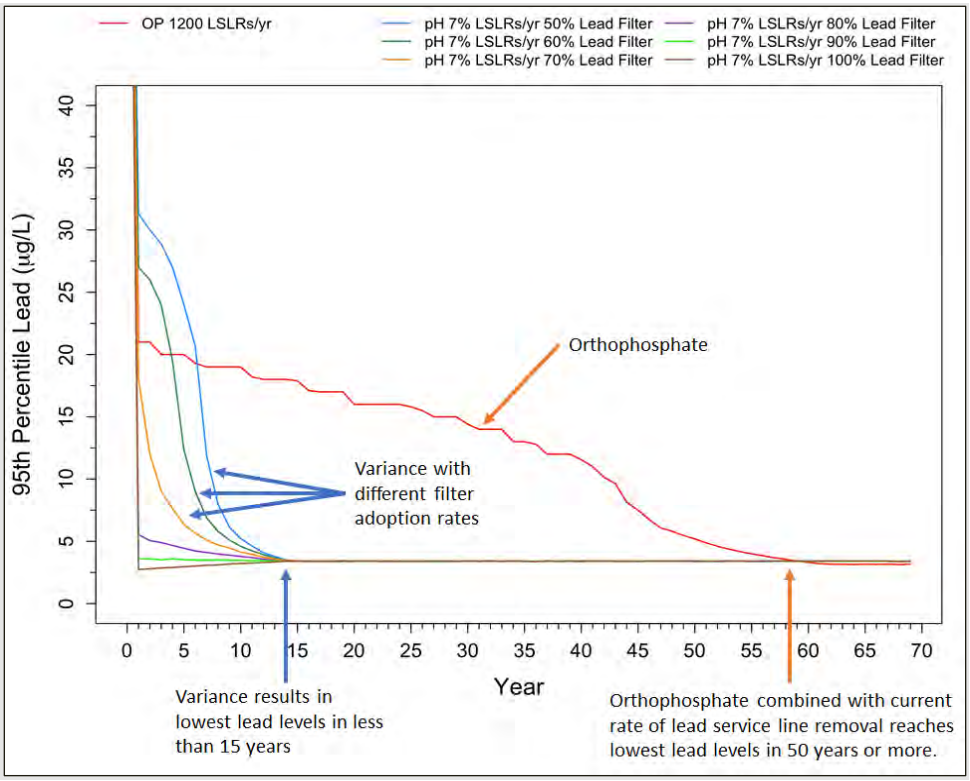
Household Number	Lead (ppb) Prior to Any Treatment Pre-LSLR*	Lead (ppb) After pH/Alkalinity Treatment with and without Filter prior to lead service line replacement		
		Filter** 97% Reduction	Variance 40% Reduction no filter/no LSLR	Variance 65% Reduction no filter/no LSLR
1	3.3	0.1	2.0	1.2
2	17.7	0.5	10.6	6.2
3	30.0	0.9	18.0	10.5
4	7.3	0	4.4	2.6
5	5.0	0	3.0	1.8
6	4.8	0	2.9	1.7
Average	11.4	0.3	6.8	4.0

An equivalency model was developed to compare orthophosphate and the variance alternative on lead exposure to all Denver Water customers. The model conservatively estimates lead concentrations using data from LCR and customer inquiry sampling, the lead service line pipe rack study and the copper with lead solder coupon study to predict lead concentrations at all connections in the Denver Water service area every year.

The equivalency model was used to evaluate the effectiveness of different filter adoption rates combined with other variance elements in reducing lead exposure as compared to orthophosphate, as shown in Figure 19.[13] The model does not do any averaging, but in order to display the model results in a digestible way, Figure 19 shows the 95th percentile lead concentration for all service lines in the Denver Water service area, including lead, copper and non-lead materials.[14] The y-axis scale of Figure 19 is adjusted for clarity. As a result, the lead concentrations for year 0 (existing condition) are not shown, and all the modeled scenarios begin at about 90 ppb. Based on this analysis, Denver Water must increase the filter adoption rate for customers with known, suspected and possible lead service lines from 37% (2017 survey) to 65% to provide equivalent protection when used in combination with accelerated lead service line replacement and pH/alkalinity adjustment. Denver Water will strive for 100% filter adoption using lessons learned from other large-scale lead reduction programs.[15]

[13] For a description of the equivalency model see Appendix II.A.
[14] Full results are available in Appendix II.A.
[15] See Appendix III.C.3.

FIGURE 19: PROJECTED LEAD CONCENTRATIONS (95TH PERCENTILE) COMPARING ORTHOPHOSPHATE (RED LINE) WITH DENVER WATER'S PROPOSED VARIANCE APPROACH (ALL OTHER COLORED LINES)



Final evaluation of the expected results of the Lead Reduction Program

Another way to compare the performance of the Lead Reduction Program (using pH or filters, before the lead service line is replaced) to orthophosphate is to evaluate the expected 90th percentile lead concentrations. The following four scenarios based on service line material and filter adoption were considered (see Table 7):

- Property with a lead service line and using a filter for drinking and cooking.
- Property with a lead service line and not using a filter.
- Property with copper piping with lead solder.
- All other properties with no lead service line and no lead solder.

Using results from pipe rack testing, lead concentrations in drinking water for customers who use filters are expected to decrease to non-detect levels. Customers who have lead service lines and do not use filters will experience a reduction in lead concentrations due to pH/alkalinity adjustment of approximately 50%, reducing 90th percentile lead concentrations to 7 ppb.

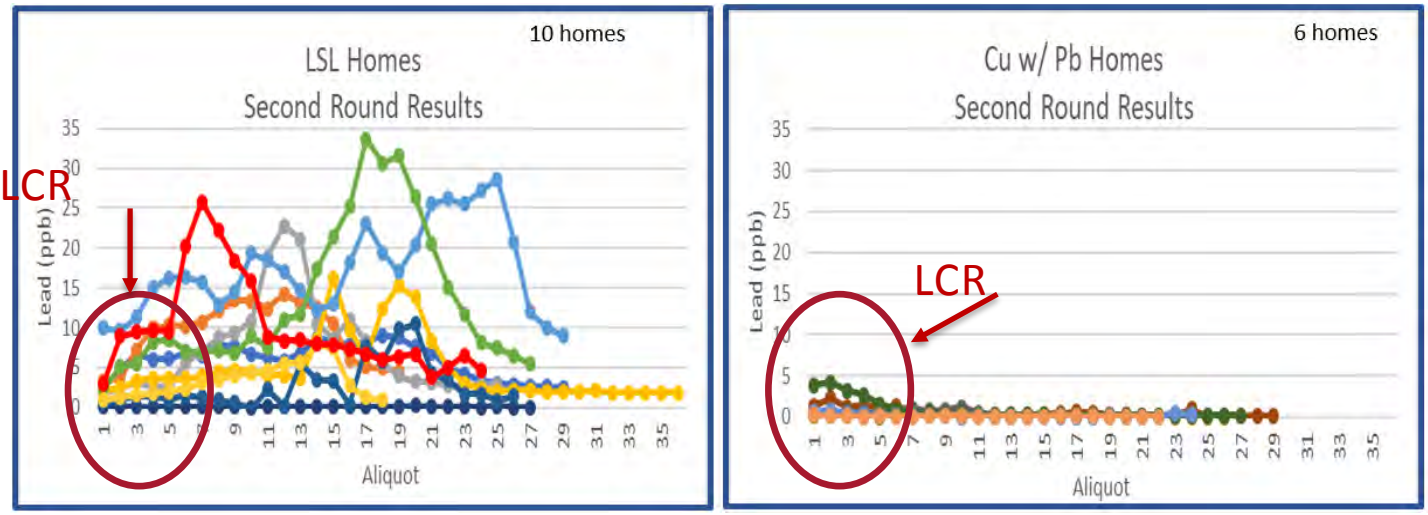
TABLE 7: ESTIMATED 90TH PERCENTILE LCR LEAD CONCENTRATIONS AS A FUNCTION OF SERVICE LINE TYPE

Scenario	Estimated 90th Percentile Lead Concentration			
	LSL + Filter	LSL no Filter	Lead Solder	Non-lead**
Number of Services	63,955		159,605	96,140
Historic LCR Lead Concentration	14.0		7.2	3.0
Lead Concentration with pH/Alkalinity (ppb)*	< 1	7.0	4.1 - 4.2	1.7 - 1.8
Lead Concentration with Orthophosphate (ppb)*	N/A	3.6	2.2 - 2.4	0.9 – 1.0

*Based on percent lead reduction observed from pipe rack testing of 50% for pH/alkalinity adjustment and 74% for orthophosphate (per March 2018 designation for optimal corrosion control treatment by CDPHE).
**LCR does not apply to non-lead service lines.
N/A = not applicable

For the approximately 160,000 customers in homes built from 1952 to 1987 with copper piping with lead solder, 90th percentile lead concentrations in the first liter of water are expected to range from non-detect to 4.2 ppb with pH/alkalinity adjustment where the occupants do not flush their water line before using water for drinking, cooking and formula preparation. Lead concentrations in the subsequent liters of water will drop to near non-detect levels based on existing data, as presented in Figure 20. Lead concentrations in all other non-lead service lines are expected to be near non-detect levels under either pH/alkalinity or orthophosphate application.

FIGURE 20: PROFILING DATA FOR COMPARISON TO LCR SAMPLING PROTOCOL WITH FIRST LITER



While the expected lead concentration results are low in the pH/alkalinity and orthophosphate approaches, the historic lead concentrations assumed for the initial concentration may not be the best representation of the lead exposure to Denver Water customers. Data from profiling indicate that the first draw sample underestimates the lead released from lead service lines and overestimates the lead released from copper piping with lead solder, as shown in Figure 19. To confirm this observation, data available from customer requested sampling from homes constructed between 1952 and 1987 with copper piping with lead solder were analyzed to understand typical lead concentrations in each bottle or draw included in the 3-bottle test. Results are shown in Table 8 and demonstrate that there is very little lead measured in the second and third draws from lead solder homes. This also supports the hypothesis that the bulk of the lead exposure comes from the estimated 63,955 lead service lines and not the estimated 159,605 copper pipes with lead solder. Lead service line replacement provides a multi-generational benefit of significantly reduced lead exposure to Denver Water customers.

TABLE 8: LEAD CONCENTRATIONS MEASURED IN CUSTOMER SAMPLES OBTAINED FROM HOMES WITH LEAD SOLDER BY BUILD DATE

Decade of Home Construction	Customer Requested Sampling 3-Bottle Test		
	90th Percentile Lead (ppb)		
	1st Draw	2nd Draw	3rd Draw
1952-1959	2.00	0.50	0.50
1960-1969	3.00	0.50	0.50
1970-1979	3.00	1.50	0.50
1980-1982	2.00	1.16	0.50
1983-1987	2.00	0.50	0.50

Conclusions

In summary, Denver Water evaluated three different approaches separately and combined, to determine if they provide equivalent public health protection when compared with orthophosphate added to drinking water at 2 mg/L. The studies show that the comprehensive approach of accelerated lead service line replacement, filter distribution and pH/alkalinity adjustment will be more efficient at reducing lead releases compared with the use of orthophosphate alone while reducing impacts to wastewater treatment plants and the environment.

III. PROPOSED LEAD REDUCTION PROGRAM

The proposed Lead Reduction Program is a holistic and permanent lead reduction approach that will reduce lead concentrations to under 5 ppb and near non-detect levels in less than 15 years. The LRP is generally more effective at reducing lead exposure than adding orthophosphate to Denver Water's drinking water and will protect public health and the environment. The essential elements of the program are:

- Execution of a **communications, outreach and education program** to help customers understand the program and ways they can reduce their exposure to lead.
- Creation of a **lead service line inventory** to inform the accelerated replacement of LSLs and to allow customers to investigate the likelihood of having an LSL.
- Implementation of a **lead removal filter program** to all homes with known, suspected or possible LSLs, reducing lead by 97%.
- Implementation of an **accelerated lead service line replacement program** that would remove the major source of lead decades ahead of the current rate of replacement (approximately 63,955 lead service lines within 15 years versus 50 years or more under current practices).
- Adjustment of pH and alkalinity for **corrosion control treatment** to reduce corrosion of lead service lines, household plumbing and fixtures.

The following sections describe how each of these LRP elements will be implemented.

III.A Communications, Outreach and Education Plans

Communications, outreach and education are the critical foundation for successful implementation of the LRP. As recognized by the EPA when adopting the Lead and Copper Rule in 1991, "the more frequently an individual is provided with information on lead in drinking water, the more likely he or she will take some action to reduce his or her exposure." 56 FR 26460-01, 26501 (June 7, 1991).

In addition to ongoing efforts since 2012, Denver Water has been working with regional community networks to begin the communications, outreach and education program during the summer of 2019. During this time, Denver Water informed and engaged the public on the variance process, including the broader topic of lead in drinking water, and supported the pilot Filter Program. Lessons learned during this initial phase will be used to inform the communications, outreach and education programs that will go into effect in 2019 or early 2020.

Detailed communications and outreach plans for the pre-variance phase laid the foundation for

Denver Water has a youth education program that reaches thousands of local families and Denver youth by directly engaging with schools in the area every year.

As a part of the communications, outreach and education efforts, Denver Water has tested more than 15,000 samples of water from schools within its service area for lead and is working with the school districts on their remediation efforts.

the development of future communications and outreach plans. Objectives and strategies for the LRP, including each of its elements, are outlined in the following sections.

COE objectives and strategies:

The overarching goals for communications will be to scale up education and outreach efforts to achieve the following:[16]

- Inform customers and stakeholders of EPA's final decision.
- Raise awareness among all customers of the change and its impacts.
- Emphasize the outcome of implementation of the LRP, namely improved water quality and reduced risk of exposure to lead in drinking water for those with lead service lines and plumbing.
- Provide clear and consistent messaging and branding.

Upon approval of the variance, Denver Water will further aim to:

- Build a platform for communitywide education and engagement regarding the Lead Reduction Program that includes communications and outreach and gathers feedback to improve the program as it moves forward.
- Facilitate training for contractors, employees and vendors to educate these groups on where to direct customer inquiries and to support consistent communications on the program.
- Provide clear, accurate and timely information and messaging about the Lead Reduction Program to target audiences.
- Educate and engage with customers, residents, families and communities in order to create a common understanding of and instill confidence in the Lead Reduction Program.
- Support a specific communications, outreach and education program targeted at expecting and existing families with formula-fed infants/children up to age 2 living in homes with copper piping with lead solder built 1983-1987.
- Educate customers to encourage consistent, proper and ongoing filter usage, and develop materials that easily demonstrate how to use the filters.
- Encourage customers to consider in-home plumbing updates.
- Encourage customers to flush the tap before drinking, cooking or preparing infant formula after prolonged periods during which water is not used, such as first thing in the morning or when returning home from work or school.
- Seek feedback from customers and others about the Lead Reduction Program to learn best practices and effective ways to implement program activities.
- Incorporate the Learning by Doing approach to improve outcomes during the life of the Lead Reduction Program.

[16] For further details regarding the COE Plans, see Appendix III.A.

Detailed communications plans will be developed for each element of the LRP: the Lead Service Line Inventory, the Filter Program, the Accelerated Lead Service Line Replacement Program and Corrosion Control Treatment. The communications plans will include an analysis of target audiences; key messaging developed in tandem with CDPHE and EPA to inform all core communications collateral and materials; and training and resources for Denver Water employees and contractors, with an emphasis on those who interact directly with customers.

Lead Service Line Inventory objectives and strategies:

The LSL Inventory is an inventory of lead service lines in Denver Water's service area, which will inform the ALSLR Program. The LSL Inventory will be regularly updated over the 15-year period of the LRP.

The communications plan for the LSL Inventory will have the following objectives:

- Inform and educate customers about their service lines – ownership, material types and plumbing.
- Engage distributors to assess lead services lines within Denver Water's integrated system.
- Work with municipalities to develop better records regarding service line material.

Denver Water employees and contractors working to educate and inform customers, assist customers with inquiries and collect data for the LSL Inventory will follow the LSL Inventory communications plan. The plan will include a variety of communications methods to reach targeted audiences, including direct mail marketing and outreach, mapping tools, water quality tests, websites with links to educational information about LSL verification methods and training resources for plumbers.

Filter Program objectives and strategies:

The Filter Program will provide filters and educational materials to customers with known, suspected or possible lead service lines and encourage consistent, ongoing and proper filter use.

The communications plan for the Filter Program will have the following objectives:

- Inform and educate customers about the Filter Program.
- Engage with customers with known, suspected or possible LSLs to ensure they receive a filter.
- Work with property owners, local housing authorities and tenants to share information and encourage filter use with residents in rental and multi-family properties.
- Encourage filter use for drinking, cooking and when preparing infant formula.
- Encourage changing the filter cartridge according to the manufacturer's instructions.
- Educate customers about flushing and provide flushing instructions to encourage flushing the tap before drinking, cooking or preparing infant formula after prolonged periods during which water is not used, such as first thing in the morning or when returning home from work or school.

The Filter Program communications plan will focus on target audiences that include customers in homes with lead service lines, local governments, distributors, elected officials, public health agencies and health providers. Communications, outreach and education will also target expecting and existing families with formula-fed infants/children up to age 2 in homes with copper piping with lead solder built from 1983 to 1987, per CDPHE guidance. It will also provide information for Denver Water staff and contractors who are distributing filters to help them direct customers to appropriate resources and channels for answers to their questions. Implementation of the communications plan will begin with notification to affected residents of the Filter Program. Communications channels will include door-to-door communications, a customer tracking system, how-to videos and local opportunities to engage residents.

Denver Water's Filter Program will target expecting and existing families with formula-fed infants/children up to age 2 in homes with copper piping with lead solder built from 1983.

Accelerated Lead Service Line Replacement Program objectives and strategies:

The ALSLR Program will replace customer-owned lead service lines and provide information on post-replacement flushing procedures.

The communications plan for the ALSLR Program will target both property owners and residents and have the following objectives:

- Inform and educate customers about their service lines – ownership, material types and plumbing.
- Inform and educate customers about their premise plumbing – sources of lead, known potential health risks and options or strategies to reduce the risk of lead exposure from premise plumbing.
- Obtain property-owner consent to replace their lead service line and share information with the owner and residents of the property on what to expect from service line replacement.
- Provide support and information on post-replacement filter use and flushing.
- Provide customers with appropriate education and resources on water quality testing and the results of testing following lead service line replacement.
- Offer Denver Water staff and contractors strategies to obtain the consent of property owners who have refused to have their lead service line replaced.

Corrosion control treatment objectives and strategies:

Corrosion control treatment of the water will help minimize the release of lead into water from lead service lines and household plumbing and fixtures that contain lead.

The communications plan for corrosion control treatment will have the following objectives:

- Provide information on the Lead and Copper Rule and metal corrosion for general audiences.
- Inform and educate residential and commercial customers about the sources of lead in plumbing.
- Raise awareness among customers of the upcoming water treatment change and its potential impacts to water aesthetics, if any.
- Emphasize the outcome of increasing the pH — improved water quality and reduced risk of lead exposure in drinking water for customers with lead service lines and lead plumbing.
- Educate customers about flushing and provide flushing instructions to encourage flushing the tap before drinking, cooking or preparing infant formula after prolonged periods during which water is not used, such as first thing in the morning or when returning home from work or school.
- Provide clear and consistent messaging and branding.

What if the COE Plans do not generate the desired awareness and engagement?

Outreach and engagement will evolve and be refined over the life of the LRP. With each year of the LRP, Denver Water staff will have an increased understanding and awareness of the engagement strategies that have been effective. Denver Water is committed to conducting ongoing assessments and annual reporting of its COE metrics to determine if corrective action needs to be taken. Additionally, Denver Water will incorporate qualitative findings from ongoing stakeholder input to identify opportunities for improvement through the Learning by Doing element described later in this section.

How will Denver Water reach all of its customers?

Denver Water will focus much of its communications efforts on households in single-family and multi-family residences that have known, suspected or possible lead service lines. These households include occupants of apartments who normally do not have a direct customer relationship with Denver Water. Communications efforts are best targeted toward this group of customers because they will also be enrolled in the Filter Program.

Denver Water recognizes that it is important to communicate with all types of customers, including critical, commercial and industrial customers, and the communications, education and outreach strategies outlined in this plan will include them as audiences, as well.

By working closely and frequently with this broad group of customers, Denver Water can better foster filter adoption and use, partner with its customers in identifying and locating lead service lines and obtain valuable input from its customers.

A key focus of the COE Plans and the targeted communications plans for each element of Denver Water's LRP is equity and accessibility. Considerations will include health equity and environmental justice and creating systems where all customers have the opportunity to thrive.

Table 9 summarizes the strategies Denver Water will use to implement the COE Plans.

TABLE 9: STRATEGIES USED TO IMPLEMENT COE PLANS

- **Develop and incorporate key messages and talking points for Denver Water, CDPHE, EPA and stakeholders.**
- **Develop external communication strategies and tools to include, at a minimum:**
  - Digital communications (customer emails, social media, DenverWater.org/Lead webpage).
  - Printed collateral (fact sheets, FAQs, direct mailers).
  - Presentations to Registered Neighborhood Organizations.
  - Community meetings and listening sessions.
  - Integration into existing Denver Water communications and outreach (water trailers, TAP news site).
  - Traditional media engagement.
  - Other tactics to be identified through discussions with neighborhood leaders and community members and in ongoing coordination with partners.
- **Subject matter conveyed to include, at a minimum:**
  - Variance process and Lead Reduction Program.
    - Potential next steps after the EPA's final decision is made.
    - Lead service line identification.
  - Corrosion control treatment.
  - Accelerated lead service line replacements.
  - Filter distribution and use.
  - How lead can get into drinking water.
  - How customers can have their water tested.
  - How customers can manage their exposure to lead.
  - Where to get more information, including on other sources of lead.
- **Support staff training:**
  - Meet with internal staff to discuss communication needs.
  - Develop and implement training for customer support.
  - Identify clear channels for customer inquiries, feedback and questions specific to the variance and Filter Program.
- **Brief regulators, elected officials, utility managers and local health departments.**
- **Create lists of special audiences per anticipated impacts of each potential treatment method (e.g., industrial/commercial customers).**
- **Share customizable outreach materials to support distributors' customer communications.**
- **Focus and prioritize education and engagement to high-risk community members (e.g., expecting and existing families with formula-fed infants/children up to age 2) such as:**
  - Leverage existing stakeholder relationships/communication channels established by Denver Department of Public Health and Environment and Denver Water.
  - Target messaging for various community organizations, doctor offices, etc.
  - Partner with community health clinics, daycare/child care providers, social service programs for women and families.
- **Provide multiple, accessible ways for all community members to engage, with an eye toward:**
  - Providing all program materials in Spanish and other languages as needed.
  - Grassroots, on-the-ground outreach that directly engages with people in the comfort of their community (e.g., existing community events, gathering places and forums).
  - Partnering with local community leaders and non-profits with established relationships and credibility in the community.
  - Scheduling and executing public events in a manner that makes them accessible (e.g., providing child care, interpretation services).

III.B Lead Service Line Inventory

Because Denver Water does not own its customers' service lines, its database of known lead service lines is limited. The existing inventory is compiled from historical records of observations made during water main replacements, leak repairs and meter installations. Past water quality test results suggest that homes built prior to 1951 are likely to have lead service lines, but some of those service lines may have been replaced over time. Denver Water will undertake a rigorous investigative effort, especially in the early years of the LRP, to build a more accurate lead service line inventory for customers, regulators and other stakeholders.

Developing a comprehensive lead service line inventory to support the program

Over the last year, Denver Water developed a comprehensive lead service line inventory using a logic-based methodology. In addition, Denver Water is using a predictive model to further refine the inventory. The inventory groups service lines into five categories, assigning each a probability score that is based on the likelihood that a service connection is made of lead. The probability score for each property is developed using known construction practices, historical records, expert judgement and data interpretation.[17]

The following three categories represent service lines most likely to consist of lead:

- Known LSL – 100% direct evidence documenting lead.
- Suspected LSL – 80% or higher likelihood of lead, based upon available data (i.e., homes built prior to 1951).
- Possible LSL – 50% or higher likelihood of lead, as some data may be conflicting or missing but there is not enough information to confirm a non-lead service line.

The following two categories represent service lines that either are unlikely to contain lead or contain no lead:

- Unlikely LSL – <10% very low likelihood of lead.
- Non-lead – 100% direct evidence or statistically defensible factors supporting categorization as a non-lead service line.

These categories enable Denver Water to:

1. Identify candidate properties for inclusion in the Filter Program and the ALSLR Program. Providing filters to all properties with a known, suspected or possible lead service line is fundamental to demonstrating the efficiency of the LRP when compared with the alternative of orthophosphate.
2. Pinpoint geographic areas or individual properties for investigation of suspected or possible lead service lines. Through subsequent water quality testing and/or field investigations, these properties will be moved to the known LSL or non-lead categories.

[17] The process used to assign a given property to one of the categories is described in Appendix III.B.2 and Appendix III.B.3.

3. Quantify and prioritize the known and suspected LSLs for efficient and targeted replacement during the ALSLR Program, focusing early on areas and homes with our most vulnerable populations and where economies of scale and opportunity can be achieved in conjunction with road projects and main replacements.

What factors help Denver Water identify the likelihood of a lead service?

As noted in Section I, Denver Water anticipates that most lead service lines in Denver will be found at properties built before 1951. Typical service line materials include copper, lead, galvanized steel and other non-lead materials. Service lines comprised of either full or partial sections of lead or galvanized steel will be documented and counted in the inventory as a lead service line.

Denver Water may use the following factors to refine the lead service line inventory:

- Historic records of observed service materials, tap sizes, water main replacements and LCR plumbing materials surveys.
- Knowledge of the materials that were used at certain periods and other likely identifiers; for example, lead concentrations in Denver Water's system drop off significantly in homes built after 1950 and lead service lines were prohibited in Denver starting in 1971.
- Information from the redevelopment of existing homes from City and County of Denver records and other entities that are subject to Denver Water's operating rules.
- Information from the entire integrated system; Denver Water will work with its distributors to identify the addresses of known or verified lead service lines and the dates when lead service lines were allowed or not allowed.

Denver Water's service area has approximately 319,700 customer service lines, including schools, businesses and multi-family units. Table 10 lists the estimated number of service lines by category (as of August 2019).

TABLE 10: PROBABILITY ESTIMATE OF SERVICE LINES

Service Line Category	Estimated Number of Services	Properties to be Enrolled in Filter Program
Known LSL*	1,066	**84,546 service lines assumed to be included as candidate properties for the Filter Program and further investigation.**
Suspected LSL	61,374	
Possible LSL	22,106	
Unlikely LSL	89,388	
Non-Lead	145,766	
Total	**319,700**	

*LSL = Lead Service Line

The service line categories shown in Table 10 were further refined to compute the expected number of lead service lines and non-lead service lines using the assigned inventory probabilities, census and other data (Table 11).

TABLE 11: OVERVIEW OF THE DIFFERENT CATEGORIES OF SERVICE LINES

	Basis	Lead Service Lines	Non-Lead Service Lines	Total
Census	Direct Evidence	316	10,244	10,560
	Evidence from Distributors	180	30,562	30,742
	Post 1972 Build Date and Tap Date	0	102,461	102,461
	Pre 1952 Property & Water Quality Results	625	7	632
Estimate	Build & Tap Dates	62,325	108,854	171,179
	Service Size	0	1,129	1,129
	Presumed Replacement	0	967	967
	Water Sales Manual Review	509	1,521	2,030
	Totals	**63,955**	**255,745**	**319,700**

As of August 2019, the estimated number of lead service lines is 63,955. Denver Water is currently engaged in a field investigation involving potholing approximately 200 service lines within the City and County of Denver to confirm the material used for service lines. The results will be used to verify the logic used in the LSL Inventory and predictive model.[18] Responses from the integrated systems will also be used to inform future inventory estimates.

The number of service lines categorized as suspected, possible and unlikely will diminish over time, while the number categorized as known and non-lead will increase. This is especially likely to occur in the first five years of the LRP as further research of historical data, results from observations during the annual replacement of lead service lines and additional field and water quality investigations inform and improve the accuracy of the numbers and factors in the inventory model.

What more will Denver Water do to improve the certainty of the LSL Inventory?

Denver Water has expanded the lead service line inventory to incorporate a predictive model[19] that integrates data from investigations and ALSLR Program results to increase the efficiency of lead service line identification within Denver Water's service area. Additional investigation methods may include:

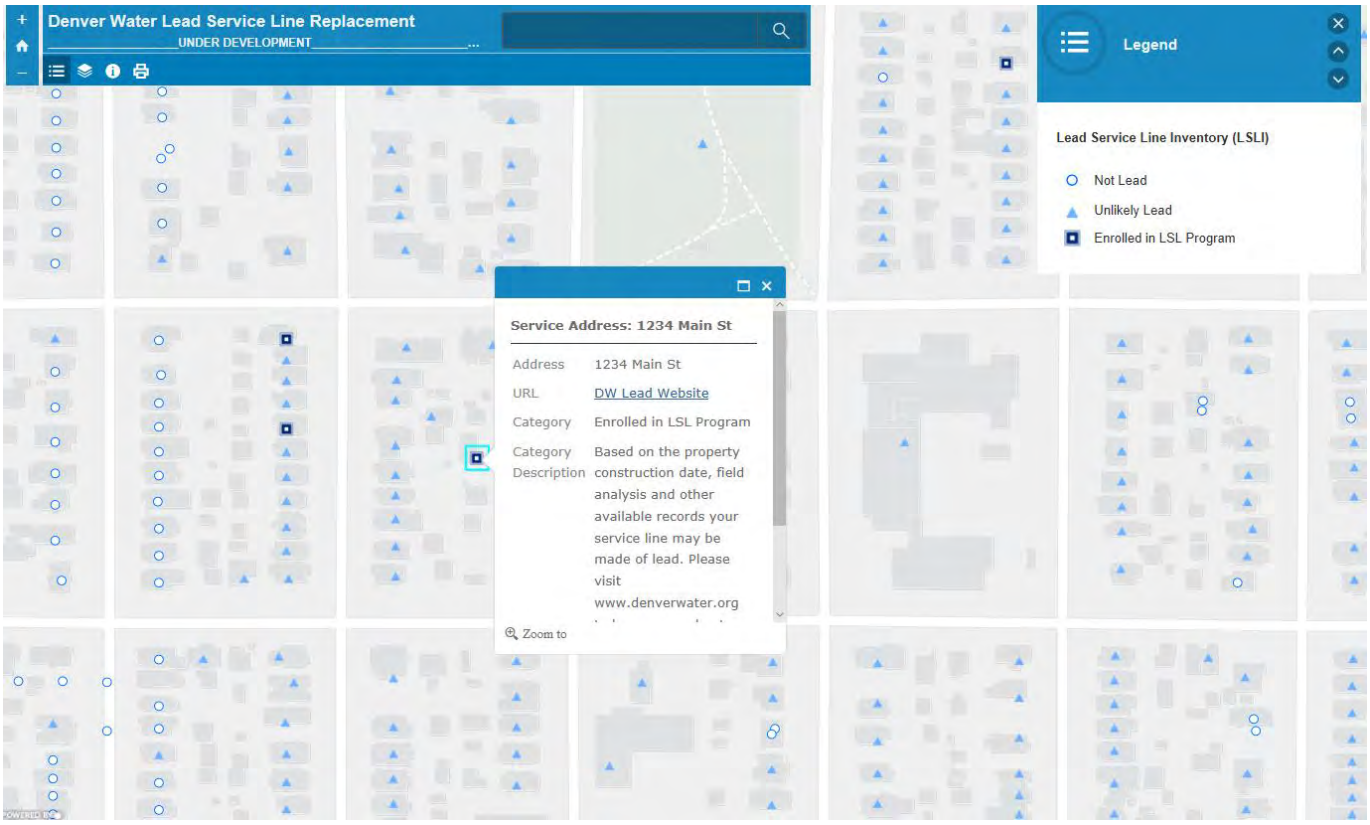
[18] As discussed in later in Section III.B.
[19] Please see Appendix III.B.3 for details.

- Water quality sampling using the 3-bottle test to establish the service line profile. Denver Water's research shows that water quality assessed from the second and third bottles is indicative of the service line material, especially lead.
- Historical data review to improve the knowledge of a given property and assess the likelihood of having a lead service line (ongoing effort).
- Visual inspection of the service line material where the line enters the meter pit and/or home, if accessible.
- Potholing to visually inspect for the presence of lead.
- Contact with property owners to determine the history of any updates to the property.

How will customers know if they have lead service lines?

To aid property owners and residents, Denver Water will maintain an interactive and user-friendly map using a GIS platform to denote service line type as documented in the LSL Inventory. The goal is to provide information for each property within Denver Water's integrated system. Denver Water expects to update the map frequently to illustrate new information gathered from its field investigations. An example of what the map of the LSL Inventory could look like is shown in Figure 21.

FIGURE 21: LEAD SERVICE LINE IDENTIFICATION MAP (EXAMPLE)



How can predictive modeling be used to better identify the location of lead service lines?

The predictive model will be used to triangulate the results of investigations completed to date and to guide future investigations, without having to undertake an excavation at every property. This will improve the overall efficiency of LSL identification and the replacement process at the properties described as having a suspected or possible LSL. In addition, investigation results will fine-tune or improve the confidence in the lead service line inventory as a whole.[20]

The predictive model, through water quality sampling, potholing and information gained from the ALSLR Program, improves its logic rules (i.e., build date or tap date) that are used to assign the likelihood of finding a lead service line at a given property. Information from the field allows the predictive model to extrapolate (or predict) the likelihood of finding lead at similar locations using logic rules and field investigation results. The field investigations may include visual inspection, water quality sampling and potholing to determine the probability of lead. Field results generated at a representative number of properties in an area of uncertainty can provide greater confidence in the model's ability to predict the service line materials used elsewhere in the water system.

How will predictive modeling be used in prioritizing replacements?

Continued refinement and utilization of the predictive model will inform Denver Water's approach to targeting communications as part of the COE Plans, enrolling customers in the Filter Program and prioritizing LSL replacements. Denver Water's annual efforts to plan the ALSLR work will focus efforts on the properties or areas with a higher risk of lead exposure. The following factors that may inform the prioritization schedule include:

- Public health considerations (i.e., relative risk–odds ratio for childhood lead poisoning per EPA and health department toxicology experts).
- Critical customers (i.e., locations of child care providers and primary schools).
- Filter adoption rates by geographic and/or demographic area.
- Age-related considerations (children under the age of six, neighborhoods with a high density of young and expecting families).
- Socio-economic and environmental factors.

The location of vulnerable populations will help inform the selection of work locations on a yearly basis. Each property associated with the LSL Inventory will be incorporated into the prioritization analysis to identify the potential risk of lead exposure.

Criticality factors associated with each property are provided a set of values (referred to as a criticality co-efficient) that are adjusted by a weighting factor (referred to as a criticality weight). The weighted criticality factor can be defined by analysis tools and/or stakeholder consensus, as shown in Figure 22. The overall criticality score for an individual property is the result of multiplying the criticality factors by the respective criticality weightings.

[20] For details, please see Appendix III.B.3.

FIGURE 22: CRITICALITY WEIGHTING PROCESS

Once the likelihood and criticality scores are generated for each property, the total risk score is calculated for a geographic area (i.e., a common spatial boundary as identified in census blocks from the American Census Records). This analysis provides both an individual and accumulated geographic risk score that can then be considered with other logistical considerations, such as planned paving schedules and water main replacement work.

The total risk density scores by geographic area will be used to sequence work to address the (high) risk of lead exposure at a property and the efficiency of working through an area of properties to relative to the risk posed to a broader portion of the community. Additionally, properties that are of high risk and consequence that are not incorporated in a census area for production will be evaluated for sequence of constructions.

What happens to properties that are reclassified as part of the inventory updates?

Depending on their location in the integrated system, properties initially classified as having a low possibility for a lead service line (and therefore not enrolled in the Filter Program) may be reclassified by the predictive model as having a higher likelihood for lead. Similarly, as the predictive model is refined with results from the field, a property initially identified as having a suspected lead service line may be reclassified as being unlikely to have a lead service line.

When a property is identified as having a possible or suspected lead service line, the resident will be enrolled in the Filter Program. If a property is initially identified as having a possible or suspected lead service line and is subsequently reclassified as being unlikely to have a lead service line, further investigation will be undertaken to confirm the service line material. If upon further investigation non-lead is confirmed, a letter will be mailed notifying the customer of the change and their participation in the Filter Program will be discontinued within six months of the change in status.

What if a lead service line is found after Denver Water completes the LRP?

Any property found to have a lead service line after the end of the program will receive a filter and be scheduled for service line replacement within six months of identification.

III.C Filter Program

The Filter Program is an interim protection measure that will supply filters that remove lead from customers' drinking water.[21] As part of the Filter Program, households with known, suspected or possible LSLs, whether owner-occupied or tenanted, will receive a filter and replacement

[21] The Filter Program Plan is included in Appendix III.C.3.

cartridges until either the service line is confirmed to be non-lead or six months after the lead service line is replaced, as shown in Table 10. Through the duration of the LRP, Denver Water will provide filters that will remove nearly all the lead but leave other important minerals like fluoride.

Multi-family properties are included in the 84,546 service lines that are part of the Filter Program, as shown in Table 10. A multi-family property has multiple household units. A household unit is an individual residence that receives a filter. Using available data, Denver Water estimates that Filter Program participants consist of 119,250 Denver Water household units, with each household unit receiving a filter.

How and when will filters be distributed?

Filter distribution to all households with known, suspected or possible LSLs will start within 90 days of the variance approval. In accordance with the COE Plans, each eligible customer will receive education/outreach material, a pitcher filter and a six-month supply of replacement filter cartridges that are NSF-certified for lead removal. A pitcher filter and six-month supply of replacement filter cartridges will be provided for each individual unit at multi-family dwellings.

Denver Water is testing the lead removal performance of multiple filter products before filters are distributed to customers in the Filter Program.

Denver Water's integrated system will be divided into sub-areas for consolidated communications and distribution of the filters. Filters will be distributed to neighborhood residents in sub-areas during the same time period to reinforce filter use, consolidate outreach and answer questions within a specific community using local community organizations and resources. The intent is to intensely target the sub-areas or neighborhoods with filter distribution using various methods:

- Primary – Direct mail to the eligible resident unit with delivery confirmation.
- Secondary – Hand delivery via door-to-door canvasing (in person or drop-off).
- Exceptions – Resident preference only: pick up at Denver Water facility, mobile unit, at community meetings or other locations and events.

Vulnerable populations, including expecting families, children and those of low socioeconomic standing, will be identified, contacted and tracked as sub-populations within the sub-areas. The criteria for vulnerable population will be used to help prioritize the order of geographic sub-population distribution within a sub-area and associated community outreach.

Replacement filter cartridges will be distributed every six months using the same methodology identified for the distribution of pitcher filters.

A property will be removed from the Filter Program six months after replacement of the lead service line or if a non-lead service line is confirmed at the property.

Communications and the Filter Program

The notification methods that will be used for customers that are eligible to receive a filter include:

- Delivery of detailed instructions regarding the Filter Program, water filter cartridge use and replacement on Denver Water's website.
- Delivery of detailed instructions regarding the Filter Program, water filter cartridge use and replacement during door-to-door campaigns, neighborhood meetings and additional strategic community outreach in identified areas as part of the overall Lead Reduction Program.
- Distribution of letters informing customers of the Filter Program with:
  - Detailed instructions regarding the Filter Program, water filter cartridge use and replacement requirements.
  - Denver Water's customer care call center phone number.
  - A link to Denver Water's Lead Reduction Program website.
- Information customized for tenants in rental properties (i.e., directed to local housing authorities and property management companies).
- Robocalls to impacted customers with:
  - Detailed information regarding the Filter Program.
  - Denver Water's customer care call center phone number.
  - A link to Denver Water's Lead Reduction Program website.
- Direct mail of water filters to select impacted customers with:
  - Information regarding filter cartridge replacement.
  - Denver Water's customer care call center phone number.
  - A link to Denver Water's Lead Reduction Program website.
  - A mail in response survey/response form (in multiple languages).
  - A quick response code for access to Denver Water's digital registration page (in lieu of mail in survey/response).
- Hand deliver water filters to select impacted customers including multi-family housing, with:
  - Information regarding filter cartridge replacement.
  - Denver Water's customer care call center phone number.

- A link to Denver Water's Lead Reduction Program website.
- A quick response code for access to Denver Water's digital registration page (in lieu of mail in survey/ response).
- A mail in response survey/response form (in multiple languages).

- Conduct follow-up communications using mail, phone or a door-to-door survey during the first six months of filter use to determine practices and preferences.

Verifying filter adoption – how will Denver Water know filters are being used?

Filter adoption assumes customers are accepting, installing (if applicable), using and maintaining the filter properly, including replacing the filter cartridge at the appropriate time.

The distribution of filters and replacement cartridges will be documented and tracked during the life of the LRP using an electronic database and GIS. A survey of randomly selected customers enrolled in the Filter Program will be conducted annually to measure the filter adoption rate. Responses from a minimum of 1,059 randomly selected customers each year will be required to estimate the filter adoption rate with at least 95% confidence and no more than 5% error, at adoption rates greater than 65% (from Figure 19 in Section II). This is referred to as the threshold for the filter adoption rate—the minimum percentage of households that use filters such that the LRP achieves results that are equivalent to those of using orthophosphate. Denver Water will complete the adoption survey each year (on a calendar year basis) using internal resources and community outreach services to generate the minimum 1,059 responses.[22]

In the last years of the Lead Reduction Program, the number of remaining lead service lines may approach the minimum required number of respondents. In this case, the survey approaches a census rather than a sample, which may cause difficulty in attaining high survey response rates. Because this can only happen near the close of a successful replacement program, it is not expected to cause issues. Any issues that do arise will be best addressed by the Learning by Doing approach.

Additionally, a customer survey will be implemented during the ALSLR Program (surveys will be distributed based on the number of completed lead service line replacements each year). The results of the ongoing surveys, including lack of responses, will be evaluated and used to estimate and improve adoption rates, develop communications, outreach and education activities for sub-area populations and make improvements to the Filter Program (Learning by Doing).

The results will also be parsed and evaluated based on geography and/or demographics to address health equity and environmental justice concerns. If certain areas are not responding to the survey, then additional COE activities would be designed and carried out to understand the issue and improve survey response.

[22] Details and assumptions used to design the survey to evaluate filter adoption are provided in Appendix III.C.1 and Appendix III.C.3.

What if Denver Water does not achieve the threshold filter adoption rate?

Increasing filter use at customer homes to 100% is the goal of the Filter Program. It is reasonable to expect that communications, outreach and education efforts to customers will help to increase the filter adoption rate. Compliance is based on a minimum filter adoption rate of 65%, and failure to remedy persistently low filter adoption rates will trigger actions, as described in Section IV.

However, to maintain filter adoption above the minimum rate of 65%, Denver Water has identified 75% as an operating target to increase outreach and education activities before non-compliance occurs. If customer use falls below 75% for filter adoption, Denver Water will:

- Increase and modify its communications, outreach and education efforts with particular attention to any sub-populations with below-average adoption rates.
- Evaluate possible modifications to the ALSLR Program.

III.D Accelerated Lead Service Line Replacement Program

Through the ALSLR Program, Denver Water will replace all identified lead service lines within 15 years. To achieve this, the Denver Water ALSLR Program will perform LSL replacements as efficiently as possible. At the same time, Denver Water will engage with and educate customers so that they understand the benefits of LSL replacement and consent to participate.

What is Denver Water committing to as part of the accelerated lead service line replacement program?

Denver Water is committing to replace all lead service lines within 15 years at a cumulative program year average replacement rate of 7.0%. Lead service lines will be replaced from the main to the first fitting inside the dwelling (defined as a full lead service line). Any partial lead service line or galvanized steel service line material downstream of an existing or previously existing lead service line will also be replaced up to the first fitting inside the dwelling. The ALSLR Plan describes in greater detail the process by which Denver Water will undertake the 7.0% cumulative program year average replacement rate over the life of the ALSLR Program.[23]

What constitutes an LSL replacement?

The following types of LSL replacements will count as credit for an entire LSL replacement:

- Full LSL replacement of a single service line.
- Replacement of an existing partial lead service line that results in a non-lead service line from the main to the first fitting inside the dwelling.
- Replacement of a galvanized service line downstream of an existing or previously existing lead service line.

[23] The ALSLR Plan is provided in Appendix III.D.1

- LSL replacements completed by property owners or third parties and inspected by Denver Water.

Summary of the LSL replacement process

Denver Water customers might notice a greater level of construction activity in their neighborhoods over the next 15 years, especially in neighborhoods with high concentrations of lead service lines. In addition to continuing to replace approximately 400 lead service lines per program year through water main replacement projects and approximately 300 leaking lead service lines per program year, Denver Water will also target the replacement of thousands of lead service lines per program year through systematic, prioritized replacements, focusing on:

- Replacing lead service lines in geographic areas with cumulative opportunities to reduce lead exposure and/or provide project delivery efficiencies. These areas may include blocks with a high density of lead service lines or neighborhoods undergoing a municipal paving or road improvement project.[24]
- Replacing lead service lines at individual properties with lead concentrations consistently above the action level and/or at properties demonstrating a significant demographic risk (for example daycares).
- Monitoring the estimated individual LSL replacement volume from redevelopment and leaks to address a potential shortfall in the overall 7.0% cumulative annual average goal.
- Coordinating with the City and County of Denver Public Works and other area municipal, utility and public sector agencies to ensure that a framework is in place to optimize construction and related activities.

Currently, 1,200 lead service lines are replaced annually through various activities by Denver Water, developers and other third parties. At this rate, it will take 50 years or more to replace all known and suspected lead service lines in Denver Water's service area

See Table 12 for a summary of this approach.

Additionally, crews will conduct investigations at properties, with suspected and possible lead service lines to identify the service line material to improve the lead service line inventory. The identification of service line material will inform the predictive model. This process will assist in future annual ALSLR planning.

[24] The ALSLR Plan is provided in Appendix III.D.1

TABLE 12: EXAMPLE OF GROUPINGS FOR LEAD SERVICE LINE REPLACEMENTS AND INVESTIGATIONS

Group/Type		Est. Annual LSL Replacements and LSL Investigations	Group Subtotals for Est. Annual LSL Replacements and LSL Investigations
GROUP A – LSLR by GEOGRAPHIC AREA	Water main Replacement	400	3,850*
	Block by Block or Street by Street	3,000*	
	Municipal Pavement and Road Improvement Programs	450	
GROUP A – LSLR by INDIVIDUAL	Leaks	300	1,400*
	Individual & High Priority LSLR	600*	
	Scrape Off and Redevelopment Properties	500	
GROUP B - INVESTIGATION	Investigations for areas with suspected and possible LSL	500*	2,000*
	Water Quality Testing of areas with expected or somewhat expected to have LSL	1,500*	

(*) asterisk indicates the values are subject to change but are provided as an example based on replacing 5,250 lead services in one program year.

Approximately 20% of the properties included in the predictive model described as having a suspected or possible lead service line will be investigated to confirm the service line material (see Table 12). This, in turn, will be used to predict the likelihood of having a lead service at all the remaining 80% of properties. Divided over 14 years of the LRP duration, this works out to investigating 1.4% per program year of the properties categorized as having a suspected or possible lead service line.

To maintain the efficiency of the ALSLR Program, completing a higher number of investigations in the early years of the program will be necessary. Investigations at 10% of all properties with a suspected or possible lead service line will occur within the first five years of the LRP, or approximately 2,000 investigations per program year. This percentage of investigations was selected based on the statistical needs of the predictive model.

The geographic area work for Group A, defined by streets or blocks, focuses on a relatively high density of properties with lead service lines that can be replaced quickly and efficiently. The geographic area is displayed on the left side of Figure 23. The properties are marked with different shapes and colors to indicate the likelihood of having a lead service line. A property identified for an individual replacement (Group B in Table 12) is represented by the right side of Figure 23. Individual replacements will not be spatially concentrated, rather the properties (known or suspected colored symbols) may be located in various areas across the Denver Water service area. The properties included in Group B were identified based on having lead concentrations consistently above the action level and/or demonstrating a significant demographic risk.[25]

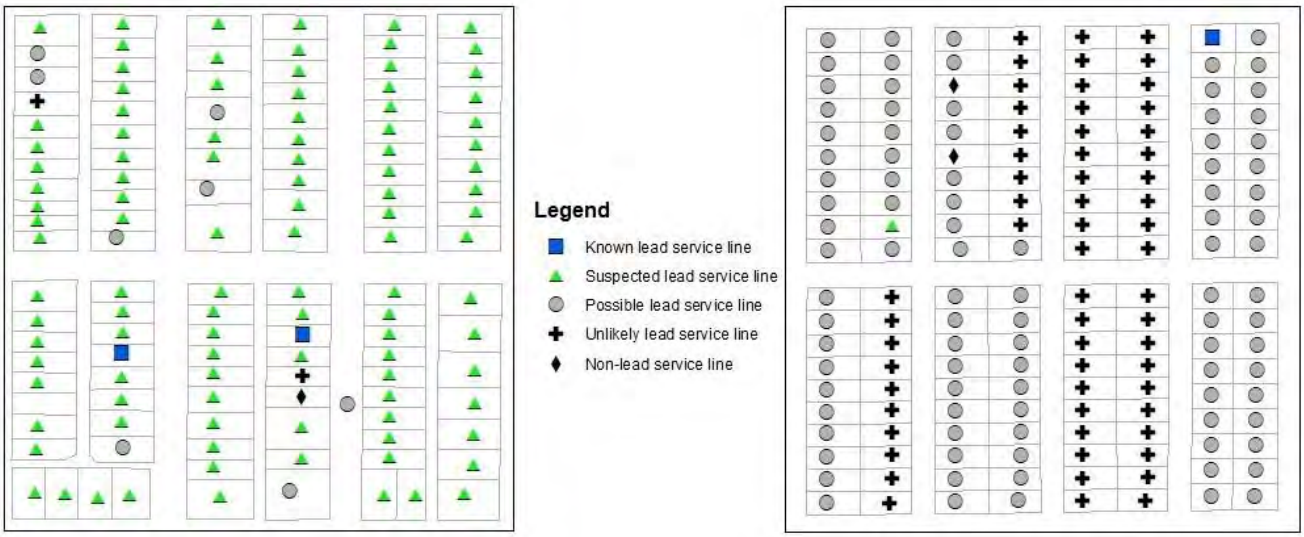
Properties types targeted for Individual lead service line replacement include:

- Multi-family units
- Daycare centers
- Private schools*
- Health facilities

These property types have a broader impact on Denver Water's customer base because their service lines provide clean drinking water to more than a single-family or customer.

* Denver Water replaced the last lead service line at a Denver Public Schools school building in spring 2019.

FIGURE 23: EXAMPLE REPRESENTATION OF LEAD SERVICE LINE REPLACEMENT BY GEOGRAPHIC AREA (LEFT) AND INDIVIDUALLY (RIGHT)



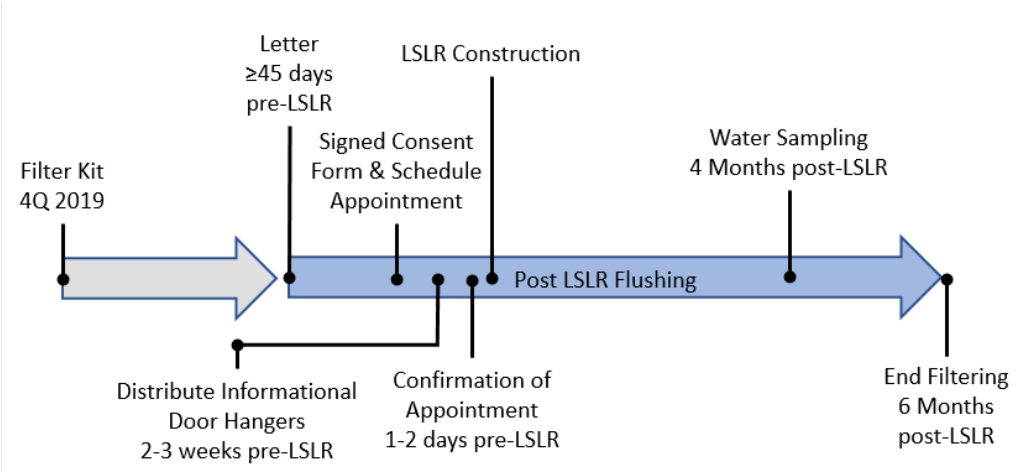
What can customers expect during a lead service line replacement?

Denver Water will contact the customer at least three times prior to the actual replacement of the lead service line. As seen in Figure 24, property owners will be (1) notified via letter at least 45 days in advance of the construction, (2) asked to set up an appointment to discuss the

[25] How these properties are prioritized and grouped is described in Appendix III.B.3

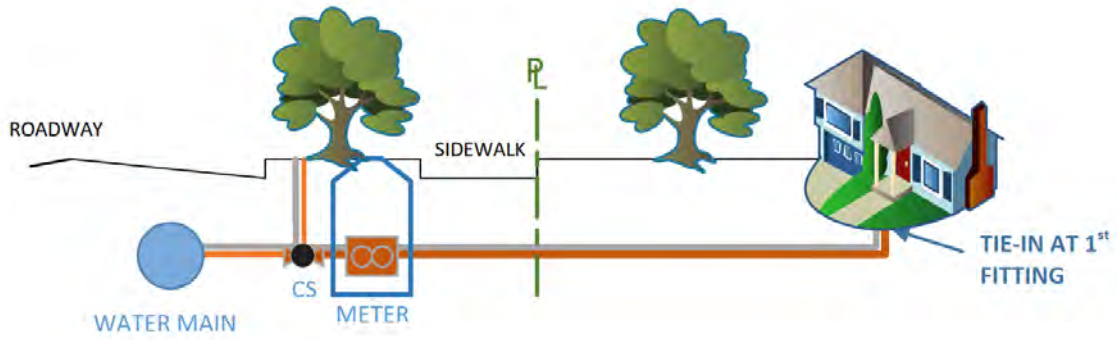
construction for their property as well as sign a consent form allowing the replacement of their lead service lines, (3) reminded via signage placed at the limits (ends of streets) within geographic work areas four to five weeks in advance of construction and (4) provided a door hanger two to three weeks in advance of construction as a reminder of the upcoming event. Also, per Denver Water policy, both owners and residents (in the case of tenanted properties) will be notified of the shutoff of service 24 hours in advance of construction.

FIGURE 24: PLANNED INTERACTION WITH PROPERTY OWNERS AND RESIDENTS DURING LEAD SERVICE LINE REPLACEMENT ACTIVITY



During construction, Denver Water will investigate the service line material and replace the service line if the material is lead. The lead service line replacement will include the service line from the water main connection to the first fitting inside the dwelling. An example of a full lead service line replacement is illustrated in Figure 25. The example shows an existing lead service line (grey) being replaced fully with a copper service line (orange). Additionally, all fittings, valves, curb stops (CS), corporation stops and water meters that are not copper will be replaced.

FIGURE 25: EXAMPLE FULL LEAD SERVICE LINE REPLACEMENT



Following construction, Denver Water will provide each property with:

- Flushing instructions (per AWWA/ANSI Standard C810-17).
- Post-replacement filter use survey.
- Educational materials on how to further reduce lead in premise plumbing.

- Additional filter replacement cartridges for use up to six months after replacement to remove any lead particles that may have been dislodged as a result of replacement.
- Water quality sampling test kit, approximately four months after replacement.

What happens if the post-replacement water quality result, at an individual property, is high?

Property owners will be educated on how to reduce lead in their premise plumbing and will be referred to community organizations and funding programs that can assist with investigating and removing lead from their home (such as the U.S. Department of Housing and Urban Development's Lead Hazard Grant Program).

How will Denver Water achieve the 7.0% replacement rate?

A number of older cities (including Pittsburgh and Detroit) have embarked on lead service line replacement plans that aim to replace several thousand service lines per program year. A review of these and other lead service line replacement programs revealed that it is reasonable to expect crews to replace upwards of two to four lead service lines per day, depending upon various factors with primary emphasis in lead service line inventory confirmation in advance of replacement.

The ALSLR Program will incorporate Denver Water's internal resources to replace up to 700 lead service lines per program year as part of water main replacement and service line leak repair work. Another 500 lead service line replacements per program year are typically performed through redevelopment. Contracting with external resources will be arranged to fulfill the remaining portion to achieve the 7.0% cumulative program year average replacement goal. Based on the practical number of replacements that can typically be completed per day (two replacements per crew per day), it is projected that Denver Water will need upwards of 13 lead service line replacement crews to meet the 7.0% goal of replacements. As the program progresses, efficiencies are expected through the annual review of lessons learned. The ALSLR Program does recognize that developers and Denver Water's LSL replacement activities will require incorporation of Denver Water and City and County of Denver processes to plan and track these replacements.

Denver Water will engage and partner with contractors through:

- Multi-year contracts to maintain flexibility and engagement of ALSLR crews to meet the 7.0% goal.
- Task orders will be issued to address investigations as part of the geographic and individual groups of the ALSLR Program.
- Contracts will incorporate a Learning by Doing approach with routine reviews of performance to identify opportunities for improvements.
- Incentive based contracts for meeting performance criteria focused on safety, quality and replacement rates.

To confirm local contracting capacity, Denver Water, in coordination with the COE Plans, conducted an Industry Day workshop to inform the contracting community of the LRP's needs. Denver Water reviewed potential contracting and procurement options and is using a

qualification-based approach to shortlist qualified contractors that will provide unit price bids. Denver Water will select the lowest and most responsive qualified contractors' unit price bid and enter into a contract for one year with the option of two one-year extensions.

What if a customer does not want their lead service line replaced?

Denver Water anticipates that, occasionally, a property owner might refuse to allow their service line to be replaced. Denver Water will use a three-step notification process along with continued outreach to try to obtain an owner's consent.

If a property owner continues to withhold consent for the LSL replacement, Denver Water may take one or more of the following actions:

- Denver Water may choose not to replace the lead service line, but instead pothole in the right-of-way to determine the service line material and proceed with other service line replacements on the same block. Restoration would be provided for the area disturbed during the investigation.
- Denver Water may perform a partial replacement of the lead service line (i.e., property cannot be accessed).
- If consent is not provided prior to the contractor entering the area, and if the property owner (or customer) is enrolled in the Filter Program, a letter will be sent to the property owner (or customer) by registered mail providing contact information and a deadline to respond with consent.
- Additional outreach and education materials will be provided to the property owner and the residents of the property to i) determine why consent was denied, ii) review the importance and features of the LRP and iii) drop off a water quality sampling kit in an effort to quantify the magnitude of lead release at the property.

Next steps if consent to replace the known lead service line is denied: If consent is still denied after implementing the above actions, the property will be added to a Service Line Refusal List maintained by Denver Water and a note will be made in the customer's account that the LSL replacement was refused. The Service Line Refusal List will be included in the annual report and made available to CDPHE.

Tracking lead service lines for replacement in the future: Upon a change in the name of the water account or property owner, Denver Water will reinitiate outreach and education efforts to determine if the new customer will consent to replacement of the lead service line. Timing for replacement will be determined on the basis of priority.

Exceptions for multi-family properties: Denver Water will make all reasonable efforts to obtain consent from a property owner of single-family and multi-family properties, including contacting out-of-state landlords where applicable. In the case of multi-family units, until the property owner provides consent to replace the lead service line, the residents (if not the property owner) will be notified by registered mail of the known or suspected presence of a lead service line, enrolled in

the Filter Program, provided with education materials to describe actions the residents can take to reduce their risk of lead exposure and provided a sampling kit. Denver Water may take action against the property owner to secure consent to replace the lead service line.

Exceptions for water main replacement: When Denver Water replaces a water main, the existing service line connection must be transferred from the old water main to the new water main. If the service line is made of lead, Denver Water will replace the lead service line as part of its water main replacement work. If consent is not given by the property owner, after three notices, Denver Water will perform a partial lead service line replacement to the water meter, the address will be added to the Service Line Refusal List and educational materials will be provided to the property owner (to encourage replacement) and the resident (if different from the property owner, to provide measures the resident can take to prevent lead exposure).

How will the predictive model be used to guide the ALSLR Program?

The goal of the ALSLR Program is to replace 7.0% of the lead service lines within Denver Water's service area annually. The predictive model will be used to generalize the results of past service line investigations to guide future investigations, fine-tune the LSL Inventory and assist in the early identification of the subsequent program year's lead service line replacement plan.

Denver Water will consider additional service line investigations, based on areas selected for replacement in a program year, to confirm information in the LSL Inventory and increase the reliability of delivering the 7.0% cumulative program year average rate of replacement.

What happens if a lead service line is found after the LRP is completed in 15 years?

Lead service lines found after the LRP is completed will be replaced within six months of discovery. Customers will immediately receive a filter and replacement cartridges (NSF-certified to remove lead) and will continue to receive shipments of replacement cartridges up to six months after the line is replaced, along with educational materials on reducing lead exposure.

How will Denver Water demonstrate a 7.0% replacement rate?

On an annual basis, Denver Water will receive credit for every lead service line replacement completed that program year, including lead service line replacements completed by third-party contributors (e.g., governmental agencies, developers, homeowners, non-profits). Denver Water will inspect all third-party lead service line replacements.

The cumulative program year average will be calculated for each program year by dividing the number of lead service lines replaced (X) during the program year by the known number of lead service lines (Y). A calculation for the cumulative program year average replacement rate can be found in Appendix III.D.1. Adjustments to X or Y can be made in agreement with EPA and CDPHE if evidence supports the adjustment and still results in a minimum 7.0% cumulative program year average replacement of all known lead service lines within 15 years. Adjustments to X and Y may include:

Potential Adjustments to X (Number of Lead Service Lines Replaced during Program Year)	Potential Adjustments to Y (Known Number of Lead Services)
No adjustment: property owner declines replacement after multiple attempts by Denver Water to encourage replacement.	**Adjust down:** known or suspected lead service line confirmed to be non-lead during investigation phase.
Adjust up: entire lead service line replaced or existing partial lead service line replaced such that entire line is non-lead after replacement.	**Adjust up:** lead service line confirmed after customer sampling reveals high lead concentrations in all three bottles.
Counts as more than one: multiple lead services replaced as part of a redevelopment project, even if replaced with on larger service line.	

The 7.0% cumulative program year average replacement rate will take effect beginning the third program year following the launch of the ALSLR Program. Although the 7.0% replacement rate will not apply during the first three years of the ALSLR Program, as a practical matter, lead service line replacement counts cannot drop below 6.0% for the first year and 6.5% for the second year, if Denver Water is going to achieve a 7.0% cumulative annual average replacing rate beginning the third program year.[26]

Can Denver Water replace lead service lines in less than 15 years?

Protection of public health and reduction of long-term program management costs will incentivize Denver Water to replace lead service lines as quickly and responsibly as possible, which may exceed the proposed 7.0% cumulative program year average replacement rate. Over the next 10 years, Denver Water is completing two large water supply resiliency projects including construction of the new Northwater Treatment Plant and the expansion of Gross Reservoir. **Denver Water must balance these projects and rate increases in a manner that supports its mission without creating affordability issues for its customers.** Note: force majeure events (e.g., severe flooding, drought or material shortage) may adversely impact Denver Water operations and by default, capital programs. As a result of these factors, Denver Water believes it is prudent to commit to the minimum 7.0% rate but will strive to do more when feasible.

III.E Corrosion Control Treatment

As part of the variance approach, Denver Water is proposing to use pH/alkalinity adjustment to reduce lead releases from copper piping with lead solder and from premise plumbing containing lead. Additionally, Denver Water will submit a modification request asking CDPHE to change the optimal corrosion control treatment designation from orthophosphate to pH/alkalinity. Denver Water must have approval of both the variance and modification request to move forward with this plan.

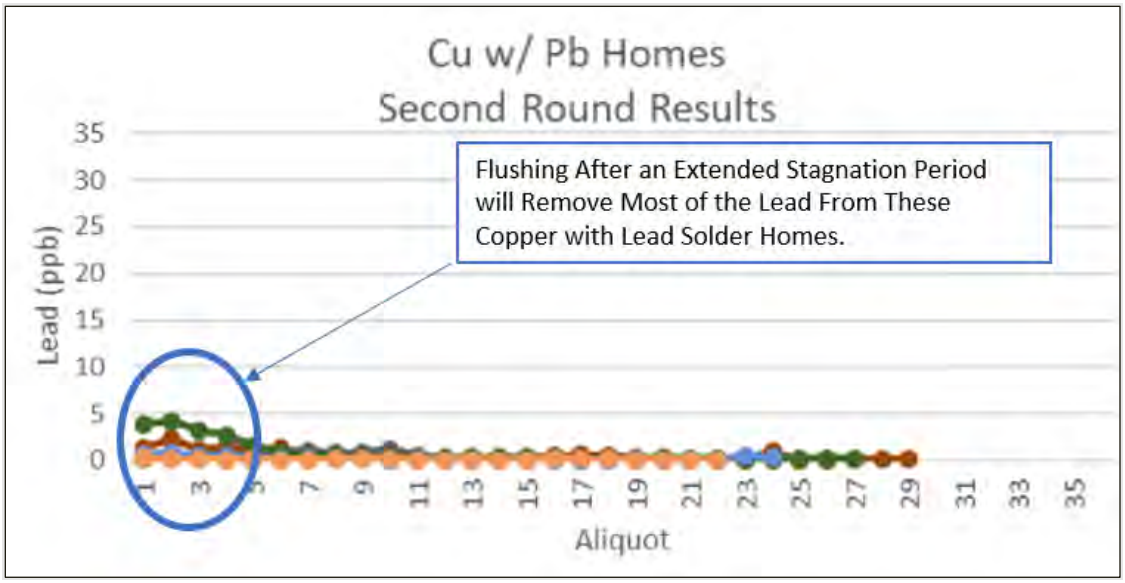
[26] See Appendix III.D.1 for example calculations for the cumulative program year replacement rate.

How will pH/alkalinity adjustment protect customers with copper piping with lead solder?

As discussed in Section II, lead concentrations in first draw samples for homes with copper pipes with lead solder are expected to decrease by 41% to 43% with pH/alkalinity adjustment.[27] Using LCR compliance data from 2011 to 2019 for homes served by copper pipes with lead solder and built from 1983 to 1987, Denver Water expects the projected lead concentrations in first draw samples under the LRP to decline from 7.2 ppb to 4.2 ppb.

As seen in Figure 26, flushing after an extended stagnation period (first thing in the morning, after work or school) will remove most of the lead. The COE Plans incorporate this messaging to help customers understand how to reduce their exposure to lead.

FIGURE 26: HOW FLUSHING CAN HELP REMOVE LEAD FROM WATER AT HOMES SERVED BY COPPER PIPING WITH LEAD SOLDER



How will Denver Water address equivalency for 1983 to 1987 homes?

The decade analysis described in Section II demonstrated that most homes served by copper pipes with lead solder will see lead concentrations drop to near non-detect limits for either pH/alkalinity adjustment or orthophosphate, except for 1983 to 1987 homes, as seen in Figure 12. To address this gap in equivalency, Denver Water has committed to the following:

- Communications, outreach and education campaigns targeted at expecting and existing families with formula-fed infants/children.
- Free water quality test kits.
- If lead concentrations exceed 3 ppb, free filters will be offered to the family.
- Replacement cartridges will be provided for the formula-fed infant/children up to their 24th month of age.

[27] Based on coupon testing, see Table 4.

Can the proposed corrosion control treatment protect customers with lead service lines who choose not to use filters?

Yes, to some extent. Customers with lead service lines who use a filter will reduce the amount of lead in their drinking water by 97%. For customers with lead service lines who do not adopt filters, the Corrosion Control Treatment alone will reduce lead concentrations approximately 50%.[28] Applying this 50% reduction to the average of all 90th percentile results from 1997 to 2019 equates to 7.0 ppb, as shown in Table 13.

TABLE 13: PAST AND PROJECTED LEAD CONCENTRATIONS IN FIRST DRAW SAMPLES FOR HOMES WITH A LEAD SERVICE LINE PROTECTED BY PH/ALKALINITY CORROSION CONTROL TREATMENT ONLY (NO FILTER)

Time Period	Average Lead Concentration (ppb)	90th Percentile Lead Concentration (ppb)
Pre-Variance: 1997 to 2019 (average)	6.7	14.0*
Projected Post-Variance: 2021 & Beyond	3.4	7.0

*Based average of all 90th percentile lead concentration reported for each monitoring period from 1997 to 2019.

How will Denver Water verify corrosion control is working?

Under the LRP, Denver Water will continue to sample at Tier 1 homes with a) lead service lines and b) copper pipes with lead solder constructed between 1983 and 1987. Samples will be collected from an unfiltered tap (by-passing the filter if used to remove lead). Samples will be collected twice a year using the sampling protocols described in the Lead and Copper Rule.

The success of the pH/alkalinity corrosion control treatment depends on Denver Water's ability to maintain a target pH within ±0.2 standard units in water leaving the treatment plants and ±0.3 standard units in water in the distribution system. Additionally, Denver Water will maintain a minimum alkalinity level to help stabilize pH in the distribution system.

Denver Water will use its real-time monitoring system to track and trend pH, alkalinity and conductivity (where on-line instrumentation is available) at the treatment plants and in the distribution system. Figures 27 and 28 display the existing monitoring screens, one for the overall distribution system and the other for one of the treatment plants, respectively.

[28] As discussed at the end of Section I.

FIGURE 27: REAL TIME DISTRIBUTION SYSTEM CORROSION CONTROL MONITORING

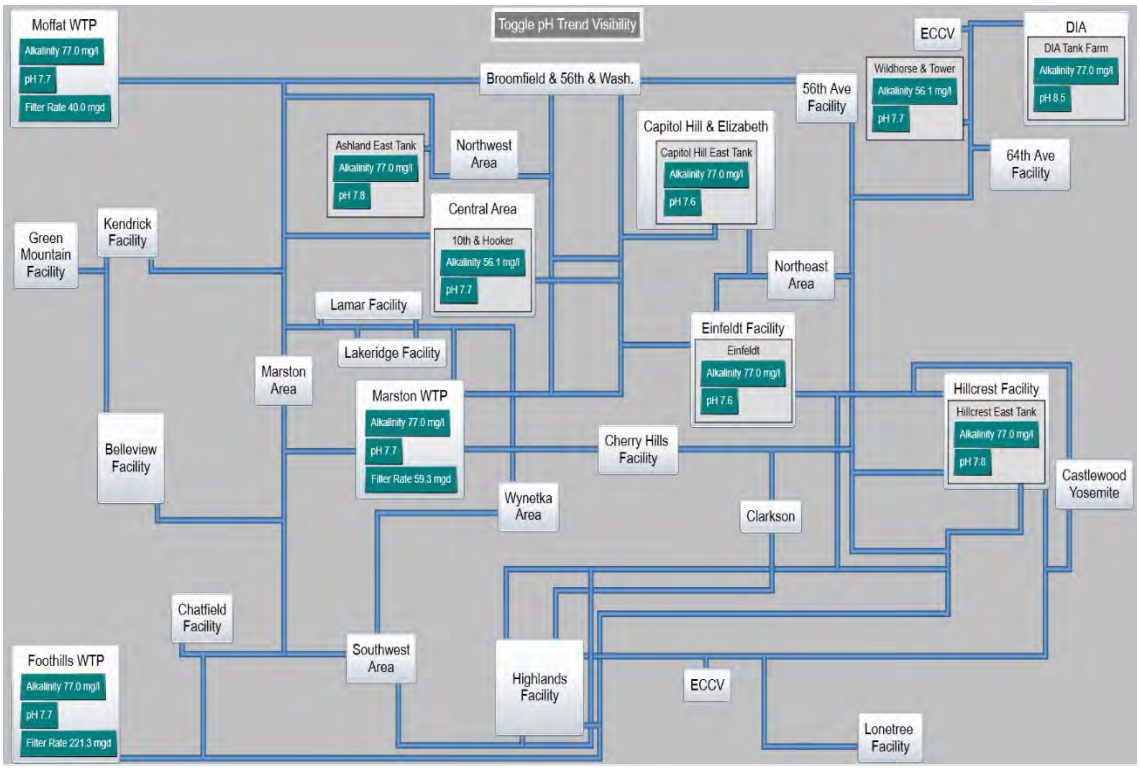
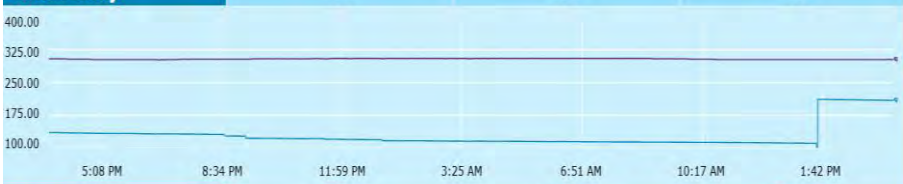


FIGURE 28: REAL TIME TREATMENT PLANT CORROSION CONTROL MONITORING

Corrosion Control Operating Conditions / Boundaries / Excursions

Parameter	Normal Range	Boundary	Excursion	Actual Value
Orthophosphate	2-3 mg/L	1.5 - 1.9 mg/L 3.1 - 3.5 mg/L	< 1.5 mg/L <> 3.5 mg/L	(Future) FWC
pH	7.70 - 7.80 +/- 0.2 Units - Treatment +/- 0.3 Units - Distribution	7.65 - 7.69; 7.81 - 7.85	< 7.65 > 7.85	FWC
Conductivity	TBD	TBD	TBD	Raw & FWC
Alkalinity	> 45 mg/L	< 40 mg/L	< 35 mg/L	e.RIS Dashboard
DIC	> 12 mg/L	10 - 12 mg/L	< 10 mg/L	e.RIS Dashboard
CSMR	< 0.4	0.4 - 0.6	> 0.6	e.RIS Dashboard

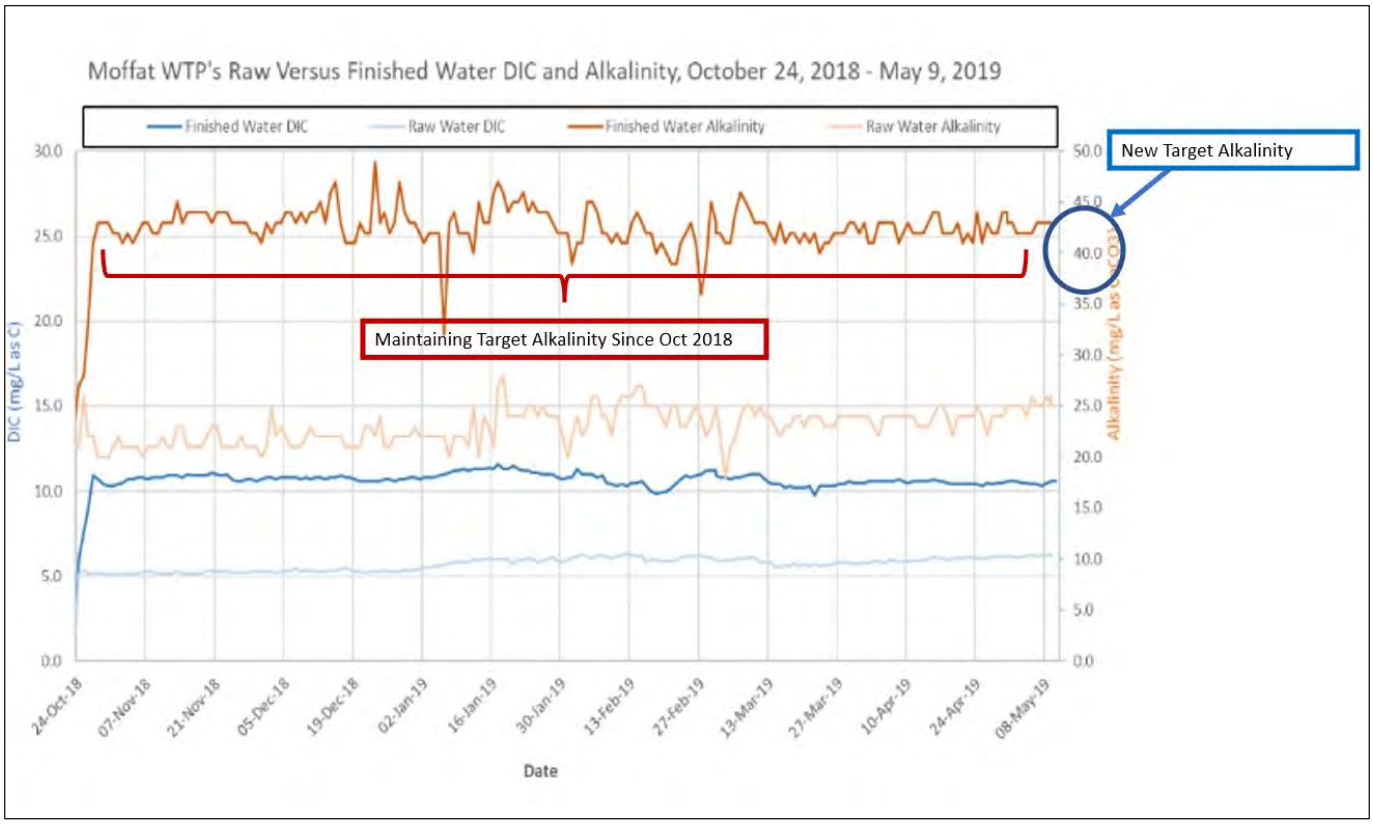


Will Denver Water have to make modifications to the treatment plants to support pH/alkalinity adjustment for corrosion control?

As a result of the 2018 CDPHE designation of orthophosphate as the optimal corrosion control treatment, Denver Water was required to install additional corrosion control treatment systems to support orthophosphate dosing, which are under construction and will be ready for use in early 2020. Portions of those systems can also be used for adjusting pH/alkalinity corrosion control, and therefore no additional modifications are necessary.

Additionally, Denver Water will have to maintain a minimum monthly average alkalinity to support consistent pH levels in the distribution system. Denver Water operates three potable water treatment plants: Moffat, Foothills and Marston. Only the Moffat Treatment Plant requires daily alkalinity control due to the low alkalinity Fraser River source water that feeds the plant. In 2018, the Moffat Treatment Plant's finished water alkalinity was raised to 40 mg/L as $CaCO_3$ which has been successfully maintained since implementation, as shown in Figure 29.

FIGURE 29: ALKALINITY IN RAW AND FINISHED WATER AT THE MOFFAT TREATMENT PLANT



The other two treatment plants receive raw water from the South Platte River and/or Marston Reservoir, which are moderately high in alkalinity, averaging between 50 mg/L and 70 mg/L as $CaCO_3$ most of the year. The alkalinity in the South Platte River can drop to levels between 20 and 35 mg/L as $CaCO_3$ for up to three weeks during runoff season (May to July). During the two to three weeks of low alkalinity that occur in the South Platte River, raw water intake can be

shifted to Marston Reservoir, as needed, to maintain a minimum monthly alkalinity in the distribution system.

Table 14 shows Denver Water's proposed water treatment objectives to support pH/alkalinity corrosion control. Denver Water will work with CDPHE during the first year of implementation to optimize pH adjustment and identify the final proposed pH and alkalinity targets.

TABLE 14 PROPOSED TREATMENT OBJECTIVES FOR PH/ALKALINITY CORROSION CONTROL TREATMENT

Proposed Water Quality Standards for Treatment Plants and Distribution System	
Treatment Plants at Point of Entry*	• pH = monthly average 8.8 standard units, with an operating range of 8.6 to 9.0 • Alkalinity = minimum monthly average of 30 mg/L as $CaCO_3$
Distribution System*	• pH = monthly average 8.8 standard units, with an operating range of 8.5 to 9.1

*Treatment objectives for pH and alkalinity adjustment to be approved by CDPHE.

Denver Water has also undertaken some changes in the types of chemicals it uses at the treatment plants to maintain a low chloride-to-sulfate mass ratio. Chemicals such as liquid ammonium sulfate and acidified alum (containing 5% sulfuric acid) help reduce the chloride-to-sulfate mass ratio, which at times can peak above 0.6 in the finished water from the two treatment plants that use the South Platte River for their source. Although much higher chloride-to-sulfate mass ratios (1+) are indicative of corrosion, Denver Water is doing what it can to keep the ratio at or below 0.6.

Will the proposed pH/alkalinity changes affect the release of lead within a service line?

During the pipe rack studies, Denver Water also evaluated the corrosion control coatings (or "protective scale") that formed on the inside walls of the service lines under each of the treatment conditions: (1) the existing pH 7.8, (2) the increased pH of 8.8 and (3) orthophosphate at 3 mg/L. The purpose of the protective scales is to prevent the migration of lead from the service line into the water.

Different protective scale layers will form based on the specific chemistry conditions established within the service line. The analysis found that the coating within Denver Water service lines, at pH 7.8, is a lead carbonate coating, or species, called hydrocerussite. Increasing the pH to 8.8 resulted in the formation of a similar type of primary hydrocerussite coating that has a lower solubility and is thus more protective than the coating formed at pH 7.8. Similar results were seen in a study of water with dissolved inorganic carbon concentrations similar to Denver Water. While there can be differences between theoretical solubility models and actual field observations, pH/alkalinity adjustment systems most frequently match the predicted phase, whereas phosphate-based systems are the least predictable.[29]

[29] Tully, J., DeSantis, M.K., Schock, M.R., 2019. Water quality–pipe deposit relationships in Midwestern lead pipes. AWWA Water Science 1, e1127.

Based on these results and the observed lead levels coming from the pipe racks when transitioning from a pH of 7.8 to 8.8[30], the proposed high pH adjustment creates favorable conditions for the formation of less soluble coatings that are more protective of public health, even during the transition between pH treatment conditions.

How does Denver Water propose to maintain and optimize corrosion control using pH/alkalinity adjustment?

For optimal corrosion control, Denver Water will:

- Incorporate continuous on-line corrosion control SCADA (supervisory control and data acquisition) monitoring that tracks and trends pH, alkalinity, dissolved inorganic carbon, conductivity, chlorine residual and temperature at the treatment plants and seven key locations throughout the distribution system, with clear action levels and response measures to be taken if the parameters are out of bounds (See Figure 26).
- As part of the corrosion control upgrades at the treatment plants, automated pH dosing control loops will be installed by March 2020 to maintain constant feedback and adjustment of pH in the finished water leaving all treatment plants.
- Complete LCR sampling of Tier 1 homes.
- Monitor lead concentrations in LCR compliance and customer requested samples on a monthly basis, looking for upward trends and adjusting treatment systems or operating practices to reverse trends, where possible.
- Monitor the chloride-to-sulfate mass ratio and adjust treatment chemical dosing to target a ratio at or below 0.6.
- Continue daily communications between treatment plants to review corrosion control targets and performance.
- Collect a weekly sample from the point of entry of each treatment plant and test for pH and alkalinity.
- Complete monthly sampling (pH, alkalinity) at 25 representative sites from across the Denver Water service area; the sites are yet to be determined and will be agreed upon as part of the CDPHE modification approval.
- Continue quarterly profile sampling at volunteer homes, with both lead and copper service lines, to gauge corrosion control effectiveness during the first year of implementation of the variance.
- Strive to consistently hit water quality goals for finished water leaving the treatment plants, as proposed in Table 14.

[30] See Appendix II.B.

Are there other water quality considerations?

Nitrification is known to occur seasonally in the Denver Water distribution system. The addition of orthophosphate can increase nitrification in cases where phosphorus is the limiting nutrient. This is likely to be the case with an alum coagulated first-use mountain water source like the source Denver Water uses. Nitrification is a biological process that produces acid as a by-product, which can lower pH, particularly in poorly buffered water. The low pH can, in-turn, result in increased lead release. Waters with pH above 8.3 have been shown to inhibit nitrification.[31] If the variance is granted, nitrification should not be a concern at the proposed pH target of 8.8 standard units.[32] To verify this, Denver Water plans to:

- Complete distribution system modeling, evaluating pH, nitrification, disinfection by-products and water age by January 31, 2020.
- Subsequently develop and implement a Nitrification Control Plan by July 2020, detailing sampling, monitoring and flushing plans for nitrification control.

It is important to note that Denver Water's disinfection by-products in the distribution system (e.g., total trihalomethanes and haloacetic acids) are and have historically been less than 50% of the existing regulations of 80 ppb and 60 ppb, respectively. These low levels are accomplished as a result of using chloramine as a secondary disinfectant rather than free chlorine. If the variance is not granted, then Denver Water will increase the amount of chlorine and ammonia added to the treated water to reduce the nitrification potential caused by orthophosphate.

III.F Learning by Doing

The Learning by Doing approach uses data in collaborative reoccurring cycles of collective inquiry and action to achieve improved LRP results. The process used in the Learning by Doing approach involves the following steps:

1. Gather evidence of current results and collaboratively evaluate with stakeholders.
2. Develop strategies and ideas to build on strengths and improve results in challenging areas.
3. Implement the strategies and ideas.
4. Analyze the impact of the changes to discover what was effective and what was not.
5. Apply new knowledge in the next cycle of continuous improvement.

Through Learning by Doing, Denver Water proposes to work collaboratively with CDPHE, EPA and other stakeholders to find new ways to efficiently implement the LRP while continuously improving upon past results with a goal of surpassing the monitoring and reporting requirements.

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[31] AWWA M56 Nitrification Prevention and Control in Drinking Water (2nd Edition), 2013.
[32] See Appendix III.E.3.

Denver Water and other stakeholders have a mutual interest in ensuring that this goal is achieved.

To implement the Learning by Doing concept, Denver Water will form an LRP Advisory Committee to inform Denver Water on more efficient and effective ways to implement the LRP to achieve the variance metrics in accordance with the terms and condition in Appendix IV.A. The LRP Advisory Committee will provide recommendations on a variety of community, public health and environmental considerations related to the implementation of the LRP.

Denver Water proposes the LRP Advisory Committee membership include representation from:

- EPA.
- CDPHE.
- Denver Water distributors.
- Organizations that advocate for health equity and environmental justice.
- Representatives from communities across Denver Water's integrated service area with specific focus on representation from underserved communities.
- Wastewater dischargers.
- Environmental organizations and/or watershed groups.
- Medical and/or public health agency professionals.

The LRP Advisory Committee will be formed no later than six months after the variance request is approved.

The LRP Advisory Committee will operate with the following goals:

- Identify, through consensus, voluntary efforts that would improve upon results achieved by the LRP.
- Provide technical input on implementation of the variance and efforts.
- Achieve consensus and seek to resolve disagreements.
- Explore methods to achieve an even greater degree of efficiency than projected in the LRP.

In implementing the Learning by Doing concept as part of the LRP, the following principles will be used to build and promote a stable, permanent, relationship that respects the interests and legal responsibilities of the parties, while achieving the goal of the program:

- All of the advisors will work in good faith to implement the Learning by Doing approach in a way that complements the LRP and its terms and conditions.

- The Advisory Committee will not seek a culprit for a failure to improve upon results but will provide a mechanism to identify issues of concern and focus available resources to address those issues.
- Because resources available to the Advisory Committee are limited, the use of those resources will be prioritized as part of the Learning by Doing effort.
- If the Advisory Committee desires additional resources beyond what Denver Water has made available, the Advisory Committee will work with other stakeholders and granting agencies to identify sources of funding to provide additional resources. If mutually defined additional resources are still desired, the Advisory Committee may agree to consider contributing more of their own resources on a case-by-case basis and within the context of these principles. Each party retains its sole discretion to provide any additional resources without further judgment or prejudice by the other parties.

The industry's understanding and utilities' experience with corrosion control and replacing lead service lines is rapidly evolving. As the industry's understanding advances over the next 15 years, Denver Water will leverage the lessons learned through the Learning by Doing element of the LRP.

As part of its existing day-to-day operations, Denver Water has a robust oversight process in place. Results from sampling from the water system and operations data from the treatment plants are used to monitor performance in conjunction with results from its LCR monitoring pool. This will allow Denver Water to identify performance issues early and have data available to take proactive steps to remain below the LCR action level.

IV. MONITORING AND REPORTING

Denver Water has developed proposed Terms and Conditions to govern the activities and outcomes of the variance as presented in the Lead Reduction Program Plan.[33] The proposed Terms and Conditions include monitoring and reporting requirements and clearly defined metrics to define whether Denver Water's LRP is being implemented as intended.

How Denver Water will evaluate performance of the LRP

For five of the six elements that together make up the LRP (COE Plan, LSL Inventory, Filter Program, ALSLR Program and Corrosion Control Treatment), the proposed program metrics will be used to determine whether the LRP is successfully being implemented (see Table 15). Because Learning by Doing is a strategy, and not an outcome in itself, performance metrics are not identified for this element of the LRP.

TABLE 15: LEAD REDUCTION PROGRAM EVALUATION FOR COMPLIANCE

Element	Compliance	Correction Active	Failure to Meet Condition
Lead Service Line Inventory	Must investigate a minimum of 1.4% of total LSLs in inventory per year.	• Achieve compliance by following year. • Provide notice of corrective action to customers with filters.	If less than 1.4% investigations occur for three program years: • Notice to all customers.
Filter COE	Outreach and education materials provided each year to at least 95% of households enrolled in the Filter Program.	• Must achieve compliance by following year. • Notice to customers with filters.	If Denver Water fails to provide outreach and education materials to at least 95% of households enrolled in the Filter Program for three years: • Notice to all customers.
Filter Program	Achieve minimum filter adoption rate of 65% per year.	• If filter adoption rate is less than 65% in a year, increase outreach and education efforts to improve filter use. • Notice of corrective action to customers with filters.	If failure to achieve 65% adoption rate for three years: • Termination of variance. • Notice to all customers.
Accelerated Lead Service Line Replacement	Must achieve 7.0% cumulative annual average replacement rate each year.	• Achieve compliance by following year. • Notice to customers with filters.	If less than 7.0% of lead service lines are replaced for three years: • Termination of variance. • Notice to all customers.
Corrosion Control Treatment	Lead and Copper Rule sampling results remain below action level for lead.	• Must adjust corrosion control and distribution management. • Customer education and notice.	If action level exceeded for two monitoring periods: • Must provide customer notice. • Termination of variance unless CDPHE requires otherwise.

[33] See Appendix IV.A.

The performance metrics presented in Table 15 are designed to communicate regulatory compliance and the overall effectiveness of the LRP, including corrective action(s) to restore compliance, termination of the variance (i.e., implement orthophosphate) and completion of the variance (i.e., all known lead service lines have been replaced).

Routine reporting

Denver Water will prepare annual compliance reports for CDPHE and EPA using the performance metrics described in the proposed Terms and Conditions.

Data will be provided such that is easily accessed via the web in a public dashboard of performance in addition to being presented to CDPHE every six months. Information that will be provided in the dashboard will include, but is not necessarily limited to, the following:

- COE program plant, contacts, and media activity.
- Lead service line inventory status and access to maps.
- Annual number of lead service lines replaced and total to date.
- Filter Program enrollment, survey responses, and filter adoption rate.
- Summary of issues and concerns from previous report reviews that Denver Water is working to correct.

The annual or end-of-year report will include:

- Key performance parameters for the LSL Inventory, filter adoption rate, and the ALSLR Program performance.
- Quantitative data to describe COE outreach, contacts, etc. and qualitative evidence, which includes documentation of stakeholder feedback, common themes, stories, etc.
- Number of partial lead service line replacements completed each program year.
- Names and addresses of property owners who have refused consent to allow replacement of their lead service lines in a given year (referred to as the Service Line Refusal List).
- Filter adoption rate and number of lead service line replacements in vulnerable communities.

V. HEALTH EQUITY AND ENVIRONMENTAL JUSTICE

The purpose of this section is to describe how Denver Water intends to address health equity and environmental justice in the Lead Reduction Program and within the specific program elements.[34]

The following HE&EJ principles inform the foundational basis for the LRP:

- All people should have the opportunity to attain their full health potential regardless of income, education, age, disability, sexual orientation, gender identity, race or ethnic background or geographic location.
- Conditions in the environments in which people are born, live, learn, work, play and age affect a wide range of health and quality-of-life outcomes and risks. These factors are known as social determinants of health.
- To achieve equity and justice, societal structural inequities (attitudes, policies and practices that create or reinforce patterns of inequity in communities) must be addressed.
- No group of people should bear a disproportionate share of the adverse environmental consequences of industrial, governmental and commercial operations or policies.
- People should have access to information and an adequate opportunity to participate in decisions about activities that may affect their environment and/or health. Meaningful decisions are made with the participation of affected citizens.
- While equal treatment of all people is often viewed as the goal, to address health equity and environmental justice, all people must be treated equitably. Equitable treatment means the conscious and deliberate investment of additional resources to populations experiencing inequity.

Denver Water consulted with EPA, CDPHE, the City and County of Denver and other jurisdictions to prioritize the integration of HE&EJ principles into the LRP. As a result of this consultation process, Denver Water received valuable input, including the following recommendations:

- Coordinate with the Offices of Health Equity for CDPHE and the City and County of Denver to identify new sources of data to implement HE&EJ principles in the COE Plans, Filter Program and ALSLR Program.
- Obtain language breakdown by neighborhood to meet translation and interpretation needs to provide effective COE materials and increase the rate of filter use.
- Tailor outreach efforts to take into account the linguistic and cultural needs of each neighborhood.

[34] This list is informed by CDPHE's June 2016 policy incorporating HE&EJ principles.

- Design the predictive model to prioritize vulnerable populations in the planning and implementation of the LRP.
- Collaborate with community organizations and other representatives to identify implementation strategies that are the least disruptive to the neighborhood.

Denver Water will continue to consult and collaborate with the organizations listed above and other HE&EJ experts, stakeholders, community members and customers to continually improve upon integration of the HE&EJ principles with the LRP.

Incorporation of HE&EJ principles in LRP planning

Experience from other jurisdictions suggests that median income level alone does not fully incorporate the HE&EJ principles and other weighting factors need to be considered. The predictive model is combined with weighted criticality factors in a risk model to address equity in LSL replacement throughout the integrated system. The criticality factors and weights were established in consultation with EPA and CDPHE.[35] For example, individual properties with a high risk of lead exposure as well as geographic groupings of households that collectively represent a high risk of lead exposure are identified in the predictive model as factors to support annual planning efforts for the COE Plans, Filter Program and the ALSLR Program. One benefit of using the risk model is that a sensitivity analysis can be performed on the results to test the assumptions for the criticality factors, their application and weightings on the prioritization results.

Denver Water will take the following steps in applying the above principles into the LRP:

- Start with collating available data to understand community demographics, language and culture, health risk factors and potential challenges to project acceptance.
- Use these data to develop targeted communications plans and LSL replacement schedules aimed at reaching vulnerable populations at greatest risk from lead exposure.
- Follow with linguistically and culturally appropriate outreach and actions to reach the communities most at risk from lead exposure.
- Use the Learning by Doing approach to address challenges and improve effectiveness of outreach in hard to reach communities.

Denver Water will create equitable access for all communities within the integrated system so that all residents will benefit from the reduction in lead exposure.

[35] See Section III.B and Appendix III.B.3.

Annual updates

Each year, Denver Water will update the ALSLR Program prioritization based upon work performed the previous year and new information learned from outreach efforts, including the filter survey responses. As part of this update, Denver Water will adjust the prioritization process and logic (i.e., criteria and weighting factors) used to plan and implement the LRP with the aim of creating a robust process coordinated in a manner that considers existing community projects and needs. Denver Water will use a similar strategy for the initial filter distribution as part of the Filter Program as well as in executing and updating the COE Plans.

The following strategies and best practices for vulnerable populations allows all Denver Water households to access the benefits of the Lead Reduction Program[36]

- **Soliciting feedback from impacted communities on lead reduction strategies**
  - Incorporate comments on the Draft Lead Reduction Program Plan.
  - Seek feedback at ongoing community presentations and events throughout impacted area.
  - Consider the comments received from the EPA 30-day public input period.
  - Include community representation in the LRP Advisory Committee.
- **Prioritizing implementation in the communities most impacted**
  - Reach households and geographic areas at most risk to lead exposure first, including schools, child care providers and expecting and existing families with formula-fed infants/ children up to age 2.
- **Removing economic barriers**
  - Allocate the necessary financial resources for the 15-year LRP.
  - Replace of the full lead service line at no cost to the property owner.
  - Provide water filters and replacement cartridges distributed for free to households.
- **Removing communication barriers**
  - Make available communications, education and outreach materials in the languages used by the communities impacted the most by lead exposure.
  - Use different methods to make information accessible (e.g., offline and available at facilities such as the library or recreation center).
  - Partner with community groups to distribute filters and encourage proper use.
- **Targeting rental properties in the LRP**
  - Provide water filters, replacement cartridges and education materials to tenants in rental properties.
- **Creating opportunities for community workforce development**
  - Partner with local workforce development organizations in the implementation of the LRP to provide training and employment for community members.
- **Addressing all sources of lead exposure**
  - Collaborate with other agencies and groups to holistically manage lead from paint, manufactured goods and other sources in addition to lead in drinking water infrastructure.

[36] Adapted from the Human Impact Partner's "Achieving Equity in Lead Poisoning Prevention Policy Making: Proceedings from a Consensus Conference," May 2019. See HumanImpact.org/LeadPolicyEquity

Addressing HE&EJ and all sources of lead exposure

Data from Denver Department of Public Health and Environment indicate that in addition to drinking water, other sources of lead exposure adversely affect Denver communities, including but not limited to lead paint, dust, soil, spices and household products imported from abroad and exposure to lead in countries where regulations for lead use are less stringent than those in the United States. Denver Water views the LRP as an opportunity to raise awareness about the risks of lead exposure and to collaborate with public health experts, medical providers, schools and community groups to reduce lead exposure from all sources, particularly in vulnerable households.

VI. PROGRAM IMPLEMENTATION SCHEDULE

The schedule for the LRP as shown in Table 16 is based on a late 2019 or early 2020 variance approval. Final schedule dates will be secured upon approval of the variance.

TABLE 16: PROGRAM IMPLEMENTATION SCHEDULE

Phase I – Submission	
September 2019	Denver Water submits Final Variance Request, Lead Reduction Program Plan and Treatment Modification Request to EPA and CDPHE and awaits decision.
Phase II — Implementation	
Late 2019/Early 2020	**Upon approval of the variance:** • Begin region wide Communications, Outreach and Education including: - Tier II Notification to all customers with known, suspected and possible lead service lines. - Publications of service line inventory map. - Community meetings. • Begin distribution of filters. • Notify customers that are identified for LSL replacement in first the year of the LRP and ALSLR Program. • Begin corrosion control treatment per CDPHE's approved schedule. **First Program Year Begins** • 91 days after approval of the variance, Lead Reduction Program begins accelerated lead service line replacement and the 15-year program begins.
Phase III — Maintenance	
Annually	**Annual compliance meetings with EPA and CDPHE:** Review progress report and develop corrective actions for non-compliant element(s). Reports will be available 35 days following the end of the program year.
15 Years After First Program Year	All lead service lines within service area have been replaced. Replacement cartridges provided for up to six months after the line is replaced.

VII. COST IMPACTS

In addition to assessing public health and environmental impacts, Denver Water estimated the life cycle costs associated with both alternatives, the variance and orthophosphate.[37] The MOU stakeholders, which include Denver Water, CDPHE and regional stakeholders, also contributed capital and operating cost data associated with downstream impacts to regional stormwater entities, wastewater utilities, water utilities, watershed basin and recreational entities.

Stormwater, watershed basin and recreational cost impacts were included because 40% of Denver Water's treated water supply is used for irrigation between the months of May and October. Under the orthophosphate alternative, a portion of the orthophosphate added to drinking water for corrosion control will accumulate in soil, runoff into stormwater collection systems, reach streams and eventually load downstream reservoirs.

The Denver metro area is situated in a high-elevation, arid environment that requires regional water entities to capture snow melt and stormwater runoff in nearby reservoirs, typically between the months of May and August, which is then used during the remainder of the year for drinking water supplies or water rights exchanges. Warm temperatures and year-round sunny conditions make these reservoirs susceptible to algal blooms, a condition expected to be exacerbated with additional phosphorus loading in the watershed.

Capital and operating costs were developed for (but are not limited to):

- Adding treatment processes and/or increasing chemical dosing at wastewater treatment plants to remove the additional phosphorus loading.
- Adding corrosion control treatment processes at connected water utilities receiving a portion of their supply from Denver Water.
- Adding treatment processes or infrastructure at downstream drinking water treatment plants to combat taste and odor compounds and potential cyanotoxins resulting from algal blooms.
- Accounting for the loss of revenue at regional reservoirs due to closures or restrictions during algal blooms.
- Adding stormwater infrastructure or street sweepers to remove phosphorus from stormwater pathways.
- Treating regional reservoirs with alum to bind up phosphorus to make it unavailable to algae as a food source.
- Increasing education and outreach to reduce other sources of phosphorus loading in the watersheds.

[37] Details are provided in Appendix VII.A.

Both low and high cost estimate ranges were calculated to reflect different assumptions for the timing and need of various capital projects.[38] For example, an underlying assumption that CDPHE and the Water Quality Control Division would allow wastewater and stormwater providers until the early to mid-2030s to remove the phosphorus loading from orthophosphate addition would result in delayed and reduced life-cycle costs for those entities but added interim costs for downstream reservoir and recreational entities to account for impacts up through 2030 or 2035.

Other major assumptions driving costs included the duration to replace lead service lines under either scenario—the variance approach (15 years) or orthophosphate for corrosion control (50 years or more).

Per Figures 30 and 31, life-cycle costs have been calculated using two slightly different approaches. Figure 30 reflects CDPHE's request to include only the incremental costs, above existing practices or already planned projects, necessary to implement either the variance or orthophosphate alternatives. Figure 31 reflects Denver Water's approach to includes costs for replacement of lead service lines, whether this occurs over 15 years under the variance alternative or over 50 years under the orthophosphate alternative. Denver Water believes customers should understand the full cost impact under either alternative. Both figures represent total costs (solid bars) plus net present value costs (striped bars) to reflect the time value of money.

As seen in Figure 30, the estimated net present value for the variance request ranges between $265 million and $362 million (depending on assumptions made for other capital projects), while the net present value for orthophosphate was estimated to range between $322 million and $505 million.

Denver Water replaces lead service lines at a rate of 700 per year based on existing operations, with an additional 500 per year replaced through redevelopment. To replace all lead services within 50, Denver Water would have to increase the rate of replacement from 700 per year to 780 per year. These costs are included in the amounts shown in Figure 31.

Using the upper estimate of the net present values (blue striped bars), Figure 32 demonstrates the cost splits among regional stakeholders depending on the alternative under consideration. Orthophosphate costs would be spread among many different entities whereas the variance costs would be largely supported by Denver Water. There is significant overlap in customers between Denver Water, Metro Wastewater and City and County of Denver Stormwater. Costs under either alternative will be supported by many of the same people.

[38] See Appendix VII.A for detailed cost information.

FIGURE 30: COST COMPARISON BETWEEN VARIANCE AND ORTHOPHOSPHATE ALTERNATIVES, EXCLUDING CURRENT LEAD SERVICE LINE REPLACEMENT COSTS

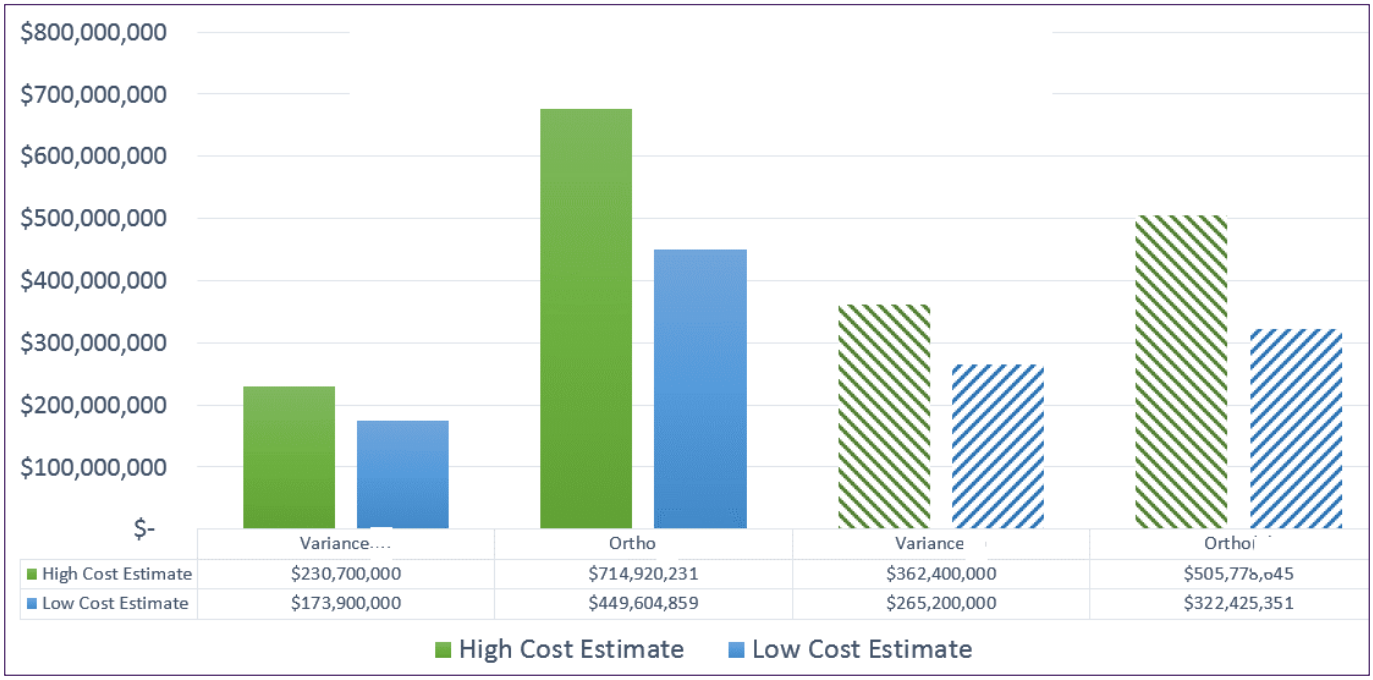


FIGURE 31: COST COMPARISON OF VARIANCE AND ORTHOPHOSPHATE ALTERNATIVES (INCLUDING EXISTING LSL REPLACEMENT COSTS)

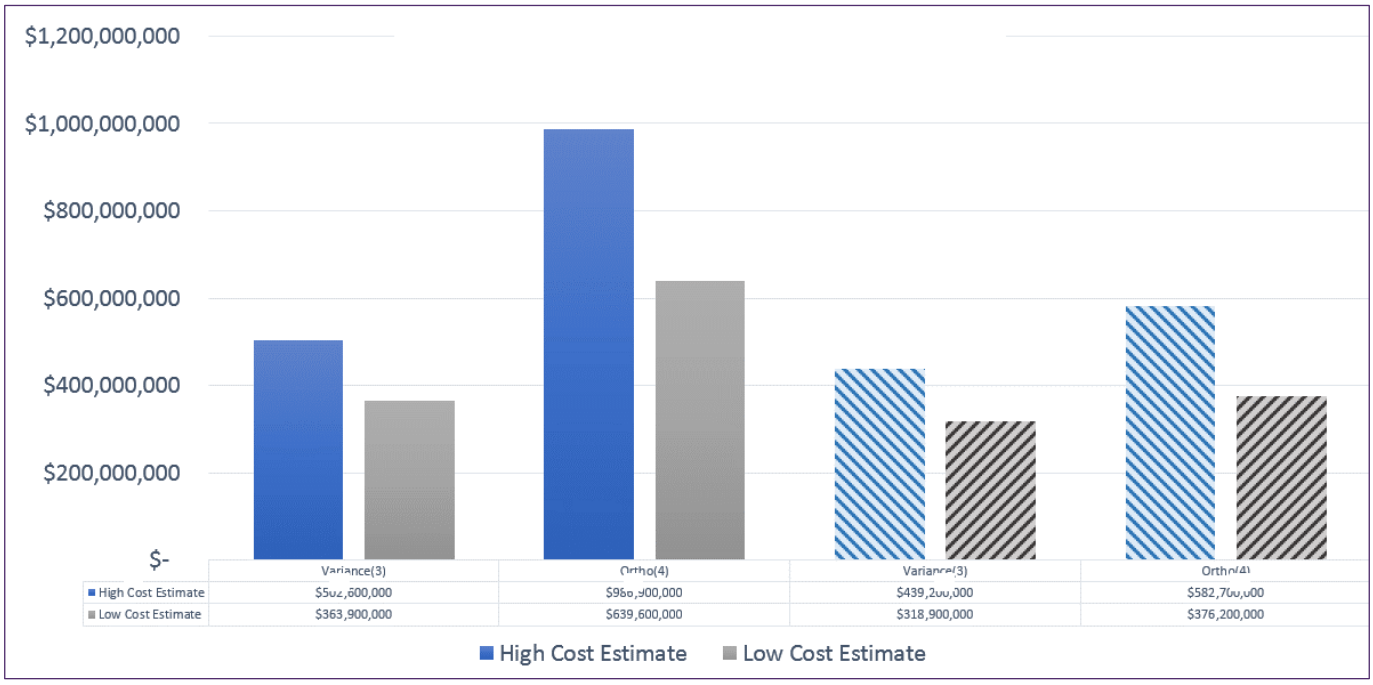
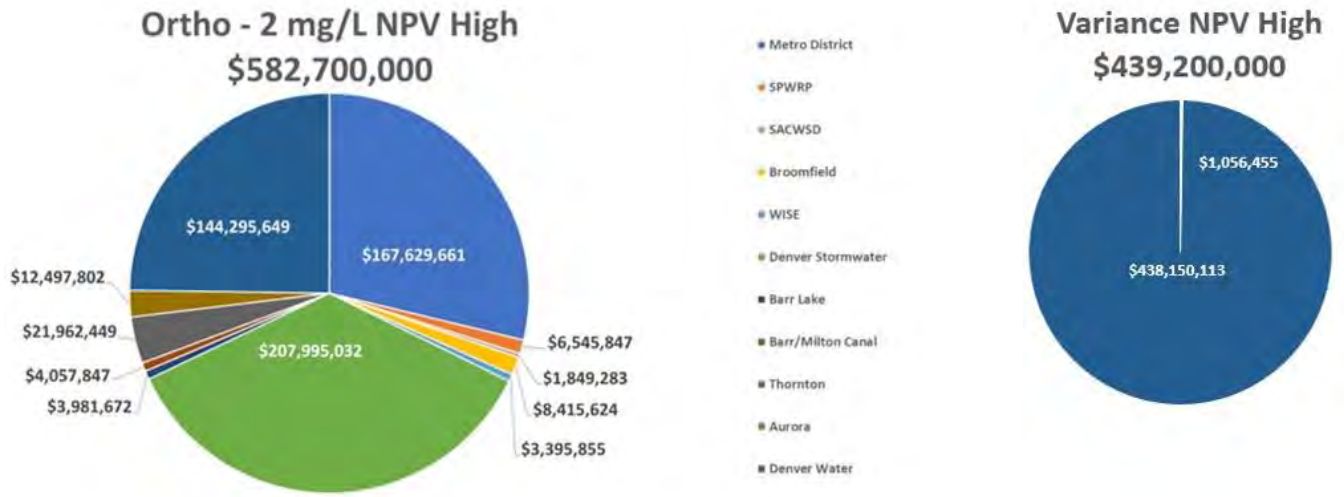


FIGURE 32: HIGH COST, NET PRESENT VALUE ESTIMATE COMPARISON OF ORTHOPHOSPHATE AND THE VARIANCE (INCLUDING EXISTING LSL REPLACEMENT COSTS)



Based on the cost estimates presented herein and in detail in Appendix VII.1, the variance cost is estimated to be less than the orthophosphate alternative while providing a holistic solution that replaces all known lead service lines 35 years sooner than the orthophosphate alternative. Other benefits include:

- The variance allows Denver Water greater flexibility with new water sources within 15 years because the lead service lines, the major source of lead contamination in the water, will be replaced. With ever increasing stresses on the Colorado River, Denver Water will have to rely more frequently on maximum utilization of its existing supplies east of the continental divide, including reuse. Reducing limitations on the type of supply alternatives as a result of corrosion control concerns allows Denver Water to be more adept at responding to ever increasing water supply constraints.
- Downstream reservoirs, including those owned by Denver Water, will see lower phosphorus loading between 2020 and 2035.
- According to the 2017 Health Impact Partners report,[39] every $1.00 spent on replacing lead service lines eventually results in a $1.30 net gain to the community attributable to future income gains and reduced public health costs. Based on the total variance costs (solid bars) presented in Figure 31, this equates to a return on investment of $471M to $652M for the Denver metro area.

[39] Human Impact Partner's "Achieving Equity in Lead Poisoning Prevention Policy Making: Proceedings from a Consensus Conference," May 2019. See HumanImpact.org/LeadPolicyEquity

VIII. GLOSSARY OF DEFINITIONS

Abbreviations, Acronyms or Terms	Abbreviations, Acronyms or Terms Descriptions
90th Percentile	The 90th percentile refers to the concentration below which 90% of samples are measured for a given monitoring period. Alternatively, 10% of samples are measured with lead concentrations above the concentration associated with the 90th percentile.
Action Level	As used in the Lead and Cooper Rule, if the lead concentration exceeds the action level, addition actions are required to control corrosion. Also referred to as the AL.
Adoption	For the purpose of the filter survey means that the customer enrolled in the Filter Program is using a filter for drinking water and cooking.
ALSLR Program	Refers to the Accelerated Lead Service Line Replacement Program.
Blood Lead Level (BLL)	A blood test can be given to measure the level of lead in an individual's blood. Measured in unit of micrograms of lead per deciliter of blood (ug/dL).
COE Plans	Refers to the Communications, Outreach and Education Plans associated with the Lead Reduction Program.
Contact	Refers to direct mailing, water bill inserts, door hangers, in person contact, email, phone call, educational materials accompanying filters and cartridges, or any other direct communication channels identified in Denver Water's communications, outreach, and education plans.
Corrosion Control Treatment (CCT)	Refers to corrosion control treatment, such as by orthophosphate addition or pH/alkalinity adjustment.
Coupon Testing	Refers to bench-scale laboratory testing with metal coupons and is used to estimate the effectiveness of corrosion control treatment. It is also referred to as immersion testing.
Filter Program	Refers to the distribution of filters and replacement cartridges to Denver Water customers with a known, suspected or possible lead service and the related survey for filter adoption.
Households	Refers to any single family or multi-family unit in Denver Water's service area enrolled in the Filter Program.
Integrated System	An integrated system is a system where a wholesale system and one or more consecutive systems have distribution systems that are physically connected, where the wholesaler has assumed responsibility for compliance with one or more of the regulatory requirements applicable to the supplier responsible for the consecutive system.

Abbreviations, Acronyms or Terms	Abbreviations, Acronyms or Terms Descriptions
Known LSL	100% direct evidence documenting that the material of the service line is lead.
LCR	Lead and Copper Rule.
LSL	Lead Service Line.
Lead Service Line	Means a water service line made of lead that connects the water main to the building inlet and any lead pigtail, gooseneck or other fitting that is connected to such lead line.
LSL Inventory	An inventory of the material used for each non-irrigation service line that is a known, suspected, and possible LSL associated with a customer premise within Denver Water's system. The inventory includes private service lines and all LSLs in the service areas of all distributors who are a part of the system.
LSL Replacement	Lead Service Line Replacement.
LRP	Lead Reduction Program.
Non-detect	Means that the concentration of a given compound is too low to be measured. The method detection limit refers to the lower limit of an analytical method below which a compound cannot be measured by that method.
Non-Lead LSL	The material of the service line is 100% confirmed to be non-lead based on direct evidence or statistically defensible factors supporting categorization as a non-lead service line.
OCCT	Optimal Corrosion Control Treatment.
Orthophosphate Treatment	Phosphate-based treatment as described in the Colorado Department of Public Health and Environment's March 20, 2018 letter to Denver Water designating orthophosphate as optimal corrosion control treatment.
Possible LSL	50% likelihood of the service line material being lead, as some data may be conflicting or missing but there is not enough information to confirm a non-lead service line.
Program Year	Has the same meaning as calendar year.
Public Notice	For the purpose of this variance, means a Tier II public notice as described in Rule 11.26 of the Colorado Primary Drinking Water Regulations, 5 CCR 1002-11, with messaging approving by CDPHE.
Suspected LSL	80% to 90% likelihood of the service line material being lead, based upon available data (i.e., homes built prior to 1951).

Abbreviations, Acronyms or Terms	Abbreviations, Acronyms or Terms Descriptions
Threshold for Filter Adoption Rate	Refers to the minimum percentage of households that use filters (i.e., filter adoption rate) such that the LRP is considered equivalent to orthophosphate.
Tier 1 Site	Tier 1 homes as defined in the Lead and Copper Rule. A Tier 1 home is a sample site that is a single-family structure built between 1983 and 1987 that (1) contains copper pipes with lead solder, (2) contains lead pipes and/or (3) is supplied by a lead service line.
Tier II Public Notice	Tier II public notice as described in section 11.33 of the Colorado Primary Drinking Water Regulations, 5 CCR 1002-11.
Unlikely LSL	Based on available data, there a very low likelihood (less than 10%) that the service line is made of lead.

Enclosure 2

Denver Water's Proposed Terms and Conditions

Denver Water Request for Variance From Optimal Corrosion Control Treatment Requirements Under the Safe Drinking Water Act's Lead and Copper Rule

Note: This document sets forth Denver Water's proposed terms and conditions that will control if the variance to the treatment technique and the modification to the designated OCCT is granted. This document is preliminary and subject to modification.

Denver Water's Proposed Terms and Conditions for its Variance Request for Optimal Corrosion Control Treatment under SDWA 42 U.S.C. § 300g-4(a)(3)

In furtherance of Denver Water's variance request from 40 C.F.R. § 141.82(e) of the Optimal Corrosion Control Treatment Requirements under the Safe Drinking Water Act's Lead and Copper Rule, Denver Water is submitting its proposed terms and conditions which control during the term of the variance approval. The following proposed terms and conditions will become binding on Denver Water only upon the date that a variance becomes effective and so long as the variance remains in place. Except as otherwise provide herein, Denver Water must continue to follow the compliance requirements under the provisions of the Lead and Copper Rule as promulgated under state and federal law, 5 CCR 1002-11, 40 C.F.R. § 141.80-141.91, and as may be modified in the future.

1. Definitions:

A. *"Action level"* has the same meaning as action level in the Lead and Copper Rule, 40 C.F.R. § 141.80(c) and §§ 11.26(1)(c) and (2)(b) of the Colorado Primary Drinking Water Regulations (5 CCR 1002-11).

B. "*Adoption*" or *"Adopted"* for the purposes of the filter survey means that the customer enrolled in the filter program is using a filter NSF/ANSI (53) certified for lead removal for drinking, cooking, and infant fed formula (ingestion). Respondents who indicate that they use bottled water or an alternative NSF/ANSI (53) certified filter for ingestion will count as having adopted the use of a filter under paragraph 5.G.i. below.

C. "*Contact*" means direct mailing, water bill inserts, door hangers, in person contact, email, phone calls, educational materials accompanying filters and cartridges, or any other direct communication channels identified in Denver Water's communications, outreach, and education plan. Communications via information posted on the Denver Water website, social media websites, water bills, distribution of filters and replacement cartridges alone, or public notices required as a corrective action or a failure to meet a condition are excluded from this definition.

D. *"Customer Premise"*, for the purpose of these terms and conditions only, means a property or a residential unit within a multi-family property that receives water service pursuant to a Denver Water or distributor tap license.

E. "*Customer(s) Enrolled in the Filter Program*" means a customer premise, as defined herein where there is a known, suspected or possible lead service line (LSL), that will automatically be distributed a filter under section 5 below, unless otherwise refused by the customer.

F. "*Day*" means calendar day.

G. "*Effective Date*" means ninety-one (91) calendar days following approval of the variance or issuance of the State's modification decision, whichever occurs later.

H. *"Integrated System(s)"* means the defined term used in section 11.42(4) of 5 CCR 1002-11, as may be modified in the future. Currently, "integrated system" is defined as a "wholesale system and one or more consecutive systems with distribution systems that are physically connected [that] . . . choose to operate in a manner where the wholesaler assumes responsibility for compliance with one or more regulatory requirements applicable to the supplier responsible for the consecutive system, if the requirements of … section 11.42(4) are met."

I. *"Ingestion"* means the use of tap water for drinking, cooking, and infant fed formula.

J. *"Investigated"* refers to any activity used to identify the service line materials including a lead water quality test, potholing, visual inspection, or other methods that allows for a determination of the service line material.

K. *"Known LSLs"* are based upon direct evidence that gives a 100% estimated probability that a service line is an LSL.

L. "*Known, suspected and possible LSLs*" collectively refers to known LSLs, suspected LSLs, and possible LSLs.

M. "*Lead and Copper Rule (LCR) Regulatory Sampling*" means the collection of lead and copper tap samples for homes that have lead solder without a lead service lines and homes with lead service lines sampled in accordance with § 11.26 of 5 CCR 1002-11 and 40 C.F.R. § 141.86.

N. Lead Reduction Program Plan (LRPP) means Denver Water's Lead Reduction Program Plan dated September 2019.

O. *"Lead Service Line" or "LSL"* 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. This definition is intended to be inclusive of the term "Lead Service Line" as defined under section 11.26(1)(g) of 5 CCR 1002-11 and 40 C.F.R. § 141.2.

P. *"LSL Replacement"* is defined in paragraph 4.B, below.

Q. "*Orthophosphate Treatment*" means phosphate-based treatment as described in the Colorado Department of Public Health and Environment's (CDPHE) March 20, 2018 letter to Denver Water designating orthophosphate as optimal corrosion control treatment.

R. *"Possible LSLs"* are based on conflicting or missing data that provides an estimated probability value between 50% to 79% that a service line is an LSL.

S. "*Program Year*" has the same meaning as calendar year.

T. "*Public Notice*" for the purpose of this variance means either:

i. a Tier 2 public notice as described in § 11.33 of 5 CCR 1002-11 and 40 C.F.R. § 141.203, initiated within thirty (30) days following a CDPHE notice of a violation of the variance with messaging approved by CDPHE provided to all customers served by Denver Water;

ii. a public notice that contains the same elements of Tier 2 Public Notice described above initiated within sixty (60) days after learning of the need for corrective action provided to customers enrolled in the filter program to be delivered by making at least two (2) forms of direct contact with the customer subset, with messaging approved by CDPHE;

iii. a public notice by Denver Water that meets the requirements as described in § 11.26(7) of 5 CCR 1002-11 and 40 C.F.R. § 141.85, including public education associated with the Lead and Copper Rule initiated within sixty (60) days to all recipients specified in § 11.26(7)(c) of 5 CCR 1002-11 and 40 C.F.R. § 141.85(b);[1]

iv. a notice included in Denver Water's annual summary report; or

v. a Tier 3 public notice as described in § 11.33(4) of 5 CCR 1002-11 and 40 C.F.R. § 141.204, initiated as soon as possible but no later than 365 days following a violation or situation notification from CDPHE.

U. *"Suspected LSLs"* are based upon available data that provides an estimated probability value between 80% to 99% estimated probability (i.e. homes built before 1951) that a service line is an LSL.

V. *"System*" means the community water system that Denver Water owns and operates (PWS ID# CO0116001) and the integrated systems covered under Master Meter, Read and Bill, and Total Service agreements with Denver Water as detailed in Appendix III.B.1 of the Lead Reduction Program Plan submitted by Denver Water in support of its variance request.

W. *"Variance End Date"* means fifteen (15) years after the effective date, unless extended by EPA.

2. Corrosion Control Treatment:

A. *pH/Alkalinity Adjustment Corrosion Control Treatment*. By the effective date, Denver Water must begin to make adjustment to pH and alkalinity as corrosion control

[1] The public notice requirements under Subpart Q of the LCR (40 C.F.R, § 141.201 *et seq.*) will continue to apply if there is a violation of the schedule, and/or any terms and conditions of the variance –tier 1 and tier 2 notices, respectively.

treatment (CCT) according to an implementation schedule and treatment targets approved by CDPHE. Denver Water must maintain the corrosion control parameters and targets within the ranges designated by CDPHE under § 11.26(3)(d)(iii) of 5 CCR 1002-11 and 40 C.F.R. § 141.82(h).

B. *Monitoring and Sampling:*

i. *LCR Regulatory Sampling for Action Level 90th Percentile Calculation.* During the variance, Denver Water must maintain Lead and Copper Rule (LCR) sampling sites pursuant to § 11.26(2) of 5 CCR 1002-11 and 40 C.F.R. § 141.86 for lead service lines and lead solder sites.

ii. *Use of Sampling Results.* Lead water quality tests collected to identify LSLs for the inventory under this variance and to verify lead concentrations post-replacement shall not be used in the calculation of the 90th percentile. Any customer-requested samples that meet the Tier 1 sampling requirements will still be included in Denver Water's compliance calculations.

iii. *Monitoring for Water Quality Parameters*. Denver Water must follow §§ 11.26(4)(j)-(l) of 5 CCR 1002-11 and 40 C.F.R. §§ 141.82(g)-(i) for treatment technique compliance determinations for continued operation and maintenance of the CCT.

C. *CCT Compliance Metrics, Corrective Actions, and Failures.*

i. *CCT Compliance.* For each six-month sampling period, Denver water must achieve LCR Regulatory Sampling at or below the LCR Action Level based upon the 90th percentile calculation.

ii. *Corrective Action.* If compliance has not been achieved under 2.C.i., Denver Water must follow the requirements of the LCR in the case of a lead or copper Action Level exceedance under § 11.26 of 5 CCR 1002-11 and 40 C.F.R. § 141.82. If Denver Water's LCR regulatory sampling exceeds the LCR's Action Level as measured at the 90th percentile for two (2) LCR monitoring periods within the duration of the variance, Denver Water has failed to meet the condition in 2.C.i., and either:

a. this variance shall terminate; or

b. CDPHE will require Denver Water to follow the corrosion control treatment steps under § 11.26(3)(c) of 5 CCR 1002-11, in which case the variance will be continued pending the results from corrosion control treatment studies until CDPHE makes a determination under § 11.26(3)(c)(ii). EPA may nevertheless terminate this variance in the interests of public health under paragraph 7.D below.

c. In either case above, CDPHE will issue Denver Water a treatment technique violation and Denver Water must conduct a Tier 2 public notice to all customers under 1.T.i above.

3. Lead Service Line Inventory:

A. *LSL Inventory*. Denver Water must create and maintain on an ongoing basis an inventory of the material used for each service line used for drinking water that is a known, suspected, and possible LSL associated with a customer premise within Denver Water's system, and update the inventory each program year in agreement with CDPHE as LSLs are replaced and the material used for service lines are investigated. The inventory must include private service lines, and must include all LSLs within the system, including in the service areas of all distributors who are a part of the system. Denver Water must complete the initial LSL inventory no later than thirty-five (35) days after the effective date. The total estimated number of known, suspected, and possible LSLs equals (Y) as further described in paragraph 4.A below. Any updates to (Y) will be submitted in Denver Water's annual summary report described in paragraph 6 below.

B. *Investigation of Service Line Materials*. On an ongoing basis Denver Water must investigate known, suspected, and possible LSLs using lead water quality tests, potholing, visual inspections, or other means that supports a determination of the service line material. The number of known, suspected and possible LSLs for the purpose of investigating properties for the first year following the variance approval will be based on the (Y) factor, as adjusted under paragraph 4.A below. Denver Water must incorporate its findings under this subsection into its required LSL inventory annual updates.

C. *Publication of LSL Inventory.* No later than seventy (70) days following the effective date, Denver Water must provide public access to its LSL inventory on its external customer website, which will allow the public to view whether service line materials used for any customer premise in the system is (i.e. lead, copper, or unknown). During the term of this variance, Denver Water must continue to provide public access to its LSL inventory, including access to any updates to its inventory required under this section 3. For owners or residents of a customer premise who call Denver Water by phone, Denver Water must disclose whether its inventory shows that the owner's or resident's service line is a known, suspected and possible LSL, is unlikely to be an LSL or is a non-lead service line.

D. *LSL Inventory Compliance Metrics, Corrective Actions, and Failures.*

i. *Compliance Metric.* Denver Water must investigate a minimum of 1.4% of the total estimated number of suspected and possible LSLs in the LSL inventory each program year until 20% of the total estimated number of suspected and possible LSLs are investigated based upon the inventory at the beginning of the first program year (based on a subset of Y as described in paragraph 4.A below) as adjusted. These investigations are performed independently of the LSL replacements under paragraph 4 below.

ii. *Corrective Action.* If Denver Water does not conduct the minimum 1.4% of investigations by the end of the program year, the denominator (Y) in paragraph 4.A below will revert to the value established at the beginning of the previous program year, less LSL replacements for the previous program year, until Denver Water achieves compliance with this paragraph. Denver Water must also provide public notice that the metric was not met in its annual summary report under paragraph 1.T.iv above.

iii. *Completion of Inventory.* When Denver Water has completed the confirmation of the material for all suspected and possible LSLs under paragraph 3.D.i., Denver Water must provide written notice to CDPHE and this variance metric will terminate.

4. Accelerated Lead Service Line Replacement Program:

A. *LSL Replacement*. By the effective date, Denver Water must begin to implement accelerated LSL replacement in its system and replace all known LSLs within 15 years of the effective date. By the end of program year 1, Denver Water must achieve a 6.0% replacement rate,[2] and by the end of program year 2, Denver Water must achieve a 6.5% replacement rate based upon the known, suspected and possible LSLs (Y) at the beginning of the program year. By the end of the third program year and every program year thereafter, Denver Water must maintain a minimum cumulative annual average replacement rate of 7.0% per year. At the end of each program year, the cumulative program year average must be calculated using the total number of LSLs replaced during the term of the variance (X) divided by the total estimated number of known, suspected, and possible LSLs (Y), consistent with the most recent update of the LSL inventory. Program year adjustments to (X) and (Y) will be made at the end of each program year with the approval of EPA and CDPHE based upon any changes to the total estimated number of known, suspected and possible LSLs in Denver Water's updated LSL inventory except as otherwise provided in paragraph 3.D.ii above; provided, however, all LSLs must be replaced within 15 years of the effective date. For program year 1, X = 3,838 and Y= 63,955.

B. *LSL Replacement Defined*. For the purpose of calculating the cumulative program year average replacement rate, the following types of LSL replacements will count as credit for an entire LSL replacement:

i. full LSL replacement of a single service line;

ii. replacement of an existing partial LSL that results in a non-lead service line from the main to the first fitting inside the structure;

iii. replacement of a galvanized service line downstream of an existing or previously existing LSL, including any lead that is part of the upstream segment of the service line; and

[2] If the effective date is after January 1, 2020, the 6.0% replacement rate for the first program year will be prorated through December 31, 2020 by dividing the number of remaining full months from the effective date to the end of the Calendar Year by 12 and multiplying this factor by the 6.0% replacement rate.

iv. LSL replacement completed by other governmental agencies, developers, homeowners, non-profits, etc. and inspected by Denver Water.

C. *Replacement to Fitting.* All LSLs must be replaced from the main up to the first fitting inside the structure excluding any portion of the service line that is copper. If there is no fitting within five feet of the location where the service line enters the structure, Denver Water must install a fitting to allow for connection of the service line at a location convenient for Denver Water.

D. *Partial LSL Replacements.* Denver Water may not make a partial replacement of an LSL during the term of the variance except when i. emergency repairs must be made to a service line or water main to protect the distribution system; or ii. property owner consent cannot be obtained or the property cannot be accessed. A partial replacement that does not result in complete replacement of all portions of the LSL shall not be counted as an LSL replacement for the purposes of the accelerated LSL replacement program until the partial LSL is fully replaced.

E. *Post Replacement Samples*. Denver Water must offer to collect and analyze lead samples at homes where LSLs have been replaced six (6) months post LSL replacement.

F. *Test Out.* The "test out" provision in 40 C.F.R. § 141.84(c) and § 11.26(6)(b)(i)(B) of 5 CCR 1002-11 does not apply while Denver is subject to this variance. Any lines that "test out" do not count toward LSLs that were replaced under the terms of this variance.

G. *Property Owner Consent.* Denver Water must contact property owners at the customer premise before replacement to secure the property owner's documented consent. Work at the customer premise may commence once consent is documented. If Denver Water has not made contact with a property owner, Denver Water must use reasonable efforts to secure consent. Reasonable efforts must include at least three attempts to contact the property owner including an attempt to send at least two (2) written requests by U.S. mail to the property owner at the most recent mailing address identified through Denver Water records for consent to replace the LSL at the property, and an attempt to obtain permission by making in-person contact with the property owner if necessary. If documented consent to replace the LSL is not granted after reasonable efforts are made to achieve consent, the property will be added to Denver Water's Service Line Refusal List as described in paragraph 4.H. below.

H. *Customer Refusals and Changes in Customer Accounts.* Denver Water must maintain records of the addresses of all structures at which the property owner does not consent to LSL replacement (Service Line Refusal List). When Denver Water customer account records indicate a change in ownership at the customer premise, Denver Water must determine whether the address is on the Service Line Refusal List, and within ninety-one (91) days of a change in Denver Water account records, undertake reasonable efforts to obtain permission from the new property owner of the customer premise to replace the LSL. Reasonable efforts include the efforts described in paragraph 4.G. above. If permission is granted and conditions allow for

the LSL to be accessed and safely replaced, Denver Water must replace the LSL. By the variance end date, Denver Water must replace all LSLs at properties on the Service Line Refusal List.

I. *LSLs Discovered After Variance Term.* Denver Water must continue to replace any LSL discovered after the variance end date and report any LSL replacements to CDPHE on an annual basis. This condition shall survive the term of the variance.

J. *Accelerated LSL Replacement Compliance Metrics, Corrective Actions, and Failures.*

i. *Compliance Metric*. Denver Water must achieve at least a 6.0% LSL replacement rate by the end of program year 1, 6.5% in program year 2, and beginning the end of program year 3 and thereafter a 7.0% cumulative annual average LSL replacement rate each program year.

ii. *Corrective Action.* If the compliance metric in paragraph 4.J.i. is not achieved after program year 3, Denver Water must increase LSL replacements to achieve a 7.0% cumulative annual average replacement rate by the end of the next program year. In addition, Denver Water shall provide public notice to all customers who have known, suspected, or possible LSLs that correction under this variance metric under 1.T.ii

5. Filter Program:

A. *Filters.* Denver Water must distribute to the occupant of all customer premises with known, suspected and possible LSLs one (1) filter and enough replacement cartridges for the first six months of use. Denver Water shall begin to distribute filters and cartridges within ninety-one (91) days of the effective date and complete distribution one hundred and eighty-two (182) days following the effective date. If Denver Water does not distribute all of the filters and cartridges by the above deadline, then Denver Water must conduct public notice to all customers enrolled in the filter program under paragraph 1.T.ii. All filters and cartridges distributed must be certified NSF/ANSI (53) for lead removal and not remove fluoride. Denver Water need not distribute a filter and replacement cartridge to a customer premises if the occupant confirms that their household uses bottled water, an existing under the sink filter certified NSF/ANSI (53) for lead removal, refrigerator filter certified NSF/ANSI (53) for lead removal, or other lead removal device that is certified NSF/ANSI (53) for lead removal for ingestion purposes.

B. *Filter Replacement Cartridges.* Denver Water must distribute replacement cartridges to customers enrolled in the filter program per the filter manufacturers' recommended replacement rate unless the customer refuses the filter or replacement cartridges. Replacement filters must be provided to each customer premise enrolled in the filter program until six months after replacement of a customer premise's LSL or until the time the service line of the property is confirmed to be non-lead. If Denver Water does not distribute all of the replacement cartridges per the manufacturers' recommended replacement rate, then Denver Water must conduct public notice to all customers enrolled in the filter program under paragraph 1.T.ii.

C. *Changes in Customer Accounts.* If a change in the customer name of the water account associated with a customer enrolled in the filter program occurs at any time, then Denver Water must distribute a new filter within thirty-five (35) days of the change in customer account and replacement cartridges per manufacturers recommended replacement rate to the new customer so long as the customer premise or a residential unit at the customer premise is enrolled in the filter program.

D. *Filters for Infants in '83 to '87 Customer Premises*. If a customer has a formula-fed infant/child up to 24 months of age and resides in a customer premise that is built between 1983-1987 and served by a copper service line with lead solder, upon customer request Denver Water must provide a free lead water quality test kit. If the water quality results in the first draw show lead concentrations above 3 ppb, Denver Water must offer a filter and enough replacement cartridges to last the customer until a child at the customer-premise exceeds the age of 24 months.

E. *Filter Adoption Assessment.*

i. *Surveys.* Denver Water must conduct a survey each program year of randomly selected customers enrolled in the filter program to receive at minimum 1,059 responses. The minimum number of required responses may be reduced upon written approval of CDPHE and EPA as the number of customers enrolled in the filter program decline during the term of this variance. The survey must inquire whether the customer has adopted the filter for water used for infant formula if applicable, cooking and drinking or is using bottled water or a filter device that is certified NSF/ANSI (53) for lead removal not provided by Denver Water for infant formula, cooking and drinking. The filter survey will be provided to and approved by CDPHE before distribution to customers enrolled in the filter program. If Denver Water:

a. Does not conduct the annual survey during any program year, then Denver Water will be issued a treatment technique violation and must conduct public notice to all customers under paragraph 1.T.i.

b. If Denver Water does not collect the minimum number of received survey responses during any program year, then Denver Water must conduct public notice to all customers enrolled in the filter program under paragraph 1.T.v, unless CDPHE determines that Denver Water must conduct public notice under paragraph 1.T.ii.

ii. *Survey of Filter Adoption Rate.* All of the received survey responses will be used to calculate the filter adoption rate based on the number of responses that confirm adoption of the filter, or use of bottled water or alternative filer device not provided by Denver Water that is certified NSF/ANSI (53) for ingestion. All respondents who indicate that they do not use the filter, bottled water, or alternative filter device that is certified NSF/ANSI (53) for cooking but have adopted for drinking water and infant fed formula, if the latter is applicable to the respondent, will be summed and multiplied by 50% and the result may be counted as having adopted a filter for the purposes of determining the average filter adoption rate in paragraph 5.G.i. below.

iii. *Bottled Water and Alternative Filter Devices*. Customers who indicate that they use bottled water or alternative filter device certified NSF/ANSI (53) will continue to be customers enrolled in the filter program unless they refuse a filter or contact Denver Water to opt-out of the filter program. Denver Water will maintain a list of customers who have refused filters or opted-out of the filter program and provide the list to CDPHE upon request.

F. *Filter Performance*.

i. *Confirmation of Filter Performance Before Distribution*. Before distributing filters to customers enrolled in the filter program in program year one, Denver Water will test the lead removal effectiveness of 12 units of each type of filter to be distributed to customers using water from Denver Water's pipe racks as described in the LRPP from at least one Denver Water treatment plant in accordance with a testing protocol approved by CDPHE to confirm that the filters meet their NSF/ANSI (53) certification. All filter testing results will be reported to CDPHE. Denver Water will not distribute a filter model that fails to meet the NSF/ANSI (53) certification based upon the lead samples collected under this paragraph.

ii. *Confirmation of Filter Performance in Field*. To confirm performance of filters in use at customer premise, Denver Water will collect fifty (50) samples from filters in use by customers enrolled in the filter program who are also enrolled in Denver Water's LCR regulatory sampling program in accordance with a testing protocol approved by CDPHE. Samples will be collected from filters used by customers enrolled in the filter program at the same frequency as LCR regulatory sampling and reported to CDPHE and EPA.

iii. If Denver Water does not complete testing of filters under this section 5.F. in accordance with the CDPHE approved protocols, Denver Water must provide public notice in accordance with paragraph 1.T.ii. above.

G. *Filter Adoption Compliance Metrics, Corrective Actions, and Failures.*

i. *Compliance.* Denver Water must achieve a filter adoption rate of 65% at the end of each program year.

ii. *Corrective Action*. If this metric is not achieved at the end of a program year, then Denver Water must achieve a 65% filter adoption rate by the end of the following program year. Denver Water will also provide public notice to customers enrolled in the filter program under paragraph 1.T.ii.

H. *Filter Communication Compliance Metrics, Corrective Actions, and Failures.*

i. *Compliance*. Denver Water must make direct contact with lead outreach and education materials to 95% of all customers enrolled in the filter program in every program year. Compliance shall be documented by mailing lists and mail receipts,

lists of customer email addresses for customers who elect to receive email communication, or other forms of documentation approved by CDPHE.

ii. *Corrective Action*. If Denver water does not achieve compliance with paragraph 5.H.i., then Denver Water must increase outreach efforts to reach 95% of Denver Water customers enrolled in the filter program, and Denver Water must also provide public notice to all customers enrolled in the filter program of its failure to achieve the metric under paragraph 1.T.ii.

6. Recordkeeping and Reporting Requirements:

A. *Reporting.* In the event that Denver Water determines that it will not meet any of the terms and conditions as defined in this document, Denver Water must notify CDPHE and EPA no later than two business days after the determination occurs. CDPHE will provide any resulting requirements (e.g., notification of violation, public notice requirements, etc.) to Denver Water (and copy EPA) in writing.

B. *Recordkeeping.* On an ongoing basis for the term of the variance, Denver Water shall record, maintain records of, and report each year the following information. Denver Water will provide any of the "raw" data to CDPHE or EPA, when requested. Unless otherwise stated, the reporting and recordkeeping requirements under the LCR remain in effect:

i. *CCT.*

a. all lead and copper regulatory sampling results, as required in § 11.26 of 5 CCR 1002-11;
b. CCT parameters for pH and alkalinity; and
c. all water quality sampling results collected as part of Denver Water's investigation of LSLs and post LSL replacement.

ii. *LSL Inventory.*

a. total number of service lines;
b. the total number of replaced LSLs during the variance;
c. the total number of known, suspected, and possible LSLs;
d. the total number of unlikely LSLs;
e. the total number of non-LSLs;
f. the number of investigations conducted each year to improve the LSL inventory;
g. an updated distribution system map; and
h. the rationale for requesting a change in the status of a service line in the inventory (e.g. investigation, replacement, water quality data, etc.).

iii. *LSL Replacements.*

a. the address and date of all LSL replacements occurring during the variance, including by year;
b. the type of LSL replacement (full, partial including galvanized, by third party);
c. the service line refusal list, including addresses of customer premises on the refusal list and documented attempts to contact the property owner; and
d. those customer premises where Denver Water performed a partial LSL replacement due to an emergency repair and property owner consent could not be obtained.

iv. *Filters.*

a. addresses of customer premises where filters and replacement cartridges have been provided;
b. the total number of filters and replacement cartridges distributed per program year;
c. a summary of filter survey responses per program year (i.e., descriptive statistics), the response rate, the percent filter adoption for each year of the variance, and the specific survey questions and responses;
d. a list of customer accounts reporting the use of bottled water or a filter certified NSF/ANSI (53) for removal of lead, and any changes in the list;
e. a list of customers enrolled in the filter program who have refused a filter or replacement cartridges or have opted out of enrollment in the filter program; and
f. filter lead sampling results collected under paragraph 5.F above.

v. *Compliance Metrics*. Results achieved under the compliance metrics in sections 2.C, 3.D, 4.J, 5.G, and 5.H above.

vi. *Communications, Outreach and Education*. A summary of activities conducted under the Communications, Outreach and Education program, including the updated communications, outreach and education plan for the new program year. The summary will include, at a minimum:

a. a description of outreach activities conducted;
b. a list of any partner organizations who conducted, or were involved in the implementation of the communications, outreach and education plan; and
c. if in-person or telephone surveys are conducted, the answers to filter usage survey questions that were asked, date and time of call.

vii. *Health Equity and Environmental Justice.* A summary of activities conducted and designed to address health equity and environmental justice (HE&EJ) principles set forth in the Lead Reduction Program Plan (LRPP), including:

a. a description of how the HE&EJ principles are being incorporated into the accelerated LSL replacement program, lead filter program, and communications, outreach and education plan;
b. socioeconomic or demographic data collected through the survey that may inform the filter adoption rate by neighborhood or demographic group to the extent practical; and
c. socioeconomic or demographic data collected from or other sources (e.g. census data, local public health agencies) to target communications, outreach and education programs to specific neighborhoods, demographic cohorts, or non-English speaking groups.

C. *Annual Program Year Reports.* No later than thirty-five (35) days following the end of a program year, Denver Water must submit a program year report to CDPHE and EPA, containing a summary of the information and data required under this section 6 for the previous program year, including an assessment of which metrics were achieved and the status of any corrective actions. This requirement remains in effect for the term of the variance. The annual report will also document any modification requests made by Denver Water to the Lead Reduction Program Plan or deviations from the LRPP during the most recent program year, along with a rationale for the request. If CDPHE or EPA provides any comments or requests related to the annual report, Denver Water must provide a written response within thirty-five (35) calendar days that addresses any identified comments/requests.

7. General Miscellaneous Provisions:

A. *Enforcement*. CDPHE has primary implementation and enforcement authority over the variance, subject to EPA oversight. CDPHE will implement, oversee, and enforce these terms and conditions, and may make recommendations to EPA to terminate or continue this variance, provided that EPA has the authority to ultimately decide whether to continue this variance.

B. *Revisions to the Lead and Copper Rule.* If EPA revises the federal LCR in a manner that affects the provisions and conditions of this variance, then EPA may modify or revoke this variance in a manner that is consistent with federal law.

C. *Lead Reduction Program Plan*. Denver Water will work in good faith to fully implement Section III of the LRPP. If Denver Water deviates from Section III the LRPP during the term of the variance or fails to implement Section III of the LRPP, Denver Water will provide notice to CDPHE within thirty-five (35) days with a description of the deviation from section III of the LRPP and the reason for the deviation. In no case shall a deviation from Section III of the LRPP modify these terms and conditions, except as provided in paragraph 7.J below. In the event of a

conflict between these terms and conditions and Section III of the LRPP, these terms and conditions take precedence.

D. *Enforcement.* Notwithstanding any metric and/or corrective action identified herein, EPA and CDPHE may take enforcement if EPA or CDPHE find, in their sole discretion, that Denver Water has not complied with any requirement of the variance in accordance with 42 U.S.C. §§ 300g-3(a)(1) and 300g-4(b) of the SDWA, including when:

i. Denver Water does not comply with its terms and conditions;

ii. A material aspect of Section III of the LRPP has not been implemented in good faith;

iii. Denver Water requests that EPA terminate the variance; or

iv. EPA or CDPHE believes that there is a risk to public health.

An enforcement action does not automatically terminate the variance.

E. A*utomatic Termination of Variance.* This variance terminates if one or more of the following conditions occur:

i. Denver Water fails to replace LSLs at the required minimum cumulative program year average rate of 7.0% for a total of three program years; or

ii. Denver Water fails to achieve a minimum of 65% filter adoption rate in a program year for a total of three program years.

If the variance is terminated Denver Water will provide public notice under 1.T.i

F. *Optimal Corrosion Control Treatment*. If EPA revokes the variance under paragraph 7.D. or the variance automatically terminates under paragraph 7.E, within 182 Days Denver Water shall install and operate orthophosphate as its designated optimal corrosion control treatment, in accordance with CDPHE's March 20, 2018, OCCT determination, and provide public notice to its customers in accordance with paragraph 1.T.i above. The initial dose of orthophosphate must be 2 mg/L. The specific orthophosphate dose may be further modified by CDPHE according to the provisions under 40 C.F.R. § 141.82(h).

G. *Effective Date of Termination or Revocation of the Variance*. Termination or revocation of the variance will be effective within 182 days of automatic termination under paragraph 7.E. above, or EPA's revocation under section 7.D. above, whichever occurs first. Failure to complete installation and operation of orthophosphate by this deadline will be considered a treatment technique violation under § 11.26 of 5 CCR 1002-11.

H. *Notice of Lead Reduction Program Plan.* No later than 14 days following effective date, Denver Water must begin a multi-media public information campaign and customer notification by written letter and pamphlet to notify customers enrolled in the filter program of Denver Water's variance, including the accelerated LSL replacement program and the distribution of the NSF/ANSI (53) certified filters for lead removal.

I. *Term of Variance.* Unless EPA revokes or modifies, the terms, this variance shall extend from the effective date through the variance end date, or until EPA accepts the notice of completion pursuant to section 7.L. below. Additionally, as described in, paragraph 4.I, Denver Water shall replace within six (6) months of discovery, any LSLs discovered after the variance end date. Denver Water must provide an annual summary of these efforts to CDPHE by January 10th of each calendar year for the previous program year.

J. *Modification of Conditions.* EPA may modify the conditions of this variance in consultation with CDPHE. EPA will notify Denver Water thirty-five (35) days prior to the effective date of any modification.

K. *Notices.* All notices, reports, disclosures, or other communications required or related to this variance must be sent via certified U.S. Mail, overnight express delivery service, or electronic means to the recipients and addresses below.

EPA:
Safe Drinking Water Branch Chief
Water Division U.S. Environmental Protection Agency, Region 8
1595 Wynkoop St.
Denver, CO 80202-1129
Current E-mail: **[To be added upon finalization.]**

Denver Water:
James S. Lochhead
CEO/Manager
Denver Water
1600 West 12th Avenue
Denver, Colorado 80204
E-mail: **[To be added upon finalization.]**

Office of General Counsel:
ATTN: Jessica Brody
Denver Water
1600 West 12th Avenue
Denver, Colorado 80204
E-mail: **[To be added upon finalization.]**

CDPHE:
Jill Hunsaker Ryan
Executive Director
Colorado Department of Public Health and Environment
4300 Cherry Creek Drive South
Denver, CO 80246
E-mail: **[To be added upon finalization.]**

All reports will be sent to Drinking Water Compliance Assurance through its on-line portal at https://wqcdcompliance.com/login or through such other means as designated in writing by CDPHE.

Attorney General's Office
ATTN: **[To be added upon finalization.]**

L. *Notice of Completion.* Denver Water may submit a notice of completion of the terms and conditions of this variance to CDPHE, with a copy to EPA, by the variance end date or earlier in accordance with this variance. EPA may either accept or reject Denver Water's notice of completion in writing within thirty-five (35) days of receipt.

Enclosure 3

August 14th Board Resolution

Denver Water Request for Variance From Optimal Corrosion Control Treatment Requirements Under the Safe Drinking Water Act's Lead and Copper Rule

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DENVER WATER

Board Resolution

TITLE: Variance from the Lead and Copper Rule to Implement Denver Water's Proposed Lead Reduction Program Plan

ADOPTED AND APPROVED ON AUGUST 14, 2019 BY THE CITY AND COUNTY OF DENVER ACTING BY AND THROUGH ITS BOARD OF WATER COMMISSIONERS

Paula Herzmark, Board President

James S. Lochhead, CEO/Manager

WHEREAS, Denver Water delivers lead-free water to its customers; and

WHEREAS, customer-owned lead service lines and lead-containing internal plumbing fixtures can release lead into the water; and

WHEREAS, the Safe Drinking Water Act's Lead and Copper Rule requires public water systems to monitor lead levels in customers' homes with known lead service lines or lead solder and implement corrosion control treatment methods to minimize the corrosivity of water as it passes through customers' service lines and lead-containing plumbing fixtures; and

WHEREAS, in 2012, the 90th percentile value for sample results of lead levels in tap water for Denver Water's sampling pool was 17 µg/L, exceeding the Lead and Copper Rule action level of 15 µg/L; and

WHEREAS, in response to the 2012 lead action level exceedance, which was Denver Water's first and only exceedance of the lead action level, Denver Water conducted a detailed study to improve its corrosion control treatment; and

WHEREAS, based on the results of the study, the Colorado Department of Public Health and Environment (CDPHE) designated orthophosphate treatment as the optimal form of corrosion control for Denver Water's integrated system and directed Denver Water to begin treatment with orthophosphate by March 20, 2020; and

WHEREAS, orthophosphate can result in increased levels of nutrients in wastewater and storm water, which may adversely affect wastewater treatment plants, storm water control programs, streams and reservoirs, and Denver Water's downstream gravel pits and other Denver Water facilities; and

WHEREAS, the estimated regional capital, operational and maintenance costs

for nutrient removal associated with orthophosphate is projected to range between a low of approximately $369,000,000 and a high of $691,000,000; and

WHEREAS, once orthophosphate treatment begins, it cannot be discontinued without risk of pipe corrosion, and is therefore a permanent form of water treatment; and

WHEREAS, based upon the input of a diverse stakeholder group, CDPHE, and the Environmental Protection Agency (EPA), Denver Water conducted additional studies of orthophosphate and alternative forms of corrosion control to determine if there are alternative approaches that are equally protective of public health; and

WHEREAS, based on this analysis, Denver Water has developed a Lead Reduction Program Plan consisting of the following elements:

- creation of a lead service line inventory to identify and facilitate the removal of lead service lines in Denver Water's integrated system;
- implementation of an accelerated lead service line replacement program to remove all lead service lines in Denver Water's integrated system within 15 years;
- distribution of filters to customers with known, likely or possible lead service lines to provide additional public health protection until all lead service lines can be removed;
- adjustment of pH/alkalinity to a level of 8.8 standard units upon approval of CDPHE;
- utilization of a communications, outreach, and education plan to provide increased public outreach to Denver Water customers regarding best practices to reduce lead levels; and

WHEREAS, the Lead Reduction Program provides equivalent or better protection of public health as compared to orthophosphate in part, by removing lead service lines, which are the primary source of lead, and providing lead filters to customers with known, possible, and likely lead service lines to provide additional protection; and

WHEREAS, the Lead Reduction Program also achieves equivalent or better protection of customers at a reduced cost with a range between a low of approximately $256,000,000 and a high of $518,000,000, without the adverse impacts to wastewater treatment plants, storm water control programs, streams and rivers, and certain Denver Water facilities; and

WHEREAS, although Denver Water does not own its customers' service lines or plumbing, the Board finds that the permanent removal of lead service lines is necessary to:

- protect public health;
- achieve economies of scale through a uniform approach to replacement of lead service lines;
- realize health equity and environmental justice for all customers, including those who are tenants, located in high traffic areas where replacement of their lead service line is difficult, and those who cannot afford to replace

their lead service lines;

- maintain Denver Water flexibility in its treatment of drinking water and ability to draw on new sources of water that might otherwise contribute to lead releases from lead service lines; and

WHEREAS, Denver Water must obtain concurrence from CDPHE and a variance from EPA to implement the Lead Reduction Program instead of orthophosphate treatment.

NOW, THEREFORE, BE IT RESOLVED:

1. Submission of Variance Request. The Board directs its CEO/Manager to apply to EPA for a variance from the corrosion control treatment requirements under the Safe Drinking Water Act's Lead and Copper Rule to implement the Lead Reduction Program in place of orthophosphate treatment with the program components described above.

2. Coordination with Distributors. In addition, the Board directs its CEO/Manager and staff to work with distributors to implement the Lead Reduction Program within their respective service areas in a cooperative manner. In doing so, Denver Water staff should explore how to integrate the Lead Reduction Program within its distributors' existing programs with minimal disruption, and coordinate with distributors to determine how best to use their methods and means of communications with their customers.

3. Operating Rule Modifications. The Board further directs its CEO/Manager and staff to review the Board's Operating Rules and make recommendations for new or modified Operating Rules to facilitate implementation of the Lead Reduction Program, as necessary.

4. Lead Reduction Program Implementation. Finally, the Board directs its CEO/Manager and staff to issue requests for proposals, implement procurement processes, negotiate contracts, and take other such actions as necessary to timely implement the Lead Reduction Program should it be approved by EPA and CDPHE.

LEAD REDUCTION PROGRAM PLAN

APPENDICES

VOLUME 1 OF 2

DENVER WATER

APPENDIX I.A – PUBLIC COMMENT FORM RESPONSES

September 2019

DENVER WATER

Appendix 1.A. Public Comment Form Responses

Denver Water conducted a public comment period from July 12 to Aug. 7 to gather feedback on the program benefits, filter preferences, communication preferences and overall support. The information was distributed through a variety of different engagement channels such as newsletters, targeted emails to stakeholders and customers who have expressed an interest in Denver Water's lead reduction efforts, TAP news site distribution, social media, distributors, neighborhood groups, etc. During this four-week period, Denver Water received 406 comments from unique IP addresses that have indicated that more than 98% of respondents support the Lead Reduction Program, emphasizing benefits for future generations, environmental health and protecting infants and children. Full results are below.

Breakdown of Most Common Respondent Zip Codes and Corresponding Results

Zip Code	Neighborhoods	Number of Respondents	Percentage of Total Respondents	Top way to make the use of filters more convenient and accessible	Percentage of Program Support (Strongly support and more likely to support)
80220	Crestmoor, East Colfax, Hale, Hilltop, Montclair, Northeast (NE), Park Hill, South Park Hill, Southeast (SE)	50	12%	Offer at-home consultations with a Denver Water representative on filter use and maintenance, as well as installation if needed.	98%
80210	Cory Merrill, Platte Park, Rosedale, Southeast (SE), University, University Park, Washington Park, Washington Park West, Wellshire	42	10%	Offer at-home consultations with a Denver Water representative on filter use and maintenance, as well as installation if needed.	100%
80205	Ballpark, City Park, City Park West, Clayton, Cole, Curtis Park, Five Points, North Capitol Hill, Northeast (NE), Skyland, Uptown, Whittier	38	9%	Provide option for filter pick-up or at-home delivery. Provide option for replacement cartridge pick-up or delivery through a cartridge voucher system.	100%
80207	North Park Hill, Northeast (NE), Northeast Park Hill, Park Hill, South Park Hill, Stapleton	38	9%	Provide customers with the option to select a preferred filter type (i.e. pitcher filter, refrigerator, etc.).	100%

80209	Belcaro, Bonnie Brae, Cherry Creek, Country Club, Polo Grounds, Southeast (SE), Speer, Washington Park, Washington Park West	32	8%	Provide customers with the option to select a preferred filter type (i.e. pitcher filter, refrigerator, etc.).	100%
80211	Berkeley, Highland, Jefferson Park, Northwest, Sloan Lake, Sunnyside, West Highland	27	7%	Provide customers with the option to select a preferred filter type (i.e. pitcher filter, refrigerator, etc.).	100%
80212	Barkeley Village, Berkeley, Berkeley Gardens, Berkeley Industrial Park, Berkeley Village, Lowell, Mastin Industrial Park, Northwest, Regis, Regis Place, Saint Claire, Sloan Lake, Sunnyside Manor, Tennyson Industrial Park, West Highland	26	6%	Provide customers with the option to select a preferred filter type (i.e. pitcher filter, refrigerator, etc.).	100%
80206	Cheesman Park, Cherry Creek, City Park, City Park West, Congress Park, Country Club, Southeast (SE), Uptown	25	6%	Provide customers with the option to select a preferred filter type (i.e. pitcher filter, refrigerator, etc.).	96%
80204	Auraria, Baker, Barnum, Barnum West, CBD (Central Business District), Civic Center, Colfax, Downtown (Central Business District), Golden Triangle, Lincoln Park (La Alma), Lower Downtown (LoDo), Sheridan Boulevard, Sloan Lake, Southwest (SW), Sun Valley, Union Station, Valverde, Villa Park	16	4%	Offer at-home consultations with a Denver Water representative on filter use and maintenance, as well as installation if needed.	93%

80223	Athmar Park, Baker, College View, Overland, Ruby Hill, South Platte, Southwest (SW), Valverde	14	3%	Provide customers with the option to select a preferred filter type (i.e. pitcher filter, refrigerator, etc.).	100%
80218	Alamo Placita, Capitol Hill, Cheesman Park, City Park West, Country Club, Five Points, North Capitol Hill, Speer, Uptown	12	3%	Offer at-home consultations with a Denver Water representative on filter use and maintenance, as well as installation if needed.	100%

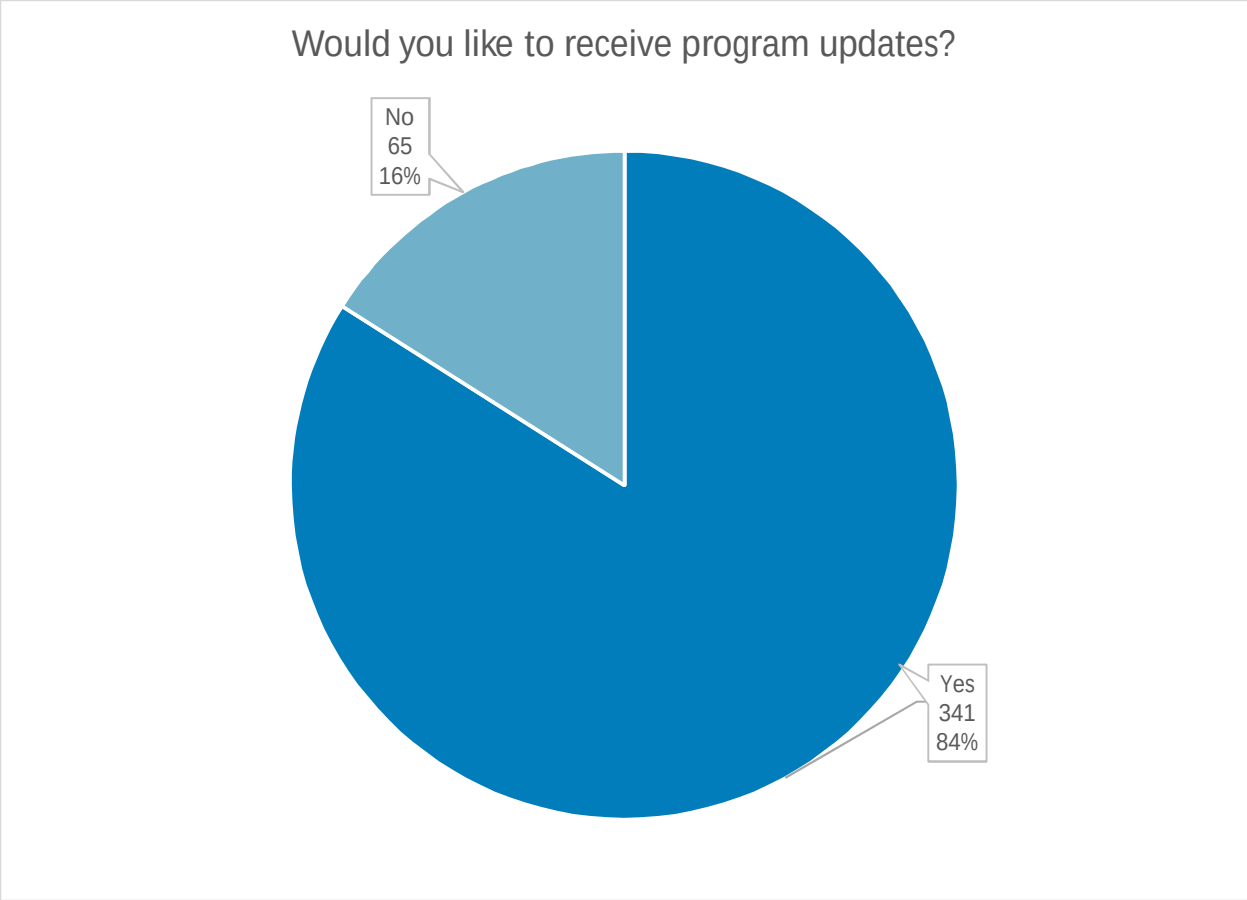
Additional respondent zip codes included:

Zip Code	Number of Respondents	Percentage of Total Respondents
80231	8	2%
80221	7	2%
80203	6	1.5%
80120	4	1%
80216	4	1%
80246	4	1%
80123	3	<1%
80219	3	<1%
80333	3	<1%
80111	2	<1%
80121	2	<1%
80222	2	<1%
80229	2	<1%
80236	2	<1%
80237	2	<1%
80238	2	<1%
01027	1	<1%
20009	1	<1%
22937	1	<1%
80004	1	<1%
80014	1	<1%
80016	1	<1%
80022	1	<1%
80035	1	<1%
80110	1	<1%
80214	1	<1%
80215	1	<1%
80224	1	<1%
80228	1	<1%
80232	1	<1%
80235	1	<1%
80241	1	<1%

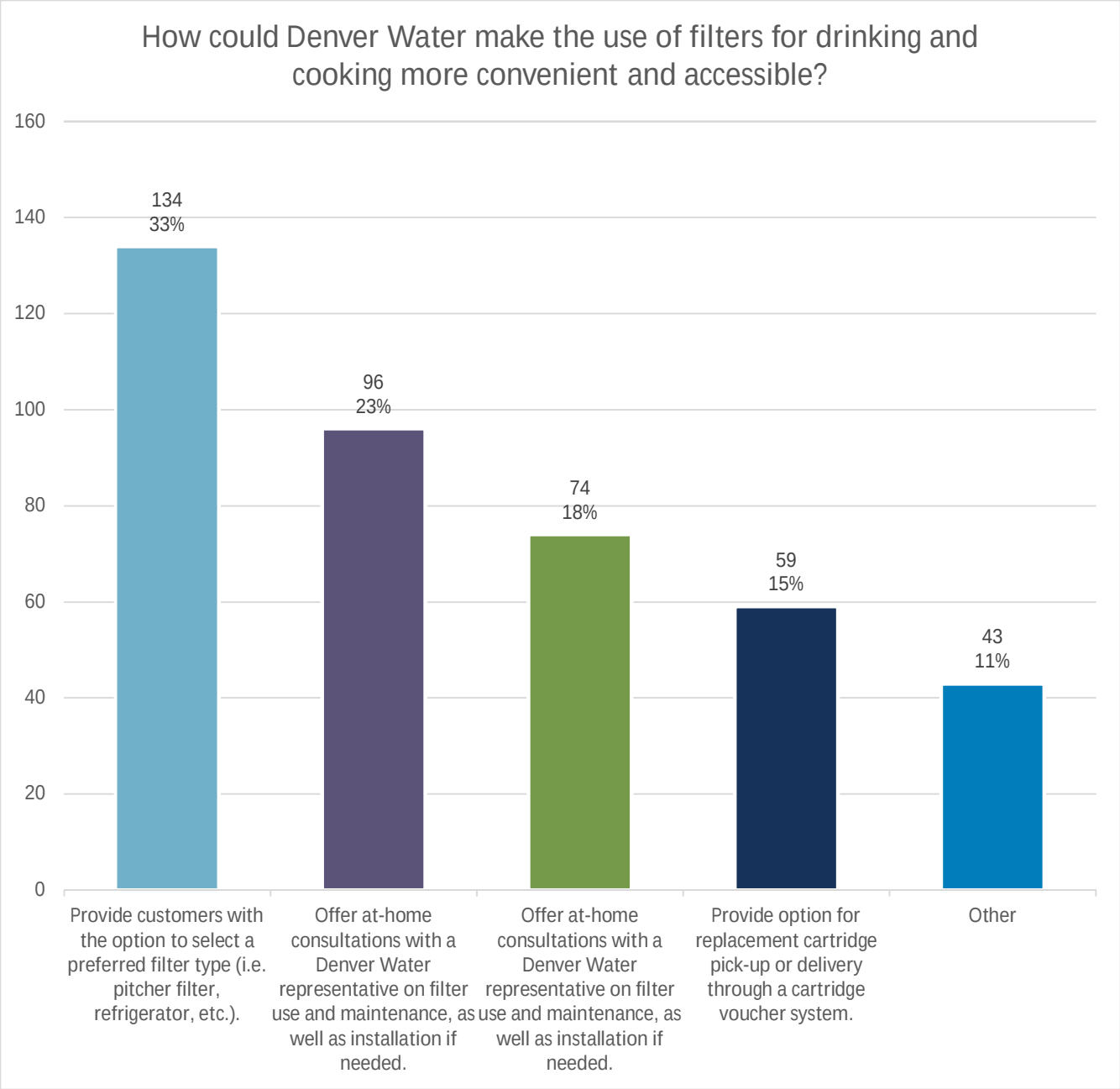
80247	1	<1%
80250	1	<1%
80401	1	<1%
80504	1	<1%
81623	1	<1%
89231	1	<1%
803204*	1	<1%

**Zip codes are presented as entered by respondents.*

Question Answer Results

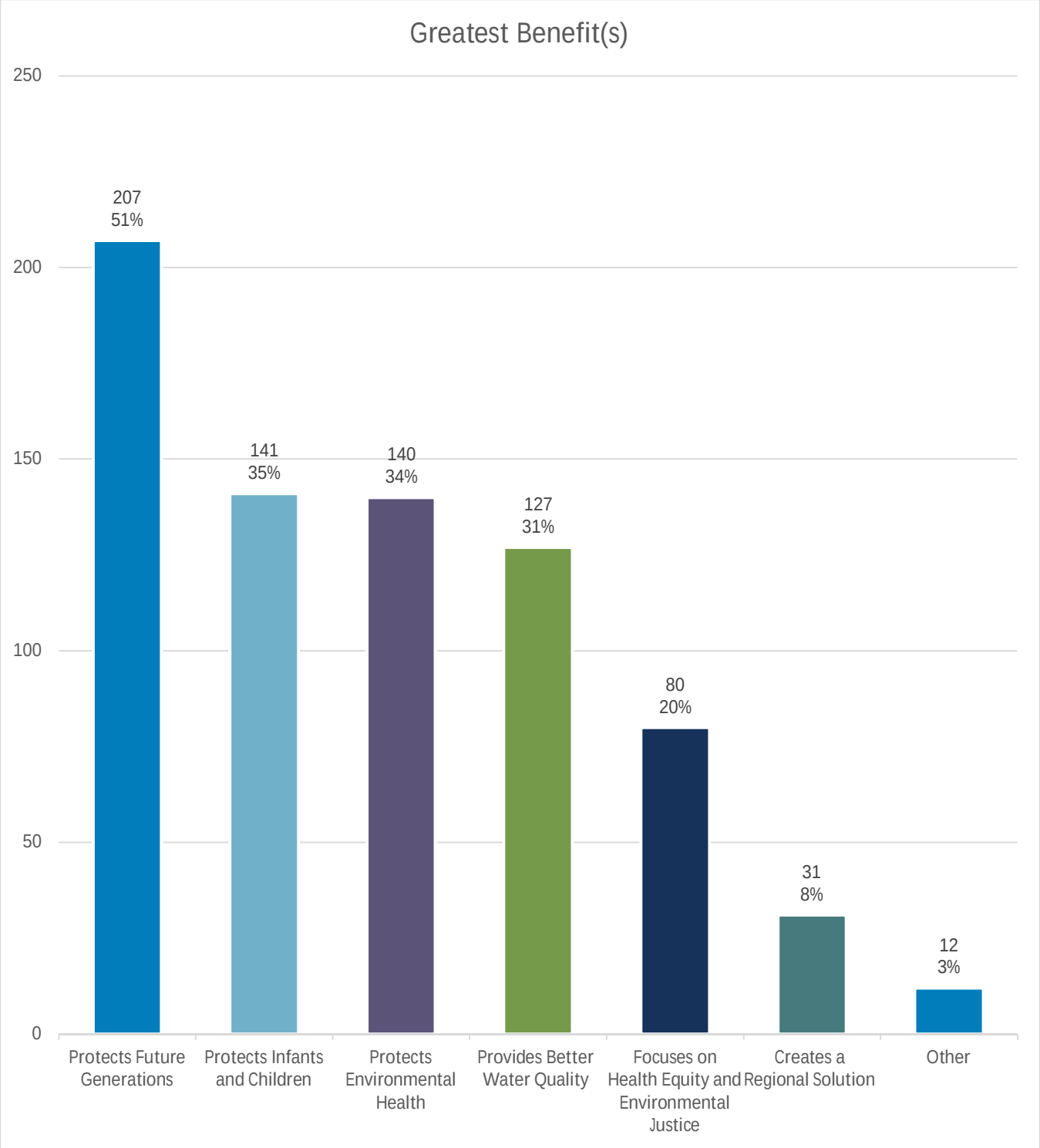


1. As part of the proposed Lead Reduction Program, Denver Water would provide at-home filters to customers with a suspected lead service line, free of charge. How could Denver Water make the use of filters for drinking and cooking more convenient and accessible? (Select one)



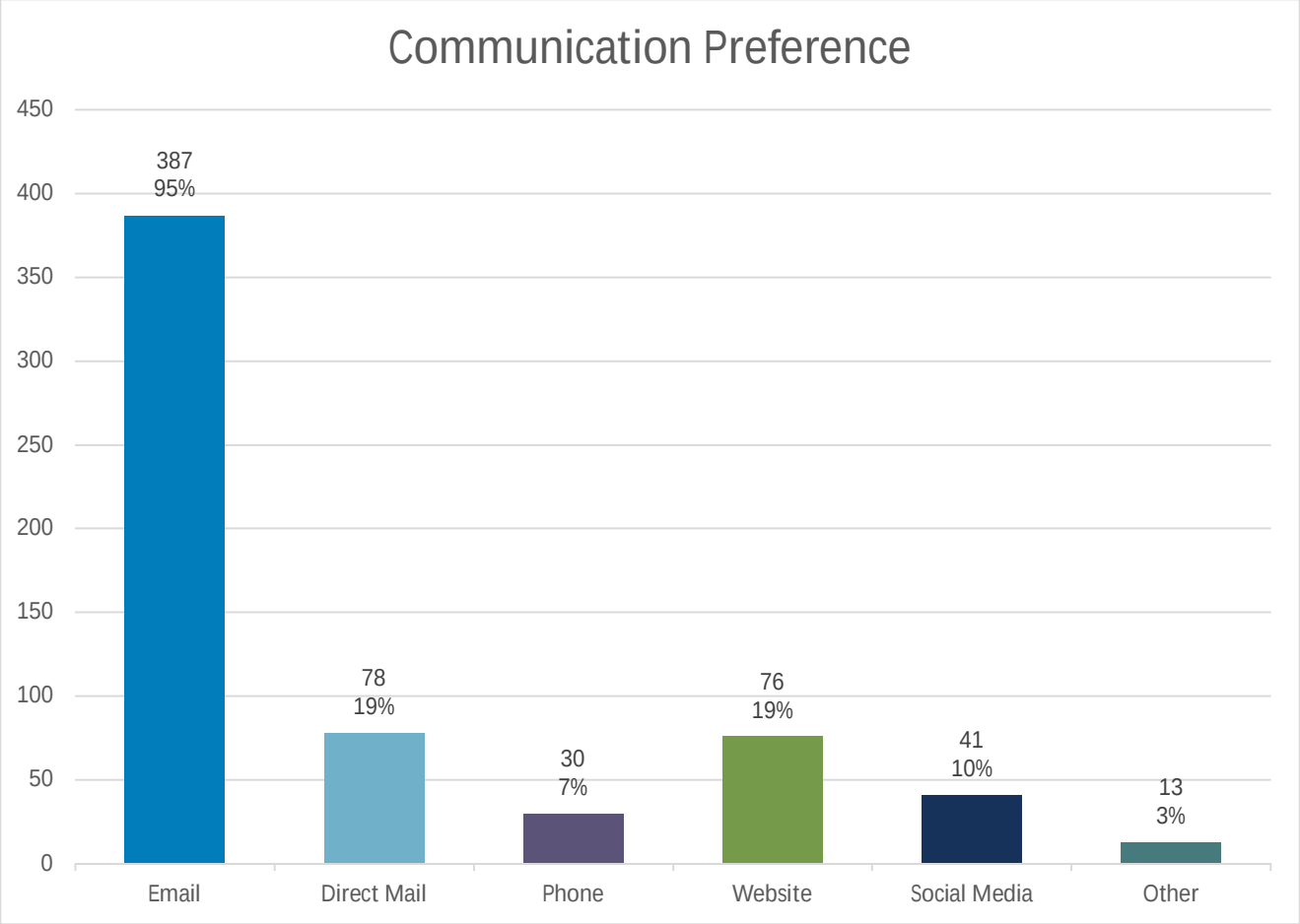
**"Other" responses available following response result graphs.*

2. What do you see as the greatest benefit of the proposed Lead Reduction Program? (Select up to two)



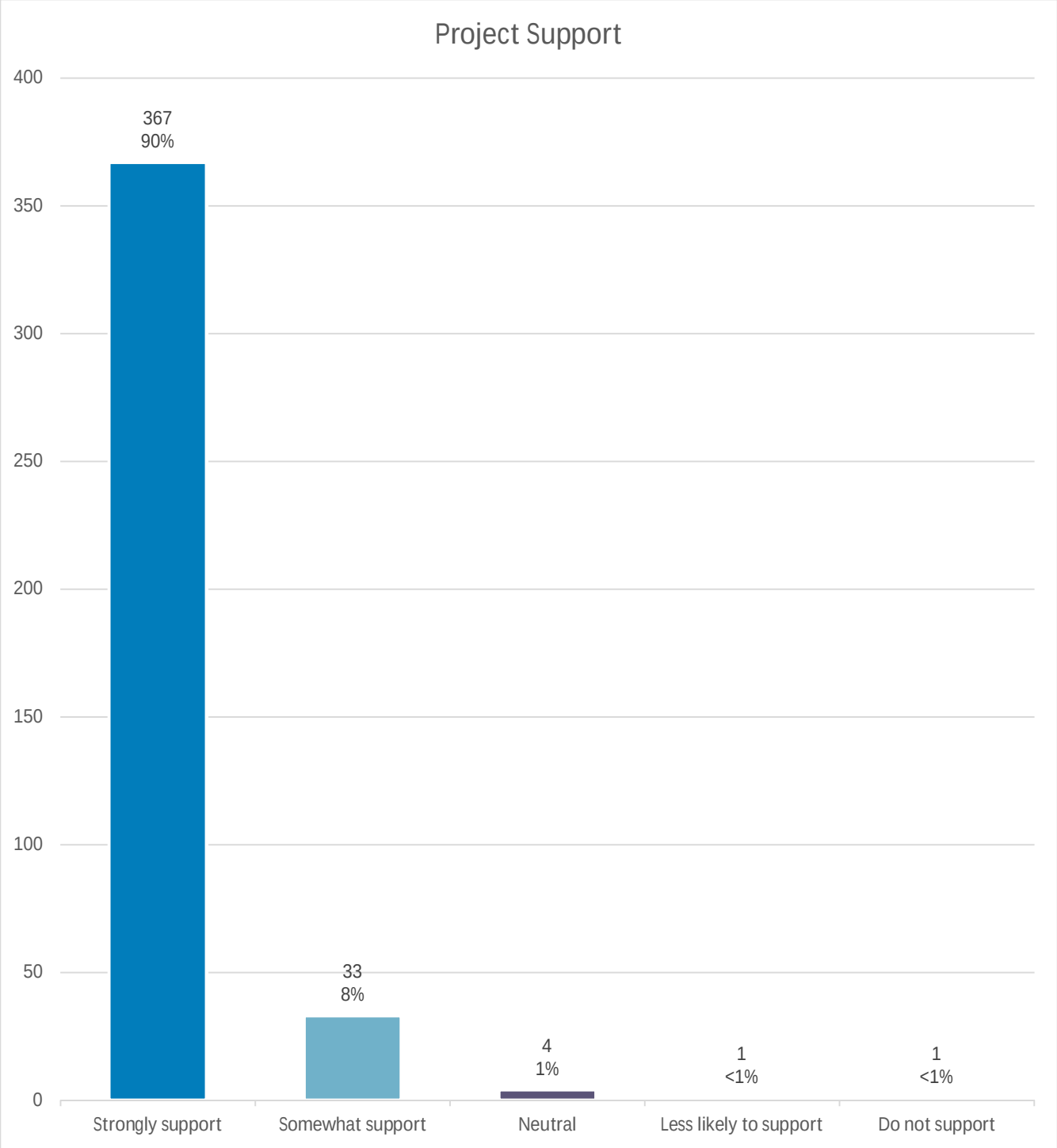
**"Other" responses available following response result graphs.*

3. What is your preference for how we communicate information and updates on the proposed Lead Reduction Program Plan? (Select all that apply)

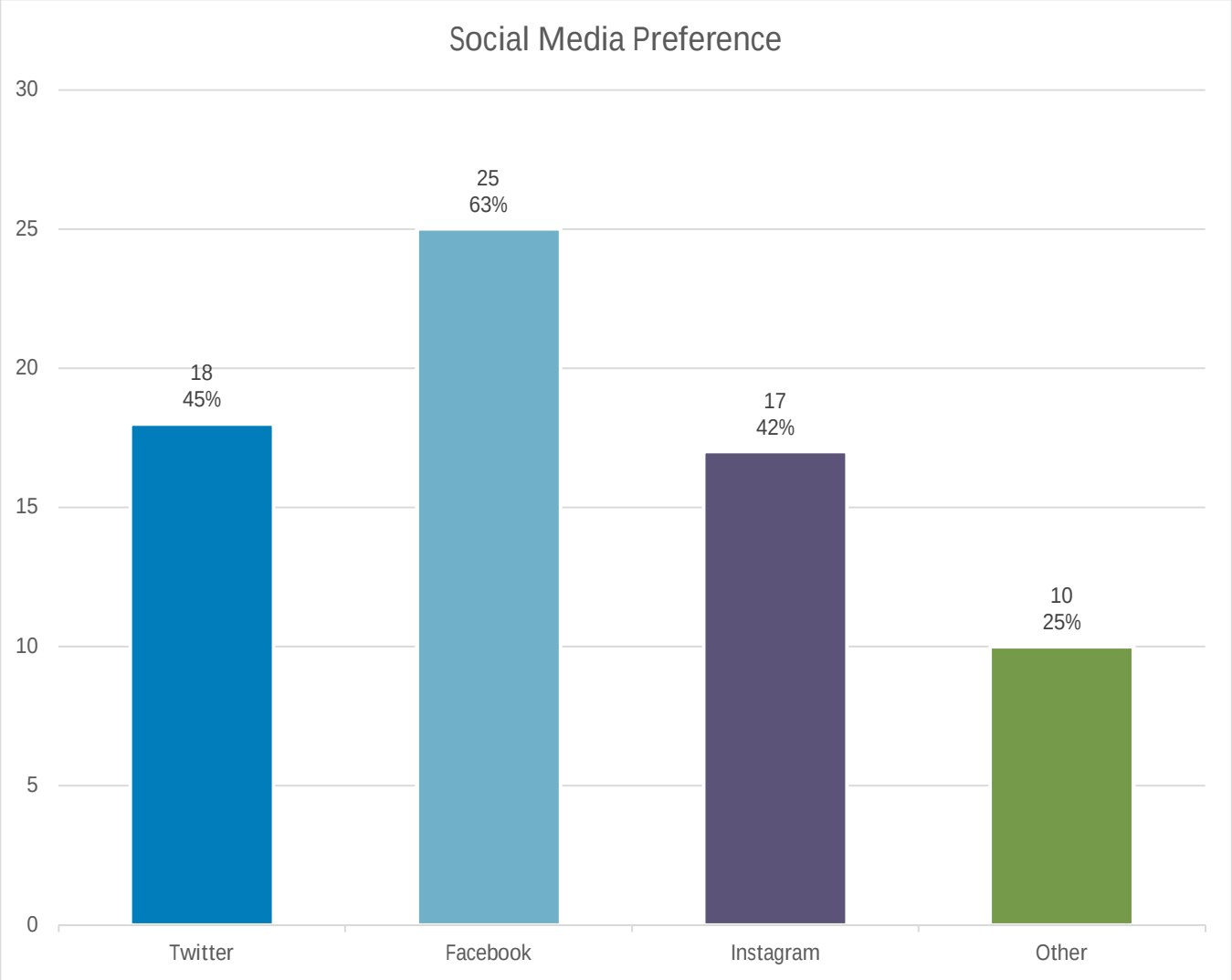


**"Other" responses available following response result graphs.*

4. How would you characterize your overall support for the proposed Lead Reduction Program?



5. Which social media option is your preference for how we communicate information and updates on the proposed Lead Reduction Program Plan? (Select all that apply)



Raw Comments

The following comments are included as they were received. No edits have been made to spelling, grammar or punctuation.

"Other" responses to How could Denver Water make the use of filters for drinking and cooking more convenient and accessible?"
all of the above
All of these options are important for helping residents use filters correctly and consistently
The basic thrust of this aspect of the lead remediation program is good. We don't have any preferences as to the four proposed methods for distributing filters.
...
Deliver filters to every home and offer consultation at the time of the delivery or scheduled at a later date, if requested.
Provide a list of allowable filters and then provide a statement credit when homeowner submits a receipt - similar to efficient toilet program. Add in a cartridge pick-up delivery program for ongoing maintenance..
I can't answer this one as I don't know the different types of filter types, or the difference between filters vs cartridges. Don't know where I'd have to go to pick up filter or voucher. If installation on the faucet is an option, I'd prefer that over a pitcher. But I need more information to be able to answer this, Maybe i need to re-read the
I think all of the above are important - customer needs to know what will work best for them and then have the opportunity to get that filter or cartridge in the easiest way possible (home delivery seems better)
All of the above
Would like to see filter attached to the main facet (in Kitchen)
I have been using an EverPure filter for 20 years - if denver will provide filter replacements - that would be terrific. My lines are lead - 1910 - I have submitted this response a cople weeks ago -it took a lot of read - read everything - resonded - call the water dept to expressmy interest in the possiblityi of a line replacement program in 2020 - I was told I would be contacted by that department (handling the lead issue once the decisions have been made - - have heard nothing.
Free, free filter replacements, delivered to homes,
Faucet filter
Faucet filter with delivery cartridge replacement
All of the above.
My choice is whatever would most increase access and participation for households most affected, especially in high-poverty areas. Otherwise I'd say being able to choose type of filter is would be helpful to make sure it's relevant to usage.
Provide water filters for ice makers
Provide the option of a whole house filter. This would make any water in the house safe to drink and use for cooking.
Provide water service and delivery like deep rock 5 gallon bottles and dispensers
Free filtration system
I have had a filter (Everpure)on my kitchen sink and ice maker since I moved into my house in 1996
Provide preferred filter type AND offer consultation. Be clear about why the filters are necessary and how and when they should be used
I want lead lines removed!
Test water at home, recommend type of filter and provide filter of choice

X
It would be great if Denver water could supply an easy at home test kit to help determine if your pipes introduce lead into your drinking water
Install whole home filtration system
Replace lines quickly. Already filling water filters to keep up with family drinking water use is cumbersome. In time, I can see folks getting lazy with dealing with it.
all of the above.
Offer undersink units
A combination of these needs to be offered rather than just one. For example combining the option of a preferred filter type, at home consultation and filter pick-up and delivery.
I understand you are requesting I select only one option, but I believe all of these options would equally make the use of filters more convenient and accessible, and I hope you decide to employ all of these options
Provide whole house water filters to be installed on the actual water line, or replace the lead pipes entirely.
Provide maintenance support for existing filters that customers have already installed
Filters need to also be installed in the showers and bathroom sinks where we brush our teeth. It will only really help if it's a whole-house filter, and my vote is for having all of the above available. Especially with the high prices we pay for water and wastewater.
I'm worried that the pitcher filter will be too slow for families to use for their needs. But the alternatives are not cost effective. Kitchen sink filter for those without fridge filter option?
Offer filtration for whole house/water main
Familiarize customers with kitchen water faucets that connect to filters under-the-counter.
Tell me where I can pick up my free (ideally) filter.
Replace service lines ASAP and/or provide subsidies to contract third party vendors to do so.
Provide under sink or whole house option as well rather then single source such as Refrigerator or single Pitcher.
Different customers may have different needs. We already have an in-refrigerator filter, and I'd appreciate replacement filters, but that probably isn't the most helpful for other households.

“Other” responses to “What do you see as the greatest benefit of the proposed Lead Reduction Program? (Select up to two)”
The DWD's proposed mixture of remedies is markedly better than simply adding a potential pollutant to wastewater and/or landscaping run-off.
...
This program benefits and protects consumers who have the means to replace their inside lead water pipes. When the city replaces water lines into people's homes and businesses, those of us with interior lead lines will continue to be exposed to lead.
silly question. Is it better to drink lead free water? of course. For all reasons above and more
I responded as described above - I will have a lot of expense to relocate my" in house" plumbing lines to a new location to hook up to new lines pulled from the street
All of the above.
I believe the root cause of the issue must be addressed, instead of a bandaid, for current residents and future generations.
repairing outdated infrastructure
Offers a more complete solution to the lead problem than any alternative
This program addresses a minority of all Denver Water customers.
all of the above.
Protects not just infants and children but also young adults, and animals in the home as well.

"Other" responses to "What is your preference for how we communicate information and updates on the proposed Lead Reduction Program Plan? (Select all that apply)"
…
Denver Water should use as many different means of communication that are feasible in order to reach the most people.
I would like to get on the list if the replacement program is the final solution that the Water deepartment decides to take!! I've tried to do what I can to make my interst known. I tested my water in April (your program - followed instruction explicitly!!)- it's not good
text/SMS with a short update and link to details
Text
Bill inserts
text message
Denver Water TAP Headlines
text message. a number of residents in our community do not have email but do use text. It is critical that everyone has access to the information that could affect their, and their children's, health.
outreach tables at community events and flyers through schools, community centers, etc.
Nextdoor
Nextdoor.com
Some neighbors might only be reachable via direct mail

"Other" responses to "Which social media option is your preference for how we communicate information and updates on the proposed Lead Reduction Program Plan? (Select all that apply)"
Via email: jeff.shoemaker@greenwayfoundation.org
There are options for automatic cross-posting on multiple social media platforms. No need to restrict sharing.
None used
email, us mail
Use all available social media tools.
I don't follow Denver Water currently on any social media
x
Neighborhood Email Exchanges
Hold a press conference(s). Get the Mayor to talk about it in his regular Friday broadcasts
Nextdoor

What would make you more likely to support the Lead Reduction Program? ***(For those who selected "neutral", "less likely to support" or "do not support" in response to "How would you characterize your overall support for the proposed Lead Reduction Program?")***
…
The report states on page 7 that the biggest issue is "customer owned service lines". I'd like to know why the 2012 exceedance of the lead action level took 5 years to result in the Optimal Corrosion Report. If Denver Water did not complete the lead service line pipe rack study during that time, then what new data was used to cause the Colorado Department of Public Health and Environment to designate the use of orthophosphate? I assume that this department knew that orthophosphates "could negatively affect rivers, streams and lakes in our region". Why, then, did they suggest that solution? What are the figures regarding the cost of treating orthophosphate corrosion at waste water treatment plants? Would the addition

of orthophosphates provide lead protection for the pipes in people's homes? My concern is that people without the means to replace their inside pipes and fixtures will be less protected from lead poisoning than Denver residents who have the means to incur these costs. Are we choosing between privately run water treatment facilities' budgets and Denver residents' budgets? I don't know enough about the Denver Water Dept and it's stakeholders but if this about saving corporate dollars at consumers' expense then this is a Health Equity and Environmental Justice issue.
For DENVER to REALLY do something about this problem!!
.
I would support it if the cost was not passed on to unaffected customers. Those with lead pipes should bear the cost of mitigation.
If it didn’t involve adding chemicals to my water. If you haven’t already, please watch documentary “The Devil You Know” about DuPont and 3M dumping toxic chemicals from Teflon. This also involves a water company, the EPA and a chemical in the water. I hope this is nothing like this. Water is a precious resource we all use and it would be unwise to add harmful additives without knowing the long term effects

APPENDIX I.B – LETTERS OF SUPPORT

September 2019

DENVER WATER

Bear Creek Water and Sanitation District
2517 South Flower Street, Lakewood, CO 80227-2912

August 1, 2019

RECEIVED
AUG 05 2019
Manager's Office
Board of Water Commissioners

Jim Lochhead
CEO/Manager
Denver Water
1600 West 12th Avenue
Denver, Colorado 80204
jim.lochhead@denverwater.org

RE: Comments on Denver Water's Lead Reduction Program Plan

Dear Mr. Lochhead,

On behalf of the Board of Directors of the Bear Creek Water and Sanitation District, I submit the following comments on Denver Water's draft Lead Reduction Program Plan (dated July 11, 2019).

The District recognizes that public health experts encourage the removal of lead service lines to provide public health protection from lead exposure in drinking water. We understand that Denver Water will prove to the USEPA that the proposed Lead Reduction Program provides a higher level of public health protection than the currently planned approach involving the addition of orthophosphate. If this is confirmed by the USEPA and CDPHE, the District will support Denver Water's Variance Request if the following changes are made to the final LRP Plan that is expected to be submitted to the USEPA in August of this year:

Increased collaboration with distributors regarding the development and execution of the communications and outreach plans associated with the Lead Reduction Program Plan (LRP) – The distributors were excluded from most of the pre-variance phase communication efforts mentioned on page 42 of the document. Details released to the public were typically provided to us on the same day press releases were issued with little advance warning. Moving forward, this needs to change and can be accomplished by specifically incorporating distributors into the communications for each of the action sections of the plan.

Collaboration with distributors is specifically mentioned several places with respect to the Lead Service Line (LSL) inventory actions, which is necessary given the distributors typically have most knowledge, whether field or historical records, regarding the existence of LSLs in their distribution networks. Upon a detailed review of the LRP Plan and associated appendices, the District noted that there is no mention of distributor collaboration in Section III.C (Filter Program) or III.D (Accelerated Lead Service Line Replacement Plan). This is a significant oversight on behalf of Denver Water given that customer communication is a shared responsibility for Read & Bill distributors and the sole responsibility of Master Meter distributors.

Bear Creek Water and Sanitation District does not have any homes with lead service lines within the District boundaries. However, Bear Creek Water and Sanitation District must be prepared to answer questions from our customers regarding Denver Water's Lead Reduction Program Plan including any impact to the District and our shared customers.

The District has worked hard to build a trusted relationship with our customers, similar to what Denver Water has done so well with its own inside City customers. To ensure that trusted relationship continues through the LRP, the District should be involved in any communications directed to them as part of the execution of the LRP Plan and Communications, Outreach & Education Plan (COE Plan).

We do acknowledge Denver Water is ultimately responsible for execution of the LRP Plan as they are the regulated entity. However, for this effort to be successful, Denver Water needs to revise the LRP Plan and the COE Plan to specifically commit to involving the distributors in communications efforts on the Filter Program and the Accelerated LSL Replacement Plan. The District requests Denver Water revise the LRP Plan and the COE Plan to include specific actions:

- Each distributor will be given the option to determine how they want to participate in the customer communications process. Some may prefer to be involved as a co-lead, others may only want advance notice, and a few may defer fully to Denver Water. All should be acceptable options offered by Denver Water and each district's preference should be respected.

- With respect to the Filter Program, include the following actions:
    - Develop communication materials that can be co-branded by distributors,
    - Include distributors in any planning efforts for door-to-door campaigns and neighborhood meetings (noted on page 54),
    - Provide training and/or talking points for distributor staff to use when engaging with customers on this topic. While the District understands that Denver Water prefers to be the primary POC for detailed information on the LRP, sufficient information needs to be provided to District staff to allow for informal conversations when we encounter questions from our customers, either in the field or during our own community events.

- With respect to the Accelerated LSL Replacement Plan, Denver Water should update the summary section located on page 57 to include a reference to coordinate construction activities with distributors. There is a specific reference to "coordinating with the City and County of Denver Public Works and other area municipal, utility, and public sector agencies"; however, coordination with distributors should be called out explicitly, especially for Read & Bill and Master Meter distributors.

In addition to the requested actions above regarding communication, we request two actions detailed below regarding the process of how the distributors should be included in COE Plan, which we understand will be more fully developed if the variance request is approved. Before submitting the LRP Plan and COE Plan to the USEPA, we would request the documents be revised to both increase the number of and provide more details for meaningful opportunities for engagement on customer communication for Read & Bill and Master Meter distributors.

Commit to the addition of a distributor representative on the LRP Leadership Committee – In the LRP Plan, Section III.F (Learning by Doing) outlines the approach to the formation and operation of an LRP Leadership Committee. The district supports the formation of this committee as an oversight entity that will guide the LRP through execution. However, we are significantly concerned that the distributors are not represented on that committee, especially given that 50% of the 1.4 million people who rely on Denver Water do so through a distributor. Although current indications are that only 5% of those people have a lead service line, many more may be impacted by the LSL inventory process, the Filter Program, or even ongoing communications about the LRP. Therefore, the District requests that, as the LRP Leadership Committee "invites other stakeholders to be members, such as representatives from watershed groups, wastewater dischargers, and public health agencies" (as stated on page 72), the Distributor Forum is allocated one representative to that Committee. In addition to participating in the Committee and working collaboratively towards the LRP Plan goals, this representative would also liaise between Denver Water and the distributors, ensuring continued support from that group and working to resolve any issues that may arise during the execution of the LRP. It may be that the Forum representative serves for the first few years of the LRP Plan execution process, working through the initial communication efforts, inventory tasks, filter distribution, and coordination efforts. Participation of the Forum representative can be evaluated every few years to ensure meaningful engagement opportunities still exist. If there are none, that representative could be sunset from the Committee.

Commit to an equitable distribution of the costs associated with the LRP Plan – The District understands there will be an extensive public input process over the next year to determine the appropriate allocation of costs associated with execution of the LRP Plan. However, the District requests an immediate commitment by Denver Water to an equitable distribution of those costs. We define equitable distribution to be an allocation of costs based upon the confirmed percentage of LSLs in the entire distributor network without the traditional multiplier applied to those costs. The distributor customers should not be required to subsidize the cost of replacing LSLs located within the City and County of Denver, which is where the vast majority of the LSLs are located (according to the current LSL inventory). We believe our customers would raise significant concerns to Denver Water if the cost of LSL replacement was distributed in any other way but as stated above. As Denver Water does not share in the cost of maintaining our customer's private systems, neither should the distributor customers be required to do that for inside City customers.

In conclusion, the District reiterates the need for Denver Water to revise the LRP Plan, including the appendix containing the COE Plan, to incorporate the requests outlined in this letter. The District will support the variance request and work collaboratively with Denver Water if those requests are incorporated into the final version of the LRP Plan. Successful execution of the LRP Plan depends on support from the distributor community as well as many other stakeholders located in the Denver metro area. Together we can achieve the goal of removing LSLs in our communities and significantly impacting public health protection through reduced exposure to lead in drinking water.

Should you have any questions or concerns about this letter, I can be reached by telephone at 303-986-3442 or e-mail at janwalker@bearcreekwater.org

Sincerely,

Jan C. Walker

Jan C. Walker
District Manager
Bear Creek Water and Sanitation District

cc: Dale L. Miller, Chairman, Bear Creek Water and Sanitation District
Denver Water Lead Reduction Program (lead@denverwater.org)
Julie Seagren, Denver Water Distributor Relations Manager
(julie.seagren@denverwater.org)

Citizens Advisory Committee

August 7, 2019

To: Lead Reduction Program, lead@denverwater.org

RE: Comments on Denver Water's Lead Reduction Program Plan

Dear Lead Reduction Program Staff,

On behalf of the Denver Water Citizen's Advisory Committee (CAC), I submit the following comments on Denver Water's draft Lead Reduction Program Plan (dated July 11, 2019).

The CAC recognizes that drinking water and public health experts encourage the removal of lead service lines to provide public health protection from lead exposure in drinking water. We are aware that Denver Water has substantial evidence and rationale to support a Variance Request from the USEPA to employ the proposed Lead Reduction Program (LRP), as it provides a higher level of public health protection than the currently planned approach involving the addition of orthophosphate. The CAC supports Denver Water's Variance Request.

On this matter, the CAC further advises that Denver Water:

- Commit to an equitable distribution of LRP costs and an early adoption of guiding principles to be applied in determining how costs will be distributed. Such guiding principles could include having property owners primarily responsible, not applying the cost adder for LRP costs for outside of City rate setting, seeking other sources of funding/financing, etc.
- Expand the LRP Leadership Committee to include representation from Water Distributors and outside of City Total Service Customers.
- Continue to coordinate an extensive communication plan with all customer classes.

Successful execution of the LRP Plan depends on support from many stakeholders located in the Denver metro area. Together we can achieve the goal of public health protection through reduced exposure to lead in drinking water.

Respectfully submitted on behalf of CAC,

Loretta Pineda
Chair, Denver Water CAC

August 7, 2019

Jim Lochhead, Chief Executive Officer
Denver Water
1600 W. 12th Ave
Denver, CO 80204

RE: LEAD REDUCTION PROGRAM PLAN — July 11, 2019 Draft for Public Comment

Dear Mr. Lochhead:

Clean Water Action appreciates the opportunity to comment on Denver Water's Lead Reduction Program Plan. For over forty years, Clean Water Action's national water programs have focused on addressing threats to drinking water and water quality by winning strong water pollution controls, including through Safe Drinking Water Act (SDWA) and Clean Water Act implementation. We also pioneer innovative collaborations to support fundamental changes in how water pollution and drinking water challenges are approached.

Clean Water Action strongly supports Denver Water's commitment to seek an alternative to orthophosphate that will achieve the same or greater reduction in lead exposure risk for its customers. Denver Water's proposal is an innovative approach to address unintended consequences of orthophosphate treatment, and if approved as proposed and carried out successfully, will provide a greater benefit to public health and the environment.

Our comments below highlight what we consider the greatest strengths of Denver Water's plan and we also offer some recommendations for the utility to consider as it continues to revise and refine its plan.

Plan Strengths

Goes after the source of lead instead of just treating the symptoms: Fully replacing all known lead service lines in Denver Water's service area within 15 years will permanently eliminate the largest source of lead in drinking water from its service area. The most effective and sustainable way to limit exposure to lead in drinking water is to remove lead at the source, which, for lead in drinking water, means fully replacing all lead service lines.

Provides health protection while customers wait to have service lines replaced: To address concerns that some residents may have to wait up to 15 years to have their lead service lines replaced, Denver Water will provide filters that reduce lead by 97 percent for all customers with lead service lines until six months after their lead service line is replaced.

Focuses on health equity and environmental justice: By replacing lead service lines at no-cost to the property owner, all Denver Water customers with lead service lines will have equal access to the health benefits of full lead service line replacement, regardless of their ability—or their landlord's ability— to pay.

Prioritizes protecting the most vulnerable: Infants and children are among the most vulnerable to lead exposure and Denver Water will work to identify daycare centers, schools, and areas with young families in order to prioritize these vulnerable populations for filter distribution and lead service line replacement.

Protects water quality and the environment: An unintended consequence of orthophosphate treatment is that its use can threaten water quality in nearby surface waters by increasing phosphorus levels that can harm fish, wildlife, recreational users, and downstream water systems. The Lead Reduction Program avoids this unintended consequence by preventing the introduction of an additional source of phosphorus into rivers, streams, and reservoirs.

Recommendations

Ensure an effective filter program for all participants: Denver Water's Filter Lead out of Water (FLOW) pilot outreach project was limited to owner-occupied single family homes. As Denver Water refines its FLOW program based on the results of that pilot, it will be important to consider how renters, especially renters in large, multi-family dwelling units, could have lower filter adoption rates due to occupancy turnover and other factors. Denver Water should also consider how to ensure daycare centers, schools, and other places serving populations most vulnerable to lead exposure are using filters properly.

Enhance school outreach programs: A robust education and outreach program to reach all customers impacted by lead in drinking water is critical to the success of the proposed Lead Reduction Program. Denver Water should expand on its existing lead reduction education outreach program in schools, including both public and private schools.

Address concerns over potential rate increase: Though as currently proposed there will be no cost to individual property owners whose lead service lines are replaced, there is the potential for a customer rate increase. As Denver Water completes its cost analysis for this program, it should consider how any potential rate increase could impact low-income customers and consider options for those who may be unable to absorb even a modest rate increase. Denver Water should communicate to its customers about any potential rate increases early on in the Lead Reduction Program.

Include messaging on regional water quality benefits in enhanced communications, outreach, and education plan: High rates of customer participation, especially in the FLOW program, are critical to the success of the Lead Reduction Program. Educating customers on the environmental benefits of keeping new sources of phosphorus out of regional streams, rivers, and reservoirs could increase willingness of some customers to participate in the program.

Include impacted community member(s) on Leadership Committee: It is critical that those most impacted by lead service lines have a voice at the table along with Denver Water, CDPHE, EPA, and other stakeholders. Community buy-in is vital to the success of this program, and we are concerned the

program may not be successful without meaningful inclusion of community members in decision making.

Clean Water Action is committed to working with Denver Water and other stakeholders to ensure the success of a Lead Reduction Program that protects public health and the environment. Protecting all of our communities from lead must be a top priority, and it is also critical to continue making progress toward reducing nutrient pollution in our rivers, streams, and reservoirs.

Sincerely,

Jennifer Peters
National Water Programs Director
Clean Water Action/Clean Water Fund
jpeters@cleanwater.org

August 7, 2019

Sent by email only

Jim Lochhead, Chief Executive Officer
Denver Water
1600 W. 12th Ave.
Denver, CO 80204

Re: Lead Reduction Program

Dear Mr. Lochhead:

Environmental Defense Fund (EDF) supports Denver Water's proposed "Lead Reduction Program Plan" as an innovative solution to a challenging problem. If approved as proposed, Denver Water's plan would fund full replacement of the estimated 75,000 lead service lines (LSLs) in their system within 15 years – thus removing the primary source of lead within Denver Water's system, while avoiding the use of orthophosphate that can further exacerbate nutrient pollution problems in the South Platte River and other downstream reservoirs, rivers, and streams. And Denver Water will go the extra step by providing filters certified to remove lead to residents with LSLs until the lines are replaced.

EDF's mission is to preserve the natural systems on which all life depends. We have more than two million members and a staff of 700 scientists, economists, policy experts, and other professionals around the world. Guided by science and economics, we find practical and lasting solutions to the most serious environmental problems. This has drawn us to areas that span the biosphere: climate, oceans, ecosystems and health. Our Health Program seeks to safeguard human health by reducing exposure to toxic chemicals and pollution, including accelerating lead service line replacement to reduce lead in drinking water. Our Ecosystems Program works to increase the resilience of natural systems, including reducing harmful nutrient pollution.

Moving forward, EDF recommends that Denver Water broaden the proposed Leadership Committee to include representatives of the communities with LSLs. Their engagement and guidance is crucial to the success of the Program. Their absence may undermine the Committee's credibility and effectiveness.

Ultimately, EDF hopes that this type of resilient solution can be adopted and replicated elsewhere both to protect public health and prevent degradation of our natural systems.

Sincerely,

Tom Neltner

Tom Neltner, JD
Chemicals Policy Director

Brian Jackson, MA
Senior Manager, Western Water

Glendale, Colorado

"The Urban Village"

Michael Dunafon
Mayor

Doris Rigoni
Mayor Pro-Tem

Jerry Peters
City Manager

Council Members:

Storm Gloor
Dario Katardzic
Lindsey Mintz

July 25, 2019

Jim Lochhead
CEO/Manager
Denver Water
1600 West 12th Avenue
Denver, Colorado 80204
jim.lochhead@denverwater.org

RE: Comments on Denver Water's Lead Reduction Program Plan

Dear Mr. Lochhead,

On behalf of the City of Glendale, I submit the following comments on Denver Water's draft Lead Reduction Program Plan (dated July 11, 2019).

The City of Glendale recognizes that drinking water and public health experts encourage the removal of lead service lines to provide public health protection from lead exposure in drinking water. We understand that Denver Water maintains that the proposed Lead Reduction Program provides a higher level of public health protection than the currently planned approach involving the addition of orthophosphate. If this is confirmed by the USEPA and CDPHE, the City of Glendale will support Denver Water's Variance Request if the following changes are made to the final LRP Plan that is expected to be submitted to the USEPA in August of this year:

First and Foremost, commit to an equitable distribution of the costs associated with the LRP Plan – The City of Glendale understands there will be an extensive public input process over the next year to determine the appropriate allocation of costs associated with execution of the LRP Plan. However, the City of Glendale requests an immediate commitment by Denver Water to an equitable distribution of those costs. We define equitable distribution to be an allocation of costs based upon the confirmed percentage of LSLs in the entire distributor network without the traditional multiplier applied to those costs. The City of Glendale customers should not be required to subsidize the cost of replacing LSLs located within the City and County of Denver, which is where the vast majority of the LSLs are located (according to the current LSL inventory). We believe our customers would raise significant concerns to Denver Water if the cost of LSL replacement was distributed in any other way but as stated above. As Denver Water does not share in the cost of maintaining our customer's private systems, neither should the distributor customers be required to do that for City and County of Denver customers.

Next, increased collaboration with distributors regarding the development and execution of the communications and outreach plans associated with the LRP – The distributors were excluded from most of the pre-variance phase communication efforts mentioned on page 42 of the document. Details released to the public were typically provided to us on the same day press releases were issued with little advance warning. Moving forward, this needs to change and may be accomplished by specifically incorporating distributors into the communications for each of the action sections of the plan.

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http//www.glendale.co.us

Michael Dunafon
Mayor

Doris Rigoni
Mayor Pro-Tem

Jerry Peters
City Manager

Council Members:

Storm Gloor
Dario Katardzic
Lindsey Mintz

Collaboration with distributors is specifically mentioned several places with respect to the LSL inventory actions, which is necessary given the distributors typically have most knowledge, whether field or historical records, regarding the existence of LSLs in their distribution network. Upon a detailed review of the LRP Plan and associated appendices, the City of Glendale noted that there is no mention of distributor collaboration in Section III.C (Filter Program) or III.D (Accelerated Lead Service Line Replacement Plan). This is a significant oversight on behalf of Denver Water given that customer communication is a shared responsibility for Read & Bill distributors and the sole responsibility of Master Meter distributors.

The City of Glendale has worked hard to build a trusted relationship with our customers, similar to what Denver Water has done so well with its own inside City customers. To ensure that trusted relationship continues through the LRP, the City of Glendale should be involved in any communications directed to them as part of the execution of the LRP Plan and Communications, Outreach & Education Plan (COE Plan). We do acknowledge Denver Water is ultimately responsible for execution of the LRP Plan as they are the regulated entity. However, for this effort to be successful, Denver Water needs to revise the LRP Plan and the COE Plan to specifically commit to involving the distributors in communications efforts on the Filter Program and the Accelerated LSL Replacement Plan.

The City of Glendale requests Denver Water revise the LRP Plan and the COE Plan to include specific action: Each distributor will be given the option to determine how they want to participate in the customer communications process. Some may prefer to be involved as a co-lead, others may only want advance notice, and a few may defer fully to Denver Water. All should be acceptable options offered by Denver Water and each City of Glendale's preference should be respected. This one specific example of how the distributors should be included in COE Plan, which we understand will be more fully developed if the variance request is approved. Before submitting the LRP Plan and COE Plan to the USEPA, we would request the documents be revised to both increase the number of and provide more details for meaningful opportunities for engagement on customer communication for Read & Bill and Master Meter distributors.

Also, commit to the addition of a distributor representative on the LRP Leadership Committee – In the LRP Plan, Section III.F (Learning by Doing) outlines the approach to the formation and operation of an LRP Leadership Committee. The City of Glendale supports the formation of this committee as an oversight entity that will guide the LRP through execution. However, we are significantly concerned that the distributors are not represented on that committee, especially given that 50% of the 1.4 million people who rely on Denver Water do so through a distributor. Although current indications are that only 5% of those people have a lead service line, many more may be impacted by the LSL inventory process, the Filter Program, or even ongoing communications about the LRP. Therefore, the City of Glendale requests that, as the LRP Leadership Committee "invites other stakeholders to be members, such as representatives from watershed groups, wastewater dischargers, and public health agencies" (as stated on page 72), the Distributor Forum is allocated one representative to that Committee. In addition to participating in the Committee and working collaboratively towards the LRP Plan goals, this representative would also liaise between Denver Water and the distributors, ensuring continued support from that group and working to resolve any issues that may arise during the execution of the LRP.

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Glendale, Colorado

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Mayor

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City Manager

Council Members:

Storm Gloor
Dario Katardzic
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It may be that the Distributor Forum representative serves for the first few years of the LRP Plan execution process, working through the initial communication efforts, inventory tasks, filter distribution, and coordination efforts. Participation of the Forum representative may be evaluated every few years to ensure meaningful engagement opportunities still exist. If there are none, that representative may sunset from the Committee.

In conclusion, the City of Glendale reiterates the need for Denver Water to revise the LRP Plan, including the appendix containing the COE Plan, to incorporate the requests outlined in this letter. The City of Glendale will support the variance request and work collaboratively with Denver Water if those requests are incorporated into the final version of the LRP Plan. Successful execution of the LRP Plan depends on support from the distributor community as well as many other stakeholders located in the Denver metro area. Together we can achieve the goal of removing LSLs in our communities and significantly impacting public health protection through reduced exposure to lead in drinking water.

Should you have any questions or concerns about this letter, I can be reached at 303-639-4501 or jbertrand@glendale.co.us.

Sincerely,

Joshua Bertrand
Director of Public Works
City of Glendale

cc: Jerry Peters, City Manager
Chuck Line, Deputy City Manager
Linda Cassaday, Deputy City Manager
Denver Water Lead Reduction Program (lead@denverwater.org)
Julie Seagren, Denver Water Distributor Relations Manager (julie.seagren@denverwater.org)

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November 15, 2018

The Honorable Jared S. Polis
Governor-Elect of Colorado
136 State Capitol Building
Denver, CO 80203

Dear Governor-Elect Polis,

I am writing you today as a student from Denver North High School Engagement Center, and as a citizen who resides in Denver. I am concerned about the amount of orthophosphates being added to our water supply by the Colorado Department of Health. We, the citizens of Colorado, should really take this problem into consideration seeing as this is the water we drink, bathe, and play in. As you are now to be the governor of Colorado, you are now the voice of the people. Now is the time to talk about this because the Colorado Department of Health is deciding to add more orthophosphates to our water supply to prevent lead corrosion. What they don't know is it will cost the state of Colorado our excellent water quality.

In my Earth Science class, we have been researching how orthophosphates can damage our bodies of water, and can create toxic algae which can lead to many health problems for humans and animals. During our field work, we found that the phosphates in the South Platte River were completely maxed out at 4 ppm (parts per million). Orthophosphates, in excess, cause nutrient pollution. Orthophosphates are a type of nutrient phosphorus, which acts as a fertilizer for algae. This is very important because if we add orthophosphates to our drinking water supply, eventually our rivers would fill up with algae, creating toxins dangerous for both animals and humans alike.

There are intended and unintended consequences to adding orthophosphates in our water supply. The intended consequence is that orthophosphates create a barrier in our lead pipes and keeps the amount of lead in our water to below 15 ppb. This is important because we don't want another incident like what happened in Flint, where the lead was nearly 300 ppb.

But the unintended consequences of adding orthophosphates are far more disastrous to our ecosystem. As stated previously, orthophosphate acts as a fertilizer, which creates more algae (since algae uses phosphorus as a nutrient). Algae is dangerous for many reasons: it steals oxygen from the water, de-oxygenating it, and eventually suffocating the fish and other aquatic animals; also, some algae contains toxins that, if they come into contact with humans or animals, cause illnesses like rashes, vomiting, and liver damage.

Mr. Polis, there is a better alternative than using orthophosphates in our water supply: change the lead pipes to CPVC pipes. These pipes do not degrade with hot water exposure (as compared to lead pipes, which corrode when exposed to hot water), and they do not contain any dangerous chemicals (like lead). Compared to draining out the de-oxygenated water from our lakes and rivers (which costs $500-$1500 every time the body of water is drained) or charcoal filters (which cost $500-$1500 per house and must be replaced every 4-6

years), simply just replacing the pipes once (for a cost of **$6,000**-$22,000 per pipe depending on location) will last a lifetime. While the upfront cost of CPVC pipes seems high, we need to think about the long-term solution for our lead problem in Colorado. Replacing the pipe lines to our homes is the best option for a long-term solution.

If we do not act now, our water pipelines will continue to corrode. So we need to take action now or we may become the next Flint Michigan. Because I know you are a former teacher, I'm hoping a students' opinions will matter to you. Also, as a citizen of Colorado, that you, the Governor Elect, will make a difference and make Colorado's drinking water safer in an eco-friendly way. Remember, the CDH is, as of right now, is making the decision to add more orthophosphates to our water. We have a time limit, not only because of our pipes, but also because of our bodies of water.

Please contact me so we may discuss this in person.

Thank you for your time,

Itati Carson

METRO WASTEWATER RECLAMATION DISTRICT

William J. "Mickey" Conway, District Manager

August 7, 2019

Mr. Jim Lochhead, Chief Executive Officer/Manager
Mr. Tom Roode, Chief of Operations and Maintenance
Ms. Nicole Poncelet-Johnson, Water Treatment and Quality Manager
Denver Water
1600 West 12th Avenue
Denver, CO 80204

Submitted Via Electronic Mail:
jim.lochhead@denverwater.org; tom.roode@denverwater.org; nicole.poncelet@denverwater.org

Re: Denver Water's Lead Reduction Program

Dear Mr. Lochhead, Mr. Roode, and Ms. Poncelet-Johnson:

Thank you for the opportunity to comment on Denver Water's Lead Reduction Program. The Metro Wastewater Reclamation District (Metro District or District) strongly supports this Lead Reduction Program. As you know, the Metro District provides wastewater treatment and resource recovery services to more than two million people in the Denver metropolitan area. As a national model tailored to the unique needs of the arid west, this Program will permanently, holistically, and sustainably address lead in Denver Water's service area without adversely affecting downstream communities and the South Platte River watershed. This collaborative and innovative program provides protection to the District's 62 public and corporate connectors, and it has the full support of our Board of Directors representing 22 of the largest municipal entities in the metro area.

Central to this solution is the alignment of two important public health concerns—lead in drinking water and nutrients in watersheds. Since 2017, the Metro District, Denver Water, and several regional partners have worked collaboratively to develop and advocate for a solution that will protect Denver Water's customers at the tap from lead, while also protecting the public health of downstream communities and maintaining the health of the South Platte River watershed from the adverse effect of nutrients.

The Metro District supports the Lead Reduction Program presented by Denver Water because the Program:

- Is expected to **reduce lead at the tap within its service area to below 5 parts per billion (ppb) for all customers and for many customers to non-detect levels**[1]; and
- **Will eliminate the use of orthophosphate** as a corrosion control inhibitor, which will avoid adverse effects to downstream communities and the watershed.

[1] Figure 18 on page 39 of the Lead Reduction Program Plan demonstrates the Lead Reduction Program will reduce concentrations at the tap more effectively than the addition of orthophosphate.

The alternative to the Lead Reduction Program includes the use of a phosphorus-based chemical called orthophosphate as a corrosion control inhibitor. The alternative would adversely affect the public health of downstream communities and the health of the watershed by significantly increasing point and non-point phosphorus pollution in the South Platte River watershed. The following table shows the additional phosphorus loads that would result from the use of orthophosphate.

Orthophosphate Loadings

Total Loading		Year 2020	Year 2030	Year 2040	Year 2050
Average Daily Water Provided by Denver Water	MGD[1]	170	199	214	214
Percent Outdoor Use	Percent	40	40	40	40
Percent Indoor Use	Percent	60	60	60	60
Outdoor Average Daily Water Use	MGD	69	80	86	86
Indoor Average Daily Water Use	MGD	101	119	128	128
Total Annual Added Phosphorus Load from All Water Provided by Denver Water[2]	Pounds as Phosphorus	**505,603**	**591,555**	**637,060**	**637,060**

[1] Million gallons per day
[2] Based on Denver Water's Optimal Corrosion Control Technique (OCCT) result showing an orthophosphate dose of 3 milligrams per liter (mg/L)

This would be a significant new source of phosphorus pollution in the South Platte River watershed. Over the last 18 months, the region has been working with Denver Water to find an alternative solution that will avoid or minimize this new source of phosphorus pollution because the region recognizes that reducing nutrient pollution is also important for public health and the environment in the region. For decades, the U.S. Environmental Protection Agency (EPA) and the Colorado Department of Public Health and Environment (CDPHE) have recognized that too much nitrogen or phosphorus in the environment produce more algae than the ecosystem can handle, resulting in environmental and human health issues.

National and State Frameworks to Reduce Nutrients

The EPA has conducted extensive research on nutrients, which is available on its website. The EPA website[2] explains the science concerning nutrient pollution and includes the following statements:

- **Nutrient pollution** is one of America's most widespread, costly and challenging environmental problems, and is caused by excess nitrogen and phosphorus in the air and water.
- **Too much nitrogen and phosphorus** in the water can have diverse and far-reaching impacts on public health, the environment, and the economy.
- **Excess nutrients can cause harmful algal blooms (HABs)** in freshwater systems, which not only disrupt wildlife but can also produce toxins harmful to humans.
- **Harmful algal blooms sometimes create toxins** that are detrimental to fish and other animals....Even if algal blooms are not toxic, they can negatively impact aquatic life by blocking out sunlight and clogging fish gills.

[2] https://www.epa.gov/nutrientpollution

- **Nutrient pollution has diverse and far-reaching effects** on the U.S. economy, impacting tourism, property values, commercial fishing, recreational businesses and many other sectors that depend on clean water.
- **Nitrates and algal blooms** in drinking water sources can drastically increase treatment costs.

To address these concerns, a 2011 EPA memorandum from Nancy K. Stoner to the Regional Administrators (*Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions)* (page 2) explains that when creating a program to manage nitrogen and phosphorus pollution, it is "of most importance" to:

- Prioritize watersheds,
- Set load reduction goals for watersheds, and
- Reduce loadings.

The State of Colorado followed the programmatic approach recommended by the EPA, which included the adoption of new regulations that prioritized watersheds, set load reductions goals, and required point sources to reduce nutrient loads.

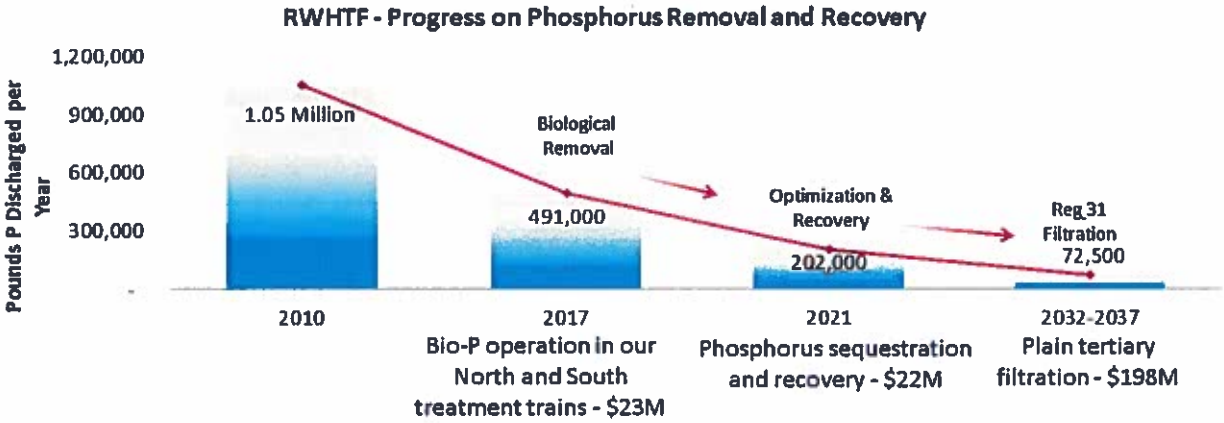
In 2012, the Colorado Water Quality Control Commission adopted parameter limitations for phosphorus and nitrogen in Regulation 85 (*Nutrients Management Control Regulation)* and numeric interim values for phosphorus, nitrogen, and chlorophyll *a* to protect domestic water supply use, recreation, and aquatic life uses in Regulation 31 (*The Basic Standards and Methodologies for Surface Water*). The CDPHE has been implementing the Regulation 85 parameter limitations in water quality discharge permits for the past several years.

In addition, in 2013 both the CDPHE and the EPA adopted Total Maximum Daily Loads (TMDL) for Barr Lake and Milton Reservoir that collectively required over 90 percent reduction in phosphorus loadings to each reservoir.

The Metro District's mission is to protect the region's health and environment by cleaning water and recovering resources. Consistent with its mission, over the last two decades, the District has partnered with the EPA and CDPHE to establish the Colorado nutrient framework and has invested in treatment technologies to reduce its phosphorus loadings.

Technological Investments and Improvements in the South Platte Watershed Water Quality

In furtherance of the national and state policy to reduce nutrients, without a current regulatory requirement to do so, the Metro District has already invested $50 million in treatment technologies to reduce phosphorus. These treatment technologies have significantly reduced the District's Robert W. Hite Treatment Facility's (RWHTF) phosphorus loads to the South Platte River watershed as demonstrated in the following graph. (Please note that the reductions presented in the graph do not include the additional load that would result from the use of orthophosphate).



The Metro District's reductions in phosphorus loads coupled with reductions achieved through the Colorado nutrient framework have resulted in measurable improvements to the water quality of the South Platte River watershed. In-stream total phosphorus (TP) concentrations downstream of the RWHTF have decreased significantly.

The nutrient reductions have also resulted in lower concentrations in the South Platte River and off-channel reservoirs, including Barr Lake and Milton Reservoir. For example:

- **Segment 15, South Platte River.** The average annual TP concentration was 0.78 mg/L in 2018, a 52 percent reduction from the 2013 average annual TP concentration of 1.5 mg/L.
- **Milton Reservoir.** The average spring TP concentration from 2014 to 2018 was 0.28 mg/L, a 60 percent reduction from the 2008–2012 average spring TP concentration of 0.72 mg/L.
- **Barr Lake:** The average spring TP concentration from 2014 to 2018 was 0.29 mg/L, a 48 percent reduction from the 2008–2012 average spring TP concentration of 0.55 mg/L and a 62 percent reduction from the 2003–2007 average spring TP concentration of 0.75 mg/L.

By avoiding the addition of a substantial amount of phosphorus into the South Platte River watershed, the Lead Reduction Program will allow the region to sustain and continue the progress already made to improve the water quality in the South Platte River watershed because of nutrient reductions.

Adding a large volume of orthophosphate to the South Platte River watershed would be a serious—and likely irreversible—setback to the progress accomplished in recent years to reduce phosphorous in the South Platte River watershed. In addition to the public health and environmental impacts, the use of orthophosphate would also result in significant financial impacts on the Metro District. To treat this significant new load of phosphorus the Metro District would install advance treatment at the RWHTF, which would increase the capital cost for advance treatment by $120 million (2017 dollars). The annual operational costs would also increase by $4.6 million due to the need for chemical addition to the treatment process. Not only would this approach conflict with the national and state frameworks to reduce nutrients, it would also put a significant financial burden on the two million ratepayers located within the service area of the District.

Maximizing Public Health through the Lead Reduction Program

The Metro District supports the Lead Reduction Program because it aligns two important public health frameworks. It achieves the greatest expected reductions of lead at the tap (short and long term) in a manner that avoids the negative impacts to the South Platte River watershed from the alternative approach, orthophosphate.

Decisions about water management in the arid west present unique challenges because of water scarcity. Throughout the arid west we are dependent upon water reuse for vibrant and healthy communities. The introduction of a large volume of chemicals, such as orthophosphate, within the water cycle will cause rippling adverse effects through the rest of the water cycle. This cannot be the right solution when there is an alternative that, on its own merits, is superior at protecting public health from exposure to lead in drinking water.

Recognizing this is a complex and interconnected issue, the Metro District and its partners have continued to advocate for the Lead Reduction Program, a one watershed and one ratepayer solution. Because of water scarcity in this region, a customized solution is more important than ever to ensure decisions today will not impair the ability of future generations to use and enjoy this valuable resource.

Sincerely,

William J. "Mickey" Conway
District Manager

July 29, 2019

Jim Lochhead
CEO/Manager
Denver Water
1600 West 12th Avenue
Denver, Colorado 80204
jim.lochhead@denverwater.org

RE: Comments on Denver Water's Lead Reduction Program Plan

Dear Mr. Lochhead,

On behalf of the Boards of Directors of the Platte Canyon Water & Sanitation District and the Southwest Metropolitan Water & Sanitation Districts (Districts), I submit the following comments on Denver Water's draft Lead Reduction Program Plan (dated July 11, 2019).

The Districts recognize that drinking water and public health experts encourage the removal of lead service lines to provide public health protection from lead exposure in drinking water. We understand that Denver Water will prove to the USEPA that the proposed Lead Reduction Program provides a higher level of public health protection than the currently planned approach involving the addition of orthophosphate. If this is confirmed by the USEPA and CDPHE, the Districts will support Denver Water's Variance Request if the following changes are made to the final LRP Plan that is expected to be submitted to the USEPA in August of this year:

Increased collaboration with distributors regarding the development and execution of the communications and outreach plans associated with the LRP – The distributors were excluded from most of the pre-variance phase communication efforts mentioned on page 42 of the document. Details released to the public were typically provided to us on the same day press releases were issued with little advance warning. Moving forward, this needs to change and can be accomplished by specifically incorporating distributors into the communications for each of the action sections of the plan.

Collaboration with distributors is specifically mentioned several places with respect to the LSL inventory actions, which is necessary given the distributors typically have most knowledge, whether field or historical records, regarding the existence of LSLs in their distribution network. Upon a detailed review of the LRP Plan and associated appendices, the District noted that there is no mention of distributor collaboration in Section III.C (Filter Program) or III.D (Accelerated Lead Service Line Replacement Plan).

This is a significant oversight on behalf of Denver Water given that customer communication is a shared responsibility for Read & Bill distributors and the sole responsibility of Master Meter distributors. The Districts have worked hard to build a trusted relationship with our customers, similar to what Denver Water has done so well with its own inside City customers. To ensure that trusted relationship continues through the LRP, the Districts should be involved in any communications directed to them as part of the execution of the LRP Plan and Communications, Outreach & Education Plan (COE Plan). We do acknowledge Denver Water is ultimately responsible for execution of the LRP Plan as they are the regulated entity. However, for this effort to be successful, Denver Water needs to revise the LRP Plan and the COE Plan to specifically commit to involving the distributors in communications efforts on the Filter Program and the Accelerated LSL Replacement Plan. The Districts requests Denver Water revise the LRP Plan and the COE Plan to include specific actions:

- Each distributor will be given the option to determine how they want to participate in the customer communications process. Some may prefer to be involved as a co-lead, others may only want advance notice, and a few may defer fully to Denver Water. All should be acceptable options offered by Denver Water and each district's preference should be respected.
- With respect to the Filter Program, include the following actions:
    - Develop communication materials that can be co-branded by distributors,
    - Include distributors in any planning efforts for door-to-door campaigns and neighborhood meetings (noted on page 54),
    - Provide training and/or talking points for distributor staff to use when engaging with customers on this topic. While the District understands Denver Water prefers to be the primary POC for detailed information on the LRP, sufficient information needs to be provided to District staff to allow for informal conversations when we encounter questions from our customers, either in the field or during our own community events.
- With respect to the Accelerated LSL Replacement Plan, Denver Water should update the summary section located on page 57 to include a reference to coordinate construction activities with distributors. There is a specific reference to "coordinating with the City and County of Denver Public Works and other area municipal, utility, and public sector agencies"; however, coordination with distributors should be called out explicitly, especially for Read & Bill and Master Meter distributors. Where there are identified LSLs to be replaced, the District would prefer a coordinated approach to identify any capital project construction synergies that could be realized during this process. Additionally, as the District already attempts to coordinate our capital projects with county paving plans, Denver Water would benefit from our existing planning efforts and relationships with those entities.

These are some specific examples of how the distributors should be included in COE Plan, which we understand will be more fully developed if the variance request is approved. Before submitting the LRP Plan and COE Plan to the USEPA, we would request the documents be revised to both increase the number of and provide more details for meaningful opportunities for engagement on customer communication for Read & Bill and Master Meter distributors.

Commit to the addition of a distributor representative on the LRP Leadership Committee – In the LRP Plan, Section III.F (Learning by Doing) outlines the approach to the formation and operation of an LRP Leadership Committee. The Districts support the formation of this committee as an oversight entity that will guide the LRP through execution. However, we are significantly concerned that the distributors are not represented on that committee, especially given that 50% of the 1.4 million people who rely on Denver Water do so through a distributor. Although current indications are that only 5% of those people have a lead service line, many more may be impacted by the LSL inventory process, the Filter Program, or even ongoing communications about the LRP. Therefore, the Districts requests that, as the LRP Leadership Committee "invites other stakeholders to be members, such as representatives from watershed groups, wastewater dischargers, and public health agencies" (as stated on page 72), the Distributor Forum is allocated one representative to that Committee. In addition to participating in the Committee and working collaboratively towards the LRP Plan goals, this representative would also liaise between Denver Water and the distributors, ensuring continued support from that group and working to resolve any issues that may arise during the execution of the LRP. It may be that the Forum representative serves for the first few years of the LRP Plan execution process, working through the initial communication efforts, inventory tasks, filter distribution, and coordination efforts. Participation of the Forum representative can be evaluated every few years to ensure meaningful engagement opportunities still exist. If there are none, that representative could be sunset from the Committee.

Commit to an equitable distribution of the costs associated with the LRP Plan – The Districts understands there will be an extensive public input process over the next year to determine the appropriate allocation of costs associated with execution of the LRP Plan. However, the Districts request an immediate commitment by Denver Water to an equitable distribution of those costs. We define equitable distribution to be an allocation of costs based upon the confirmed percentage of LSLs in the entire distributor network without the traditional multiplier applied to those costs. The distributor customers should not be required to subsidize the cost of replacing LSLs located within the City and County of Denver, which is where the vast majority of the LSLs are located (according to the current LSL inventory). We believe our customers would raise significant concerns to Denver Water if the cost of LSL replacement was distributed in any other way but as stated above. As Denver Water does not share in the cost of maintaining our customer's private systems, neither should the distributor customers be required to do that for inside City customers.

In conclusion, the Districts reiterate the need for Denver Water to revise the LRP Plan, including the appendix containing the COE Plan, to incorporate the requests outlined in this letter. The Districts will support the variance request and work collaboratively with Denver Water if those requests are incorporated into the final version of the LRP Plan. Successful execution of the LRP Plan depends on support from the distributor community as well as many other stakeholders located in the Denver metro area. Together we can achieve the goal of removing LSLs in our communities and significantly impacting public health protection through reduced exposure to lead in drinking water.

Should you have any questions or concerns about this letter, I can be reached at (303) 979-2333 or pjfitzgerald@plattecanyon.org.

Sincerely,

Pat Fitzgerald
District Manager
Platte Canyon Water & Sanitation District
Southwest Metropolitan Water & Sanitation District

cc: Richard Rock, Board of Directors, Platte Canyon Water & Sanitation District
Anthony Dursey, Board of Directors, Southwest Metropolitan Water & Sanitation District
Denver Water Lead Reduction Program (lead@denverwater.org)
Julie Seagren, Denver Water Distributor Relations Manager (julie.seagren@denverwater.org)

Comments on Denver Lead Reduction Plan

The Lead Reduction Program Plan proposed by Denver Water represents a comprehensive, proactive strategy for the nearly immediate reduction of lead exposure in drinking water at the highest risk homes by distributing filters at all lead service line homes, while beginning the longer term process of permanently removing lead service lines and optimizing corrosion control for addressing remaining sources of lead in Denver's drinking water infrastructure. The comprehensive approach also approaches the program from an equity perspective, ensuring that all high-risk customers have access to filters and lead service line replacements, regardless of ability to pay. This approach, which places public health protection and permanent removal of lead service lines as the highest priority, should be seen as a model for addressing lead in drinking water. The execution of the program as described in the program plan and the verification that all program components are executed as described will ultimately determine how successful the program is at reaching and reducing risk for all lead service line customers. The success of this program is dependent on each of these programs following through consistently. We know that any individual staff member can be the weakest link. Rigorous tracking protocols and regular program audits will be critical for verifying the program is working as intended.

The Proposed Lead Reduction Program Plan includes aggressive commitments to protect all customers in lead service line homes. However, on the whole the program evaluation criteria proposed present a low bar for identifying a system that failed to meet criteria and must proceed with a corrective action. When the program is built around the concept that all lead service lines homes have filters and the information they need to use them on a daily basis, then to meet expectations the annual filter adoption rate should be very close to 100% and the need for corrective action should be triggered when the number falls below 95%. The corrective actions should focus on providing the necessary resources to achieve the programmatic goals rather than changing course entirely as suggested in the corrective actions currently listed.

It should be noted that, contrary to the information on page 12 of the executive summary, actual "lead-free" plumbing components are not available. Plumbing components labeled "lead-free" contain up to 0.25% lead by weight. Materials that Denver Water distributes to its customers should not obscure the fact that installing new plumbing components still continues to add new lead to household plumbing systems.

Page 52 of the lead reduction program plan states that if the LSLR program is complete and a new LSL is identified, Denver Water has 6 months to replace the line. This seems far too long, given that at this point Denver will have finished the rest of the lead service line replacements and know how to replace the lead service line more efficiently than ever. After 15 years of unknown lead exposure, another 6 months if far too long for this home to race.

Page 61 of the lead reduction program plan describes a process for investigating homes with water quality above the action level. This answer implies that the inspection will identify lead in water risks in the home, but the programs described historically have not addressed drinking water sources of lead. This response should be updated to clarify the procedures of community organizations and grant programs for incorporating lead in drinking water into their lead reduction programs.

On Page 62, the service line material should be positively confirmed for any home that chooses to not participate in lead service line replacement so that it can be accurately captured in Denver Water's inventory.

On Page 71, last paragraph, please clarify the frequency with which corrosion control adjustments are made based on monthly data. Are Water Quality Parameters also adjusted from month to month to reflect this program?

Page 72, the concept of learning by doing as presented here appears to implement water treatment changes while distributing water to customers, implying that customers might be treated like guinea pigs and the water system will come back and continue to make adjustments until treatment is optimized. Updating protocols as new information becomes available is always appropriate, but it must be done in a way that does not put customers at greater risk.

Page 84, there are many limitations in using blood lead data to be able to correlate exposure to lead in drinking water to an elevated blood lead level. I recommend that this lead reduction plan does not imply that Denver is seeking evidence of elevated blood lead levels to establish causation from drinking water. The time to address lead in drinking water is when lead is detected in the water, not in children. http://graham.umich.edu/project/revised-lead-and-copper-rule/faq?faq=2

Elin Betanzo

SafeWaterEngineering.com

248-326-4339

August 6, 2019

Denver Water
Attn: Lead Reduction Program
1600 W. 12th Ave.
Denver, CO 80204

Dear Denver Water,

We are writing to commend Denver Water's Lead Reduction Program Plan. The plan's foundational statement, "When it comes to lead in drinking water, no levels are safe," its accelerated city-funded lead service line replacement plan, and its focus on protecting pregnant women, formula-fed infants and young children are exemplary science-driven actions.

The submitters of this comment are participants in Project TENDR (Targeting Environmental Neuro Developmental Risks). TENDR is a diverse group of experts in epidemiology, toxicology, exposure science, pediatrics, obstetrics and gynecology, nursing, public health, learning, intellectual and developmental disabilities, federal and state chemical policy and environmental justice, along with child and environmental advocacy organizations.

In July 2017, three Project TENDR leaders, David C. Bellinger, PhD, MSc, Aimin Chen, MD, PhD, and Bruce P. Lanphear, MD, MPH, published a Viewpoint article in *JAMA Pediatrics* titled "Establishing and Achieving National Goals for Preventing Lead Toxicity and Exposure in Children." In that article, Bellinger, Chen and Lanphear reviewed the science on the impacts of lead exposure including intellectual deficits, diminished academic abilities, attention deficits, and problem behaviors in children and affirmed the finding that there is no safe level of lead exposure.

The focus of the Denver Water Plan is on prevention, the best way to protect children and other vulnerable groups. The Plan seeks to reduce the sources of childhood lead exposures rather than solely identifying children who have already been unduly exposed or attempting to ameliorate the toxic effects after lead exposure has occurred. Thus, the Denver Water Plan is right on target to enhance public health.

We also applaud the plan's inclusion of "Focused and prioritized education and engagement to high risk community members (e.g., families with young children, including formula-fed infants, and pregnant women) with efforts to:

- Leverage existing stakeholder relationships/communication channels established by Denver Department of Public Health and Environment and Denver Water.
- Target messaging for various community organizations, doctor offices, etc.

- Partner with community health clinics, daycares/child care providers, social service programs for women and families.

Prioritizing the protection of the most vulnerable community members is sound public health policy. While the city is replacing lead service lines, the provision of effective water filters to women during their pregnanices as well as to families with formula fed infants and young children will lower the risk of neurodevelopmental harm for thousands of Denver's youngest residents. We hope the City will continue to monitor the water supply for lead levels after the new service lines are installed.

Thank you for developing a water plan grounded in science that puts children's health first; the Denver Water Plan provides a great model for others.

Sincerely,

David C. Bellinger, PhD, MSc
Research Director, Boston Children's Hospital
Professor, Harvard Medical School, Harvard T.H. Chan School of Public Health

Asa Bradman, PhD, MS
Associate Adjunct Professor, Department of Environmental Health Sciences
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COLORADO
WASTEWATER
UTILITY COUNCIL

Support Statement for Denver Water Optimal Corrosion Control Treatment (OCCT) Variance Request by the Colorado Wastewater Utility Council

The Colorado Wastewater Utility Council is in support of the Denver Water OCCT variance request to the U.S. Environmental Protection Agency. Provided the variance request is deemed to be as protective to public health as the approved OCCT option, we believe it is a better overall solution. The variance request avoids addition of chemicals to the water supply that is a less sustainable alternative. The variance request proposal addresses the root cause of the problem in the form of accelerated lead service line removal rather than providing a secondary fix, which could have unintended environmental consequences.

As wastewater treatment plants, our members' first concern is the health and safety of the public and the environment. The variance would eliminate many concerns of wastewater plants impacted by the OCCT determination. These issues include addition of phosphorus to watersheds that can degrade water quality in lakes and streams. Wastewater plants are currently working on treating phosphorus and other nutrients to comply with Regulation 85 nutrient limits, and even more stringent Regulation 31 limits in the future. The variance eliminates the need for plants to remove an additional phosphorus load on the road to this end.

The Colorado Wastewater Utility Council (CWWUC) is a nonprofit organization whose members include many of the wastewater treatment plants in Colorado. The Council has always strived to find common-sense approaches to protecting the environment and meeting regulatory requirements. We feel the Denver Water OCCT variance request is in alignment with this approach and we support it.

Please let me know if you have any questions or would like to discuss this further.

Thank you,

Julie Tinetti

Julie Tinetti, CWWUC Chair

357 McCaslin Blvd., Ste. 100 * Louisville, CO 80027 * 303.317.6537 * www.cwwuc.org

Conservation Colorado is writing in support of Denver Water's proposal to accelerate the removal of customer-owned lead service lines to address the utilities 2012 exceedance of the EPA's allowable levels of lead in drinking water.

We believe this approach is the best method to permanently reduce lead in drinking water within its service area. The Utility is currently using orthophosphates to comply following the 2012 test results. While the use of orthophosphates is an effective tool for lead reduction, it comes with with negative effects to streams, rivers, reservoirs, and wastewater treatment plants by increased rates of algae blooms and phosphorus loading at wastewater treatment facilities.

We are particularly supportive of the Utility's plan because it is comprehensive and designed to meet the needs of the diverse water users who rely on Denver Water. The plan includes the provision of free of charge water filters to all customers until their lines have been replaced. Denver Water also aims to first address pipe replacement in lower socioeconomic communities which aligns with our organizational focus on equity and community health.

Conservation Colorado's support is contingent upon Denver Water's commitment of not solely being dependent upon customer rates to pay for this effort. It is our understanding that a variety of methods will be utilized to pay for this effort. This aspect is crucial to our support as we do not want to see dispropriate effects on lower socio-economic households. Additionally, we also expect the Utility to ensure the free of charge water filters distributed to all customers are functioning as anticipated.

Conservation Colorado is the state's largest environmental advocacy non-profit with 60,000 members throughout the state. For over 50 years, we've worked with communities statewide to ensure that our quality of life and our environment are protected. We recognize that not all Coloradans have access to a clean and safe environment. Communities of color, indigenous communities, and families living on lower incomes are far more likely to live, work, and play near pollution. We are fostering equity, diversity, and inclusiveness to ensure all Coloradans are fully represented and engaged in our work to protect this state we love.

We are very appreciative of Denver Water's leadership to address the issue of lead in drinking water.

Sincerely,
Josh Kuhn
Water Advocate Conservation Colorado

APPENDIX II.A - COMPARING IMPACTS OF OPTIMAL CORROSION CONTROL TREATMENT AND VARIANCE IMPLEMENTATION

September 2019

DENVER WATER

Appendix II.A

Comparing Estimated Impacts of OCCT and Lead Reduction Plan Implementation on Lead Exposure at Denver Water Customers

Date: Revised August 16, 2019
March 22, 2019

To: Denver Water

From: Corona Environmental Consulting, LLC

Executive Summary

The following analysis compares the estimated reductions of lead exposure to Denver Water customers from implementing either the designated optimal corrosion control treatment (OCCT) or the Denver Water proposed Lead Reduction Plan (LRP) conditions. The analysis demonstrates with supporting data that the requested LRP conditions of pH and alkalinity adjustment for CCT, accelerated lead service line replacement (LSLR), and distribution and validation of lead filters to customers served by lead service lines can achieve equivalent or greater lead reductions than the OCCT conditions of orthophosphate treatment and the current lead service line replacement rate. The analysis conservatively utilizes the best available data to inform the comparison through statistical analysis to compare impacts system-wide for all customers in the integrated service area.

The analysis outputs a predicted lead concentration at every tap in Denver Water's integrated system through time in one-year increments with only the number of lead service lines changing yearly due to replacements. This model analysis utilized an estimated number of lead service lines presently existing in Denver Water's integrated system of 74,138. The model was also exercised to analyze 55,000 lead service lines to test sensitivity to this parameter. The results are presented herein in multiple ways to fully represent and compare the impacts of implementing either OCCT or LRP conditions.

Implementing either OCCT or the LRP conditions achieves significant public health protection by limiting lead exposure at Denver Water customer's taps. Lead filters put customers in control to best limit lead exposure making it possible to provide the greatest protection to those at the highest risk (high lead concentrations, children, etc.). Replacing lead service lines removes the primary source of lead in drinking water. At 65% filter adoption, implementing the LRP conditions achieves greater lead reductions than OCCT implementation alone.

Objective

The objective of this analysis is to compare the estimated impacts of the designated optimal corrosion control treatment (OCCT) with the Denver Water proposed Lead Reduction Plan (LRP) conditions on lead exposure to Denver Water customers.

Approach

Corona has developed and exercised a statistical model to conservatively compare the impacts of orthophosphate addition as OCCT and LRP implementation of increased pH/alkalinity with accelerated

lead service line replacement and lead filter deployment on lead exposure to Denver Water customers. The model estimates lead concentrations for all connections in the Denver Water service area every year using defined inputs under the scenarios detailed in Table 1. Because the model predicts a lead concentration at every tap and uses pilot rack data for lead concentrations from lead service lines, it will not be representative of current or future LCR compliance data.

Table 1 Description of conditions for OCCT and LRP scenarios.

Variables	**OCCT**	**LRP**
Total Service Connections	335,457	
Estimated existing lead service lines	74,138	
Implementation Start	March 20, 2020	
Corrosion Control Treatment (CCT)	Orthophosphate starting at 3 mg/L and reduced to 2 mg/L within first year of implementation	pH/alkalinity adjustment to pH 8.8
Lead Service Line Replacement (LSLR) Rate	1,200 annually Estimated to be completed in 62 years	7% annually of initial lead service line estimate (7% * 74,138= 5,190) Estimated to be completed by July 31, 2034.
Lead Filter Implementation	No	Yes Estimates of lead filter adoption rates of 50-100% considered

Data Sources

The model uses data from the following sources.

(1) Inventory Estimate: updated by Corona on 7/31/2019 using databases provided by Denver Water on 6/17/2019 and 7/12/2019. See Appendix III.B.2 - Preliminary Identification of Lead Service Lines for more detail. The estimate provides p-values for all taps in the service area. It also includes parcel year built for most taps.

(2) Source of Supply Shape File: provided by Denver Water on June 14, 2018 The shape file was paired with the inventory to determine water supply from Marston and Foothills (S. Platte R. supplies), Moffat (Fraser R. supply), and blend areas.

(3) LCR and Customer Requested Sampling Database: provided by Denver Water on 7/22/2019 from LIMS. The data were filtered to include only first draw lead samples. The database provides project year built for customer requested samples, addresses for all samples, and lead concentrations. These data were paired with the inventory using a list of tap numbers paired with addresses provided by Denver Water on 6/7/2019. Samples taken after this date may not have been paired with tap numbers. Samples for which a tap number was not assigned were not used in the model inputs.

(4) Pipe Rack Experimental Data: updated on 7/11/2019 from Denver Water LIMS. Data from the pre-treatment period and the control racks were used for pre-treatment lead release in the model. Data meeting the target operational conditions were used for post-treatment lead release in the model. See Appendix II.B - Lead Pilot Results for additional details.

(5) Immersion Study Experimental Data: updated on 7/31/2019 from Denver Water LIMS. Only data from the copper with lead solder coupons were used in the model. See Appendix III.E.2 additional for details.

Model Assumptions

The following assumptions were informed by the listed data sources.

(1) **Total Service Connections:** The total number of service connections in the integrated Denver Water system is used to define the extent of Denver Water customers in the integrated system. For this analysis, a total of 335,457 connections are considered. Services are distributed to the approximate sources of supply: Marston/Foothills 162,540, Moffat 59,369, Blend 108,472. 5,076 services were not assigned a source in mapping and were therefore excluded from the calculated ratios.

(2) **Estimated Number of Existing Lead Service Lines (LSLs):** The estimated number of existing lead service lines is used to define the expected lead concentrations experienced at those connections under current and potential future conditions. The estimated number of lead service lines in Denver Water's integrated system used at the time of this model analysis is 74,138. Lead service lines are distributed to the approximate sources of supply: Marston/Foothills 28%, Moffat 25%, Blend 47%. The model was also exercised to analyze 55,000 lead service lines to test sensitivity to this parameter.

(3) **Estimated Number of Existing Copper with Lead Solder (CuLSs):** The estimated number of existing CuLS is used to define the expected lead concentrations for homes with CuLS under current and potential future conditions. A conservative number of CuLSs was determined by selecting the taps with a parcel build year before 1988. The number of lead service lines mathematically assigned to the same subset of taps was subtracted from this total. The total number of CuLS taps is 152,630. CuLSs are distributed to the approximate sources of supply: Marston/Foothills 38%, Moffat 49%, Blend 13%. This estimate is conservative because many of these services would have CuLS premise plumbing replaced with non-lead bearing materials.

(4) **Source of Supply:** The source of supply for each tap is assigned based on the shape file, which represents only a certain time period when the data were collected. When lead release data for blended sources is not available, samples are drawn from either Marston or Moffat data. For example, when the service is a lead service line, the fraction of samples drawn from the Marston data are equal to the number of lead service lines in the Marston zone divided by the total lead service lines in the Marston and Moffat zones. Inversely, the fraction of samples drawn from the Moffat pipe rack is equal to the number of lead service lines in the Moffat zone divided by the total lead service lines in the Marston and Moffat zones. The same procedure is used for CuLS and other.

(5) **Lead Release from Lead Service Lines (LSLs):** The lead release from lead service lines is taken from the data from the pipe rack experiments for both pre- and post-CCT. These data are used instead of the LCR data because the pipe racks directly test the effectiveness of orthophosphate and pH adjustment. The lead concentrations coming off the pipe rack have high variability and can exhibit 2 to 3 times the peak concentrations observed from sequential sampling (profiling) studies undertaken by Denver Water.

(6) **Lead Release from Copper with Lead Solder (CuLS):** The lead release from CuLS is taken from the LCR database. These data consist of LCR compliance samples and first-draw customer requested samples. Samples are identified as CuLS when the inventory parcel year built is less than 1988 and the p-value assigned in the inventory is less than 0.8 (which are likely to be lead service lines).

For samples with no parcel year built, project year built from the LCR database is used. A lognormal distribution was fit to these data and used to determine lead release at each tap.

(7) **Lead Release from Other Materials:** The lead release from other lines is taken from the LCR database. These data consist of first-draw customer requested samples (no LCR compliance samples are taken at homes without lead service line or CuLS). Samples are identified as other when the inventory parcel year built is greater than 1987. For samples with no parcel year built, project year built from the LCR database is used. These data were also fit to a lognormal distribution.

(8) **Corrosion Control Treatment (CCT):** Either orthophosphate or pH/alkalinity adjustment is considered for corrosion control treatment. The effectiveness of these approaches on minimizing lead release for lead service lines come from results of the lead service line pipe rack experiments. The reductions achieved in CuLS and other lines come from the immersion study. The data from only copper with lead solder coupons are used. Bootstrapping is used to calculate the reduction from the pH or orthophosphate treated jars in comparison with the control jars. Since lead release is not expected to increase as a result of CCT, negative reductions were changed to zero.

The remaining assumptions are a function of the OCCT and LRP conditions.

(9) **Implementation Start Date:** Either the OCCT or LRP option will be implemented on March 20, 2020.

(10) **Lead Service Line Replacement (LSLR) Rate:** Denver Water currently estimates 1,200 lead service lines are replaced annually as a result of main replacement projects and parcel redevelopment which is assumed to continue at a constant rate in the OCCT scenario. As a part of the LRP, Denver Water will implement accelerated lead service line replacement rate of 7% annually (5,190 lead service lines/yr calculated as a 3-year running annual average). After replacement of a lead service line, the service is conservatively assumed to contain CuLS as premise plumbing. The model assumes the lead service lines will be randomly selected for replacement. The LRP will prioritize high lead concentration areas and sensitive sub-populations.

(11) **Lead Filter Implementation:** As a part of the LRP, Denver Water will distribute and verify use of NSF/ANSI 53 certified lead filters at homes with known or suspected lead service line until 3 months after the lead service line is confirmed to be removed. NSF/ANSI 53 certified lead filters achieve lead reduction to the detection limit of 1 ppb (Bosscher et al., 2019). This analysis considers estimates of filter adoption rates from 50 to 100% in increments of 10%.

Model Configuration

A flowchart of the model configuration is shown in Figure 1. The model starts by estimating current lead exposure conditions across the Denver Water service area for connections characterized by having a lead service line, CuLS, or other material. The model represents lead exposure at lead service line served connections as those experienced by the lead service line pipe rack experiments. The model represents lead exposure at CuLS and other using the historic LCR samples.

The model applies a variable reduced lead release due to CCT for lead service lines by randomly drawing from the treated pilot rack data for the appropriate CCT (orthophosphate or pH). The lead reduction for CuLS and other materials is determined by calculating percent reduction from random draws of immersion study data for CuLS coupons with the appropriate CCT (orthophosphate or pH). Negative reductions were changed to zero because CCT is not expected to increase lead release. This calculation is applied to both CuLS and other material lines even though only CuLSs are represented in the immersion study because no site-specific lead reduction data for other materials are available.

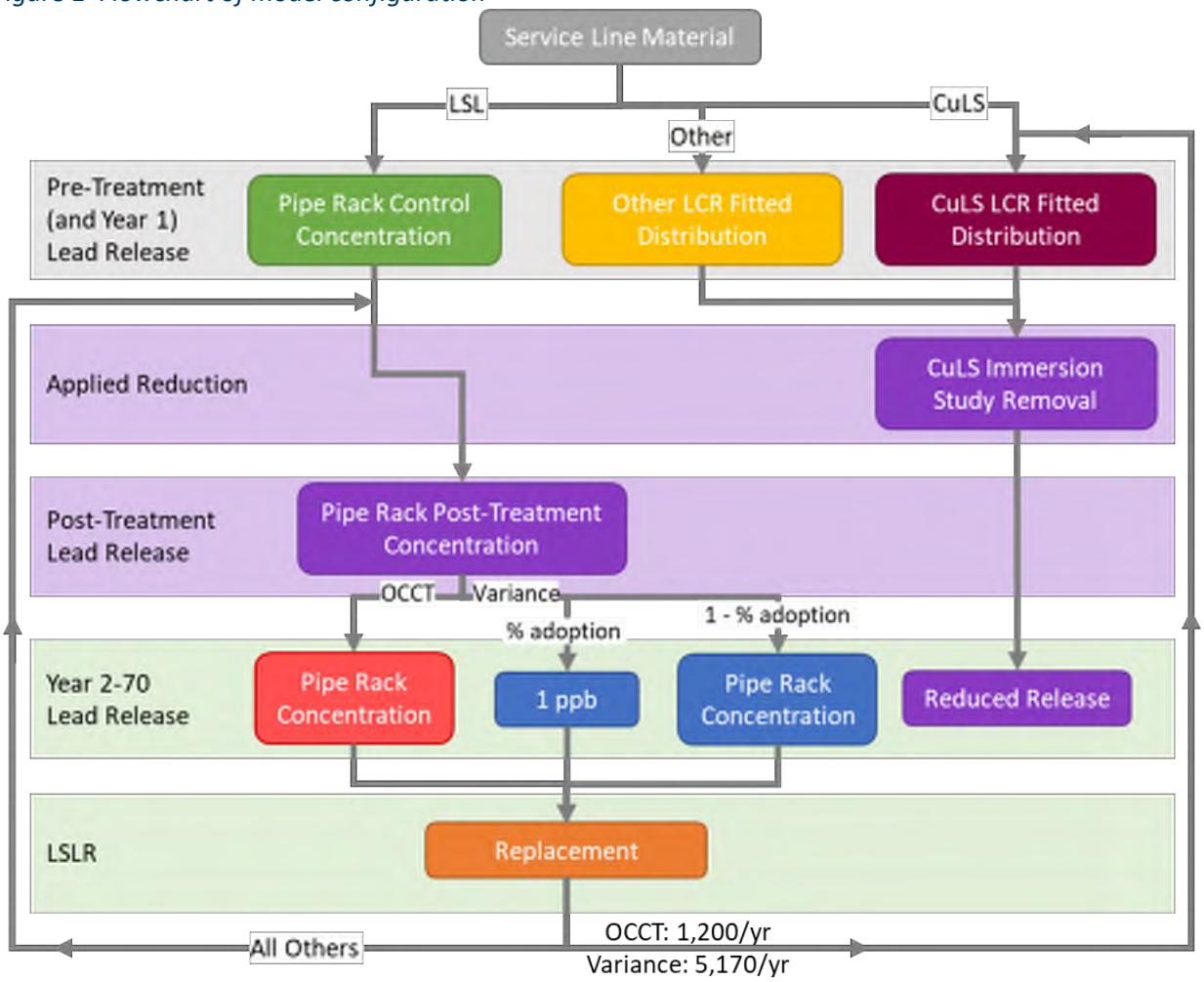
Lead filter exposure in the model is set to 1 ppb lead. Lead filters are only applied to remaining lead service lines; therefore, once a lead service line is removed, so is the filter. This service line will then be drawn from the CuLS distribution which can result in a lead concentration greater than 1 ppb.

Lead service line replacement is modeled by shifting the inventory of lead service lines in the integrated service area from lead service lines to CuLS by the number of lead service line replacements in each year.

All taps and distributions are divided by source: Marston, Moffat, or blend. The model simulates lead release from all individual taps every year for 70 years. The only parameter that changes through time is the number of lead service lines and CuLS due to replacement.

Further details describing the modeling approach, model inputs, choices, and assumptions are provided in Appendix B. Histograms of the underlying data can be found in Appendix C.

Figure 1 Flowchart of model configuration



Results

The model outputs a predicted lead concentration at every tap in Denver Water's integrated system through time in one-year increments (the only parameter to change through time is the number of lead service lines due to replacements). The results have then been summarized in multiple ways.

Lead concentration over time compares the effectiveness of the different chemical treatments and lead service line replacement rates. Figure 2 displays the 95th percentile lead concentration of the entire integrated service area over the time frame from the beginning of treatment to after the last lead service line is removed (figures showing other percentile outputs can be found in Appendix A).

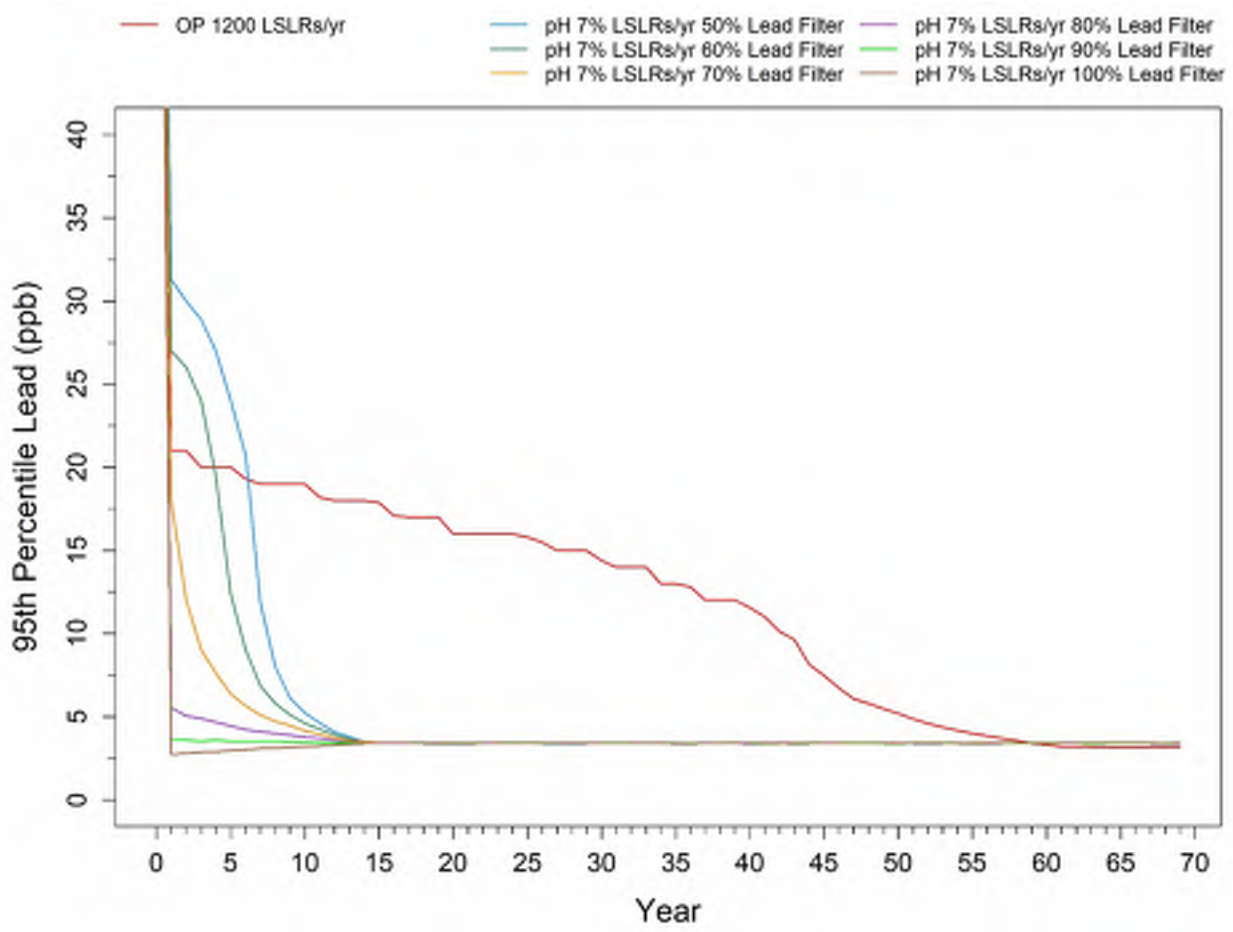
The OCCT condition of orthophosphate is shown in red, while the LRP conditions are shown in different color lines. Each LRP condition line represents a different lead filter adoption rate from 50 – 100%.

Figure 2 shows that the 70% lead filter adoption rate results in lower lead concentrations than the OCCT scenario under the conditions modeled. This is confirmed from outputs at other statistical descriptions as shown in Appendix A. The 60% lead filter adoption rate shows slightly higher concentrations than the OCCT scenario in years 1–4. Therefore, the lead filter adoption rate that demonstrates lower lead concentrations than the OCCT scenario for all tested statistical descriptions is between 60–70%. At the limits of the model, the OCCT scenario indicates lower concentrations than the LRP. This is a result of the lead reduction due to orthophosphate being higher than pH for CuLS.

Similar behavior at other statistical outputs is observed and shown in Appendix A. The 95th percentile outputs were chosen for reporting because it is the most conservative case. Model outputs indicate the LRP conditions result in lower lead concentrations at any lead filter adoption rate of at least 50% at 50th, 75th, and 90th percentiles. At the 99th percentile output, the LRP condition indicated lower lead level at all filter adoption rates 60% and above.

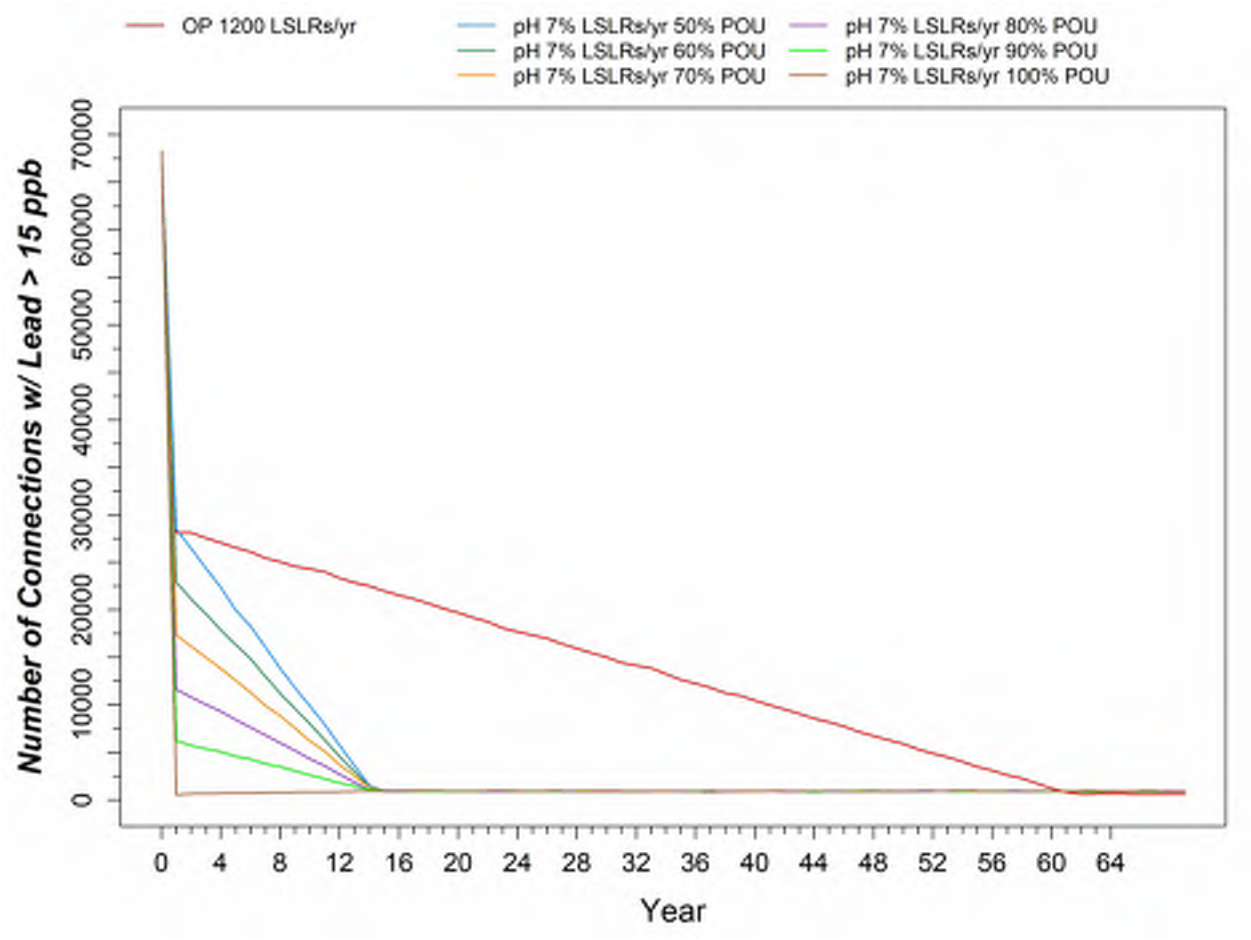
The OCCT condition shows a relatively gradual reduction in 95th percentile lead concentrations over time, while the LRP conditions show more dramatic reduction over the first 15 years. This result is due to the effective lead removal from the lead filters coupled with accelerated lead service line replacements that are included in the LRP. In the LRP condition with 100% lead filter adoption, there is a minimal increase in the 95th percentile lead concentration between years 1 and 15. The increase happens because when a lead service line is replaced, the customer will no longer get credit for use of a lead filter. The lead concentration at the tap will be drawn from the copper with lead solder distribution and therefore may have a higher concentration than with a lead filter.

Figure 2 95th percentile lead concentration over time



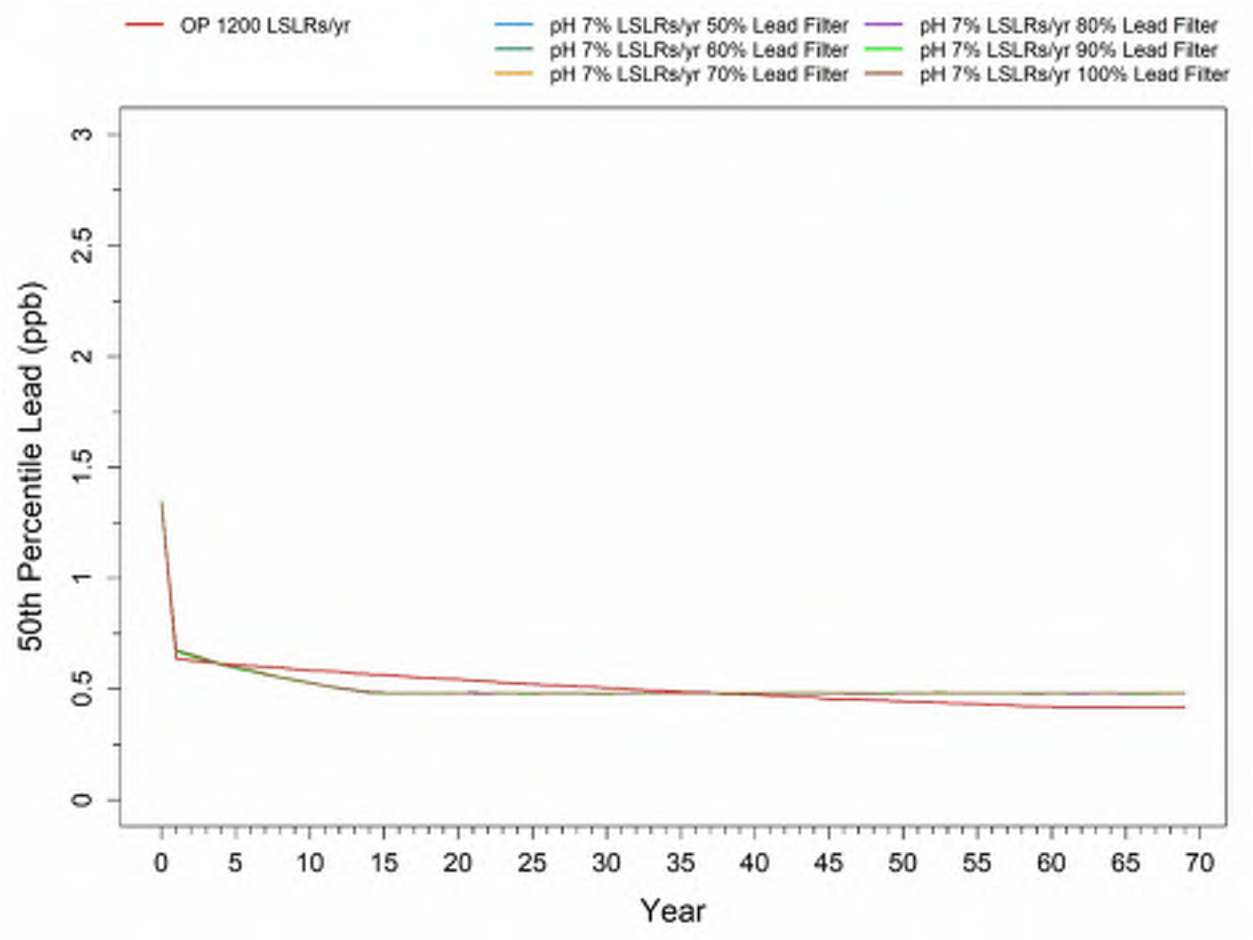
Another way to visualize the results is to compare the number of service connections above a threshold concentration. These results are presented in Figure 3 which indicates that the LRP results in a lower number of services with high lead concentrations under all filter adoption rate scenarios above 50%. Note again that this is not a prediction of the actual service connection lead concentrations but a tool to compare the conditions of the LRP to OCCT.

Figure 3 Number of connections above 15 ppb lead concentration over time



The model can also be used to look at the lead concentrations at lower statistical outputs. Figure 4 presents the median lead concentration (50th percentile), which is representative of copper with lead solder plumbing materials. In addition to the low lead concentration ranges, we see equivalent performance between the LRP and OCCT. This indicates that the LRP achieves its objectives of addressing the public health concern of the lead service lines while providing equivalent protection for the entire system.

Figure 4 Median lead concentration over time



Corona also exercised the model under two scenarios to test the senetivity of the model to major assumptions. First we tested the effect of the concentrations from lead service lines, then we tested the model for a lower inventory estimate of lead service lines.

In general, the lead concentrations from the pilot control racks range from 50 - 100 ppb. The peak lead concentrations from three rounds of profile sampling of seven in situ lead service lines generally ranges from 20 to 40 ppb. Therefore, the lead concentrations used in the model are about 2x higher than we might expect in the distribution system. The model was run with all lead service line concentrations halved; Figure 5 shows the 95th percentile results. As expected, concentrations decrease; however, the equivalence point between the OCCT and the LRP does not change substantially.

The estimated number of lead service lines is calculated based on conservative p-values and may; therefore, be high. The model was also run with 55,000 lead service lines; 95th percentile results are shown in Figure 6. The equivalence point shifts to lower filter adoption rates. In addition, the OCCT condition reaches its minimum sooner, since the rate of lead service line replacement is not dependent on the total number of lead service lines.

Figure 5 95th percentile lead concentration over time with lead concentrations from pilot racks halved to be more representative of actual lead concentrations observed in the distribution system

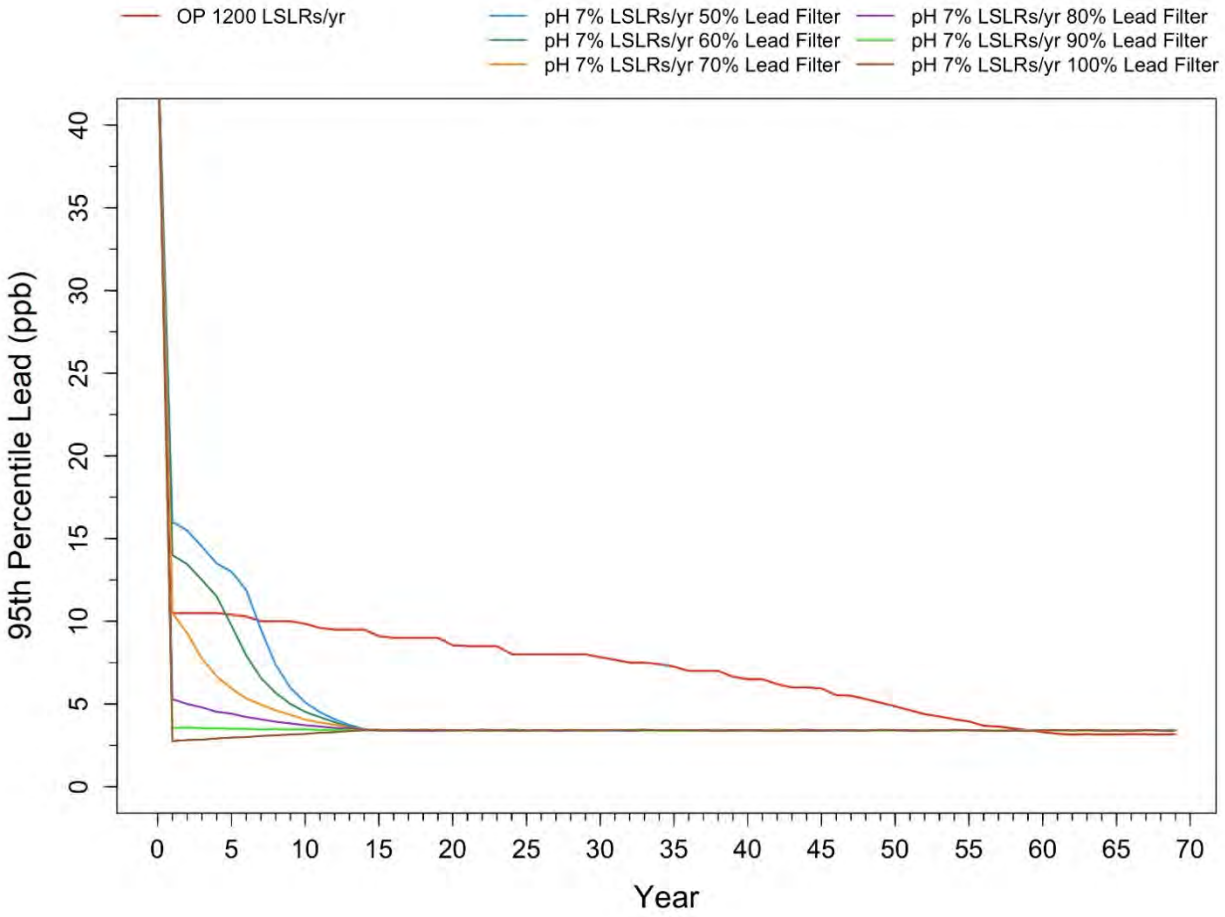
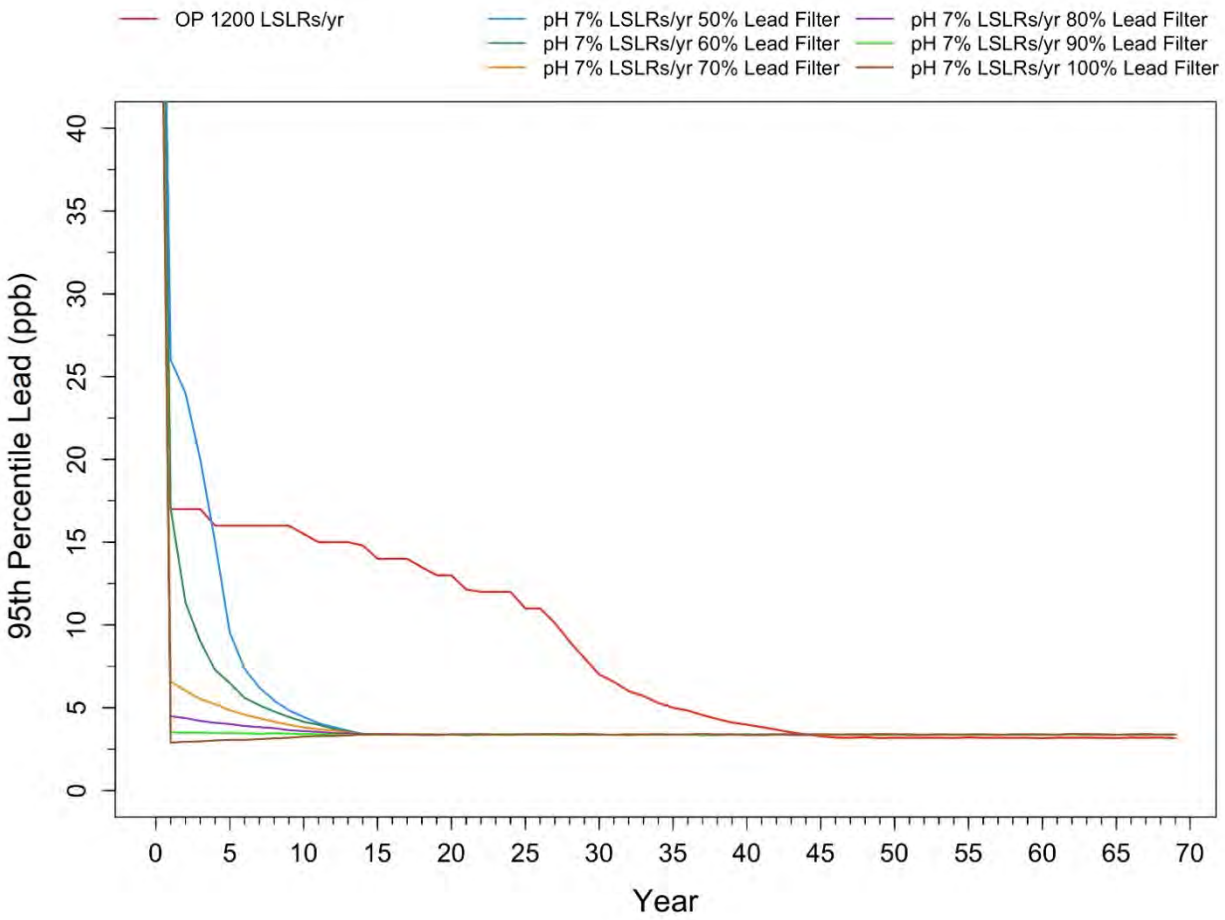


Figure 6 95th percentile lead concentration over time with number of lead service lines changed to 55,000



Each of the previous plots is a statistical summary of the data for every year. For a better understanding of the actual lead concentrations, the distribution of lead release for select years is shown in Figure 7 with each service line material in a different color. The y-axis is cropped at a count of 10,000 due to the high number of services with lead levels below the detection limit. Year 1 shows the lead concentrations without a lead reduction strategy. Year 2 shows the immediate impacts of each lead reduction strategy. For OCCT, the shift to 5–25 ppb in lead service line concentrations is due to the implementation of orthophosphate treatment. For the LRP scenario, the lead service line distribution shifts to a higher range of 10–50 ppb. However, the counts in this distribution are lower because 60% are served by lead filters, which result in a release of 1 ppb. In addition, both scenarios have fewer lead service lines due to replacement. In Year 16, all lead service lines have been replaced in the LRP scenario. Therefore, the high lead concentrations are eliminated. For the OCCT scenario, there are still an estimated 56,000 lead service lines remaining, which leaves a distribution of lead service lines lead release from 5–25 ppb. However, higher lead release is also observed. In Year 63, all lead service lines have been replaced in the OCCT scenario. High lead release has been eliminated in both scenarios. The difference between the two CCT techniques is visible in the remaining bars, with the OCCT distribution shifted slightly left of the LRP distribution. More years are shown in the Appendix.

Figure 7 Lead concentration distribution for select years at 60% filter adoption

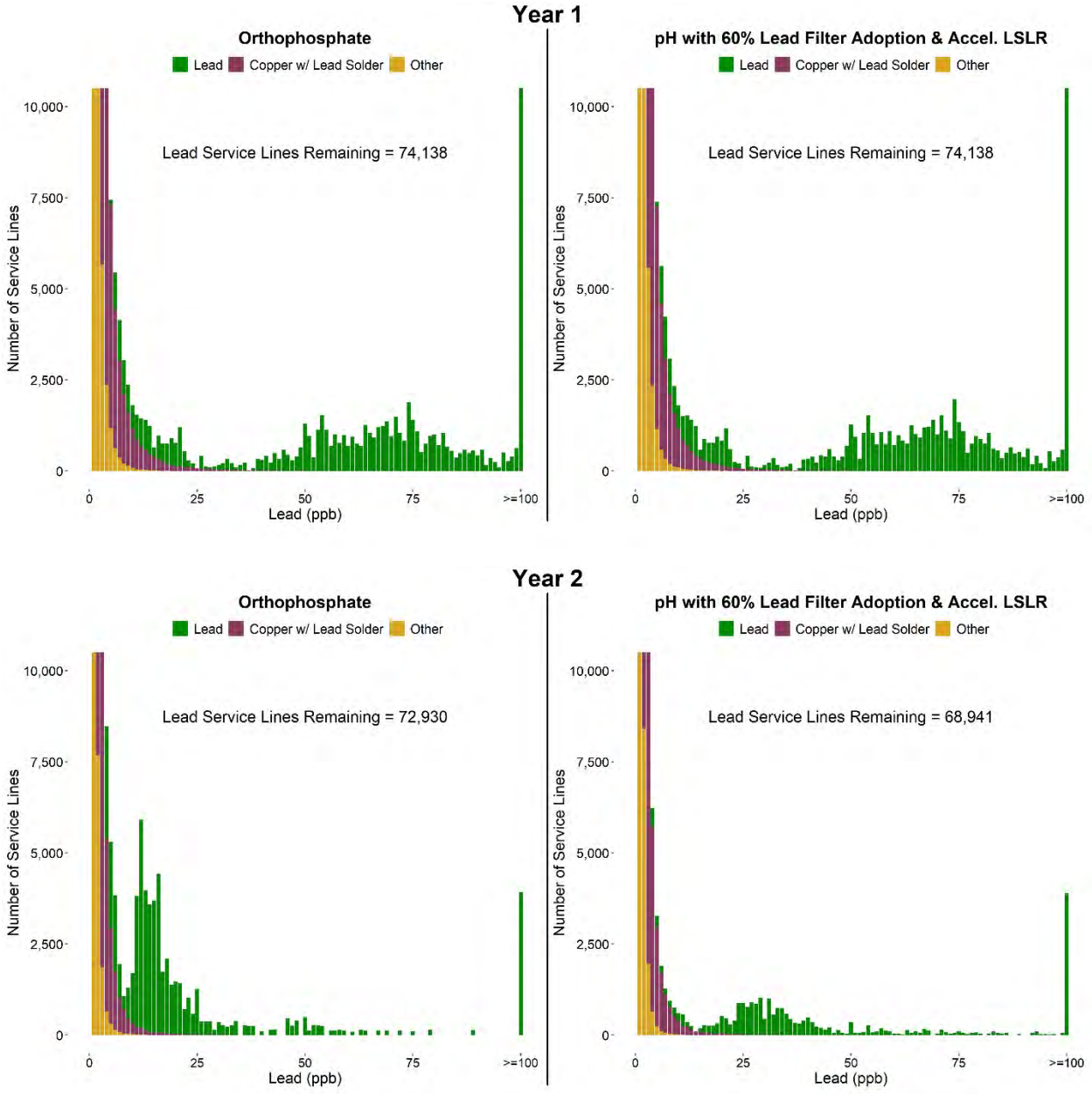
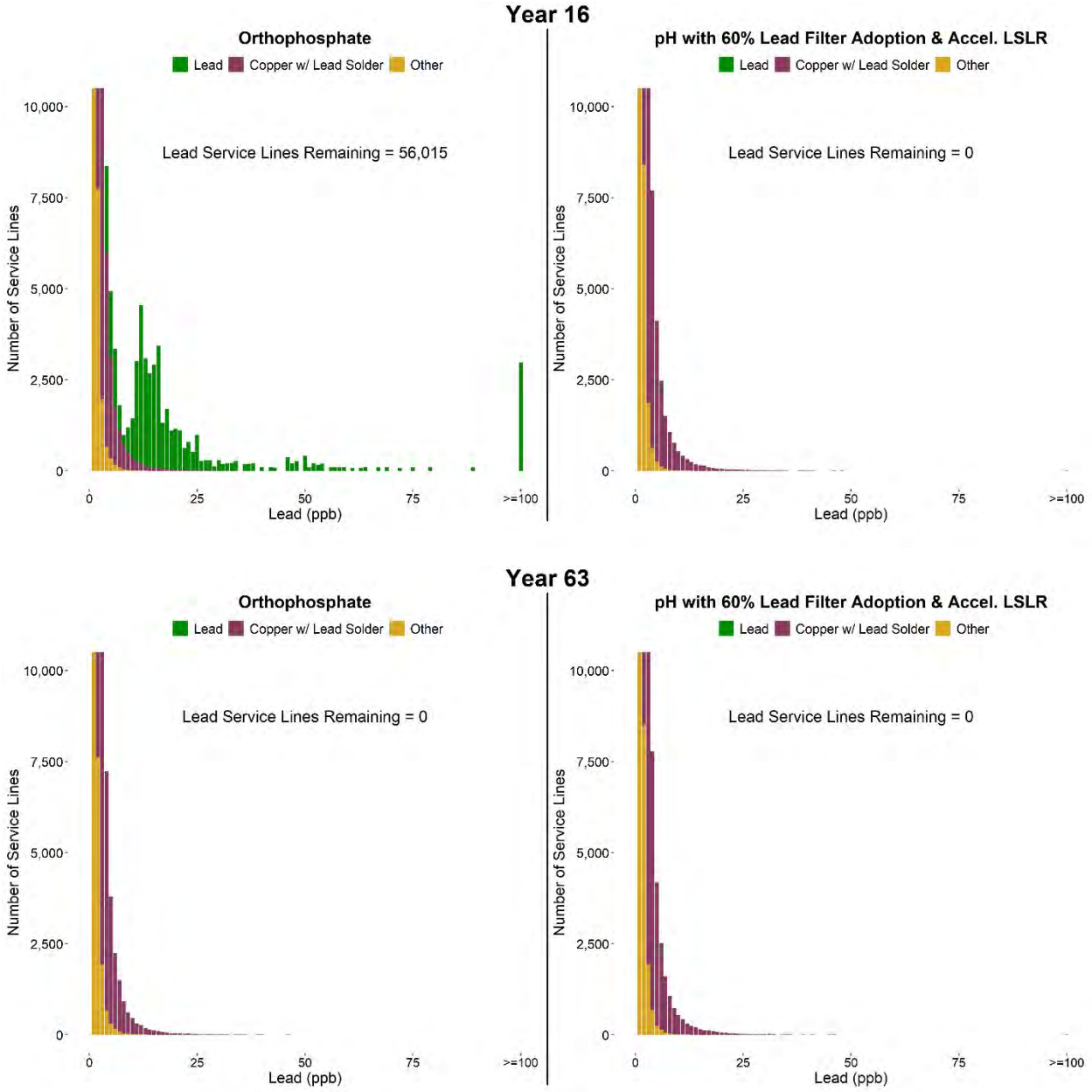


Figure 7 Lead concentration distribution for select years at 60% filter adoption



Conclusions

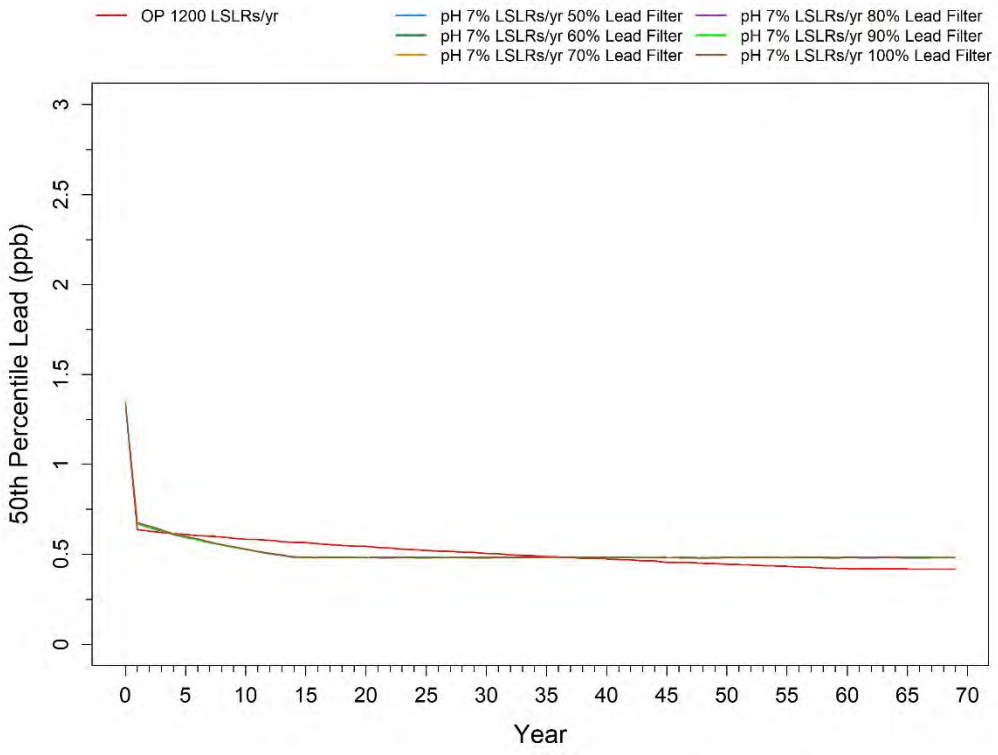
Implementing either OCCT or the proposed LRP conditions achieves significant public health protection by limiting lead exposure at Denver Water connections. At lead filter adoption of 65% and greater, implementing the LRP conditions achieves equivalent or greater lead reductions than OCCT implementation alone.

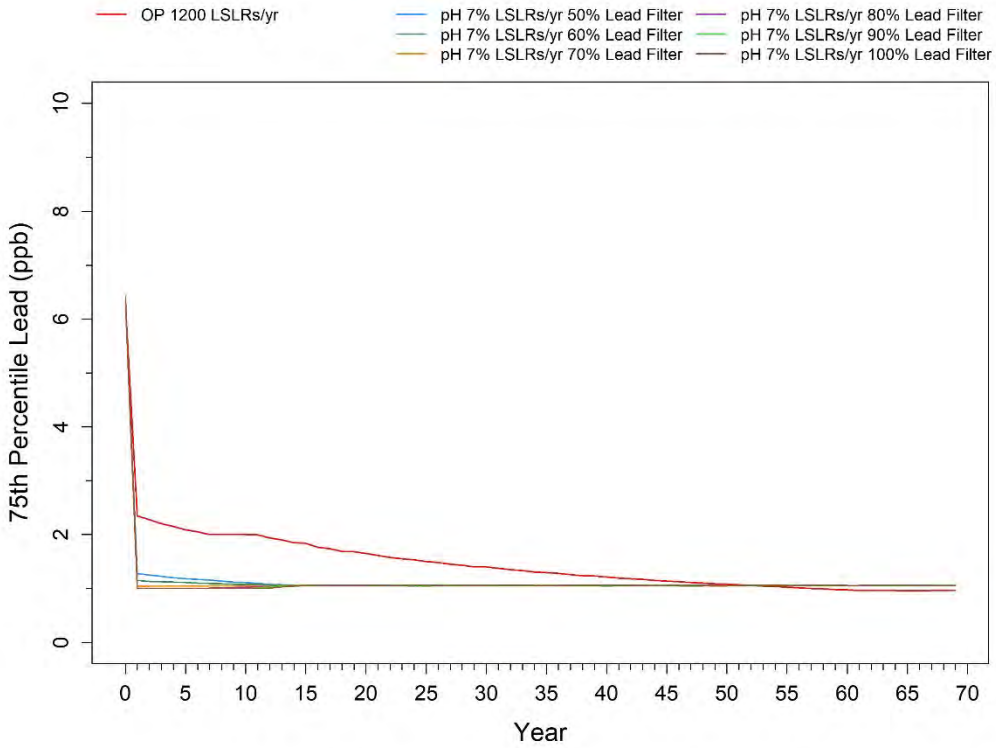
References

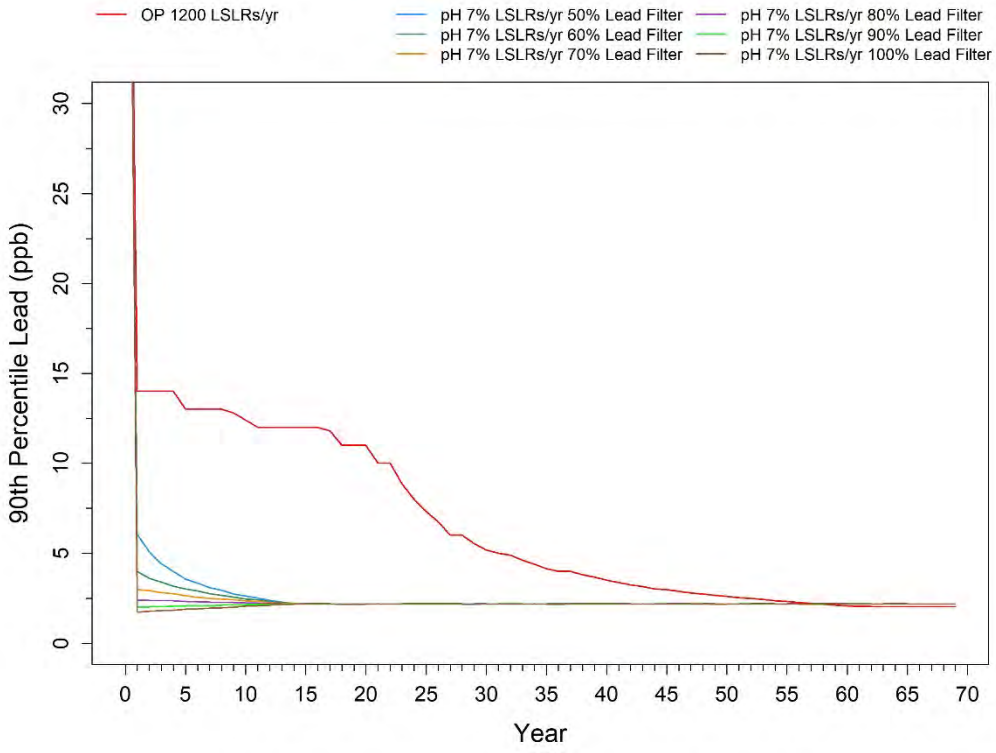
Bosscher, V., Lytle, D. A., Schock, M. R., Porter, A., Del Toral, M. (2019). POU water filters effectively reduce lead in drinking water: a demonstration field study in Flint, Michigan. *Journal of Environmental Science and Health* 54(5) 484 – 493.

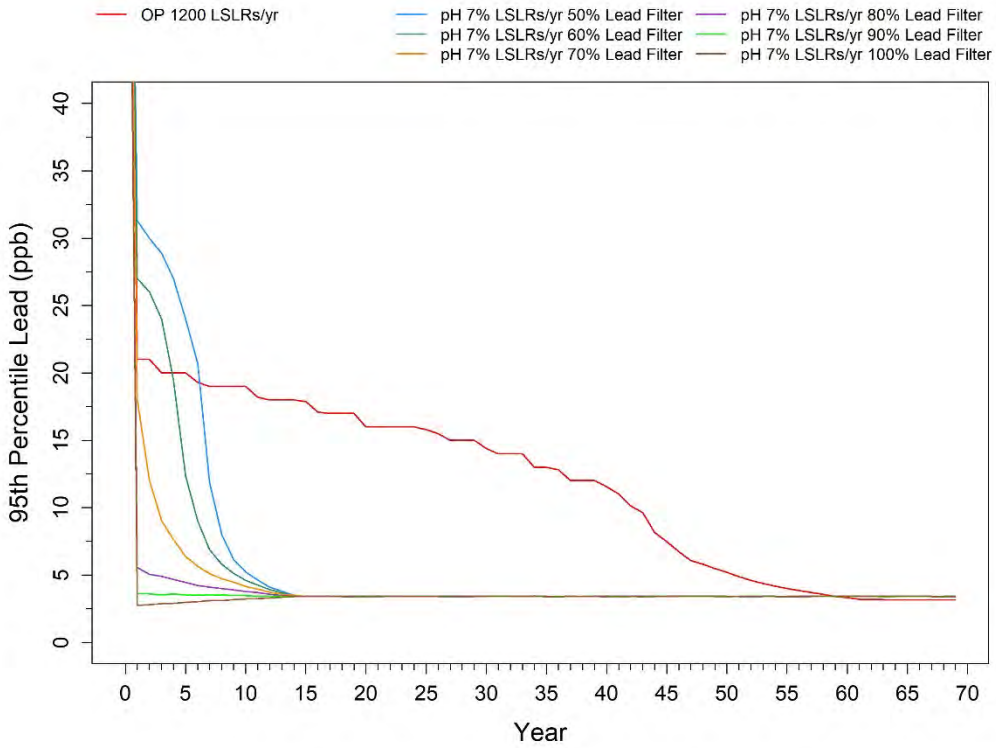
Appendix A: Additional Model Outputs

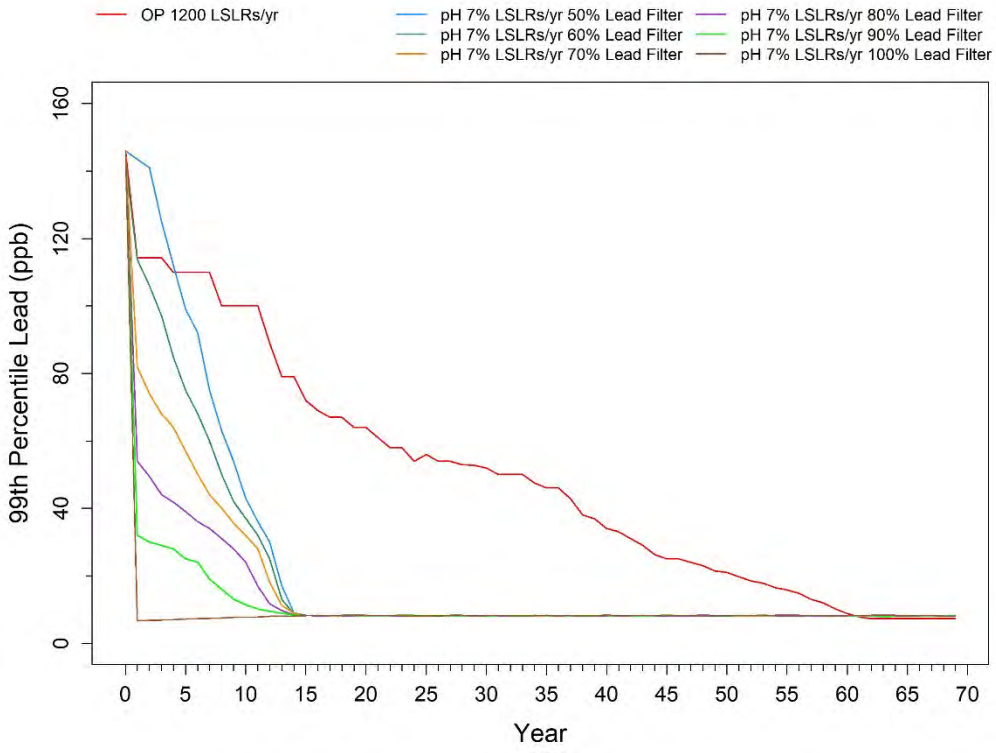
50th, 75th, 90th, 95th, and 99th percentile lead concentration over time



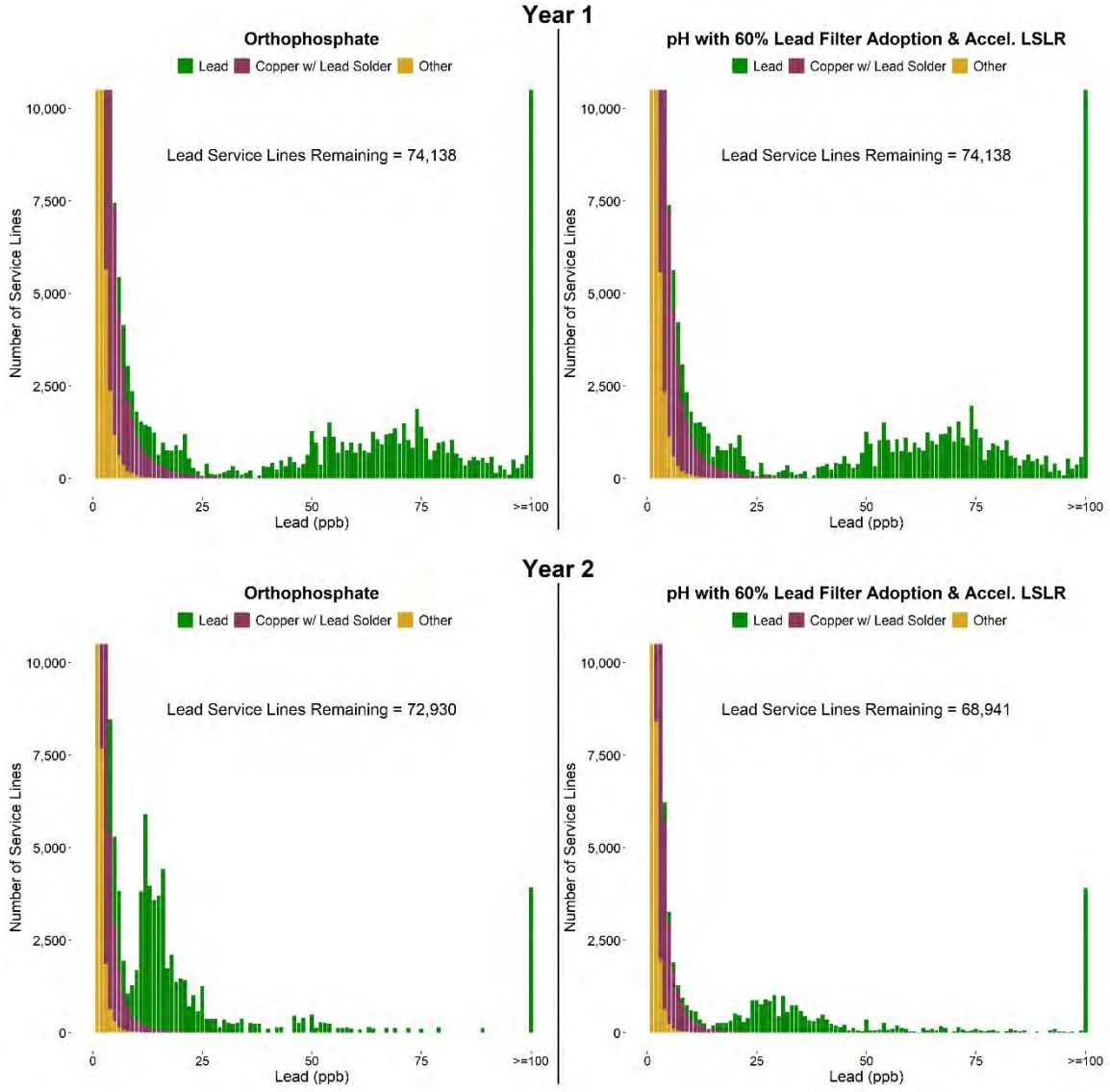

OP 1200 LSLRs/yr
pH 7% LSLRs/yr 50% Lead Filter
pH 7% LSLRs/yr 60% Lead Filter
pH 7% LSLRs/yr 70% Lead Filter
pH 7% LSLRs/yr 80% Lead Filter
pH 7% LSLRs/yr 90% Lead Filter
pH 7% LSLRs/yr 100% Lead Filter
75th Percentile Lead (ppb)
0
2
4
6
8
10
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Year

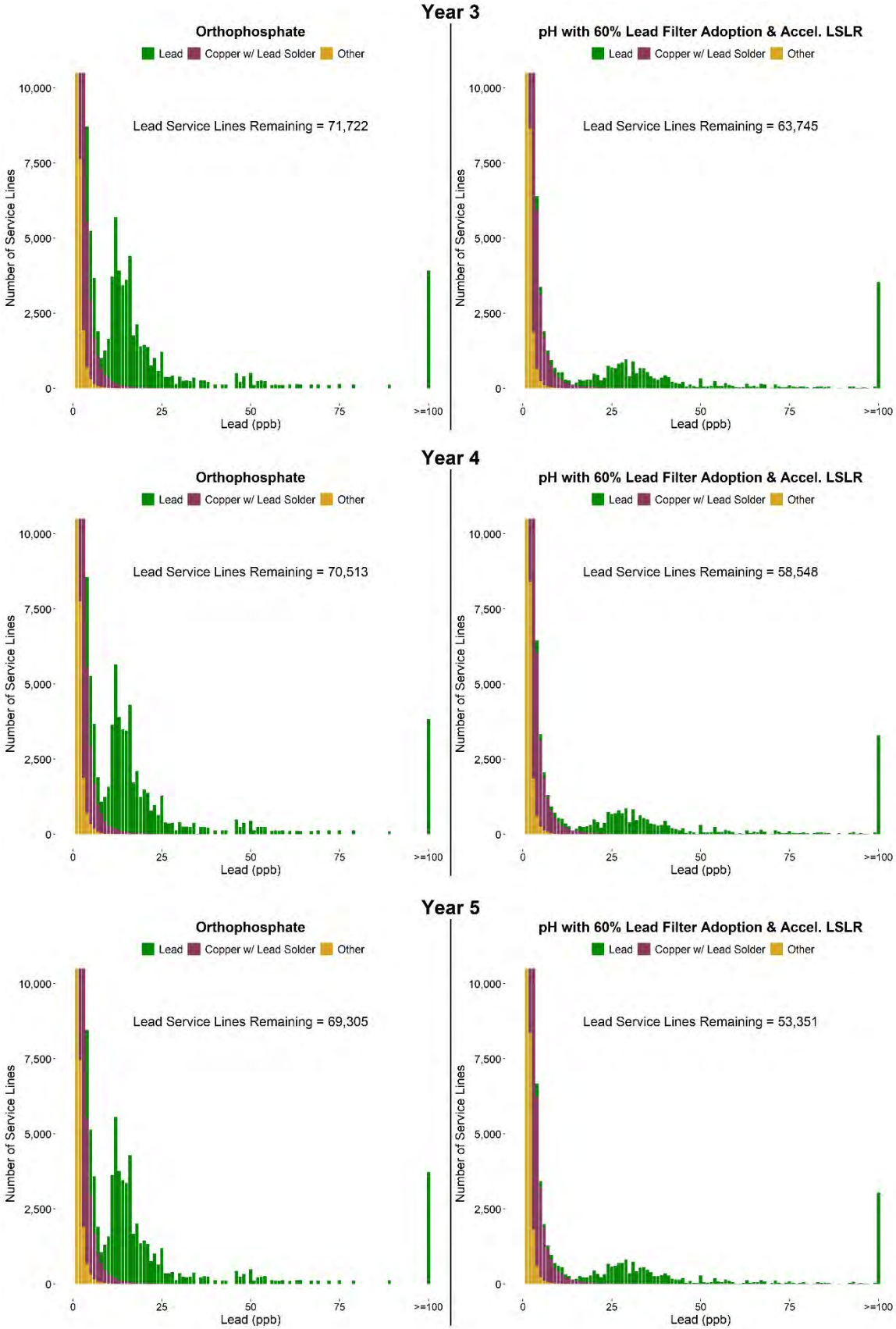

OP 1200 LSLRs/yr
pH 7% LSLRs/yr 50% Lead Filter
pH 7% LSLRs/yr 60% Lead Filter
pH 7% LSLRs/yr 70% Lead Filter
pH 7% LSLRs/yr 80% Lead Filter
pH 7% LSLRs/yr 90% Lead Filter
pH 7% LSLRs/yr 100% Lead Filter
90th Percentile Lead (ppb)
0
5
10
15
20
25
30
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Year

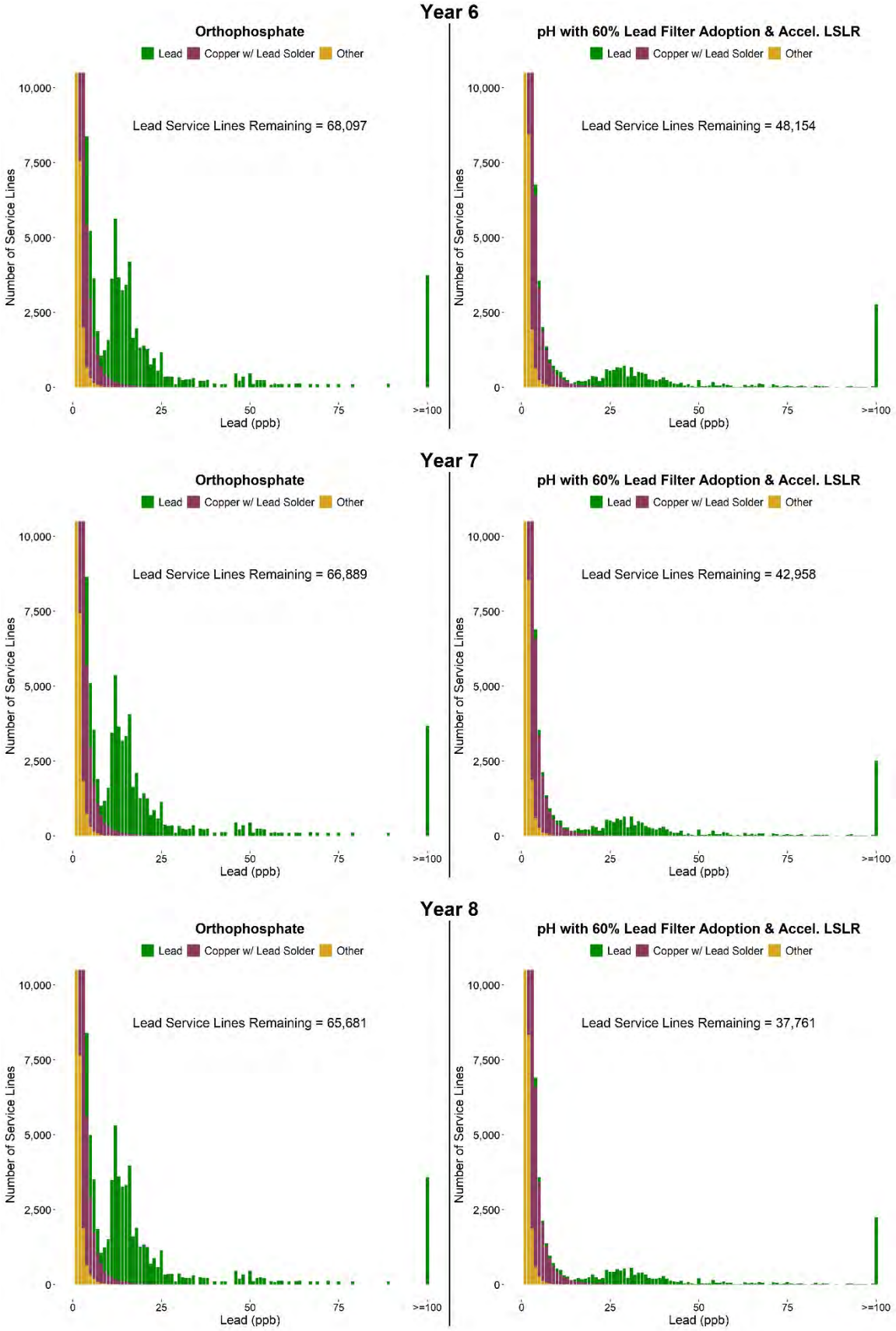

OP 1200 LSLRs/yr
pH 7% LSLRs/yr 50% Lead Filter
pH 7% LSLRs/yr 60% Lead Filter
pH 7% LSLRs/yr 70% Lead Filter
pH 7% LSLRs/yr 80% Lead Filter
pH 7% LSLRs/yr 90% Lead Filter
pH 7% LSLRs/yr 100% Lead Filter
95th Percentile Lead (ppb)
0
5
10
15
20
25
30
35
40
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
Year

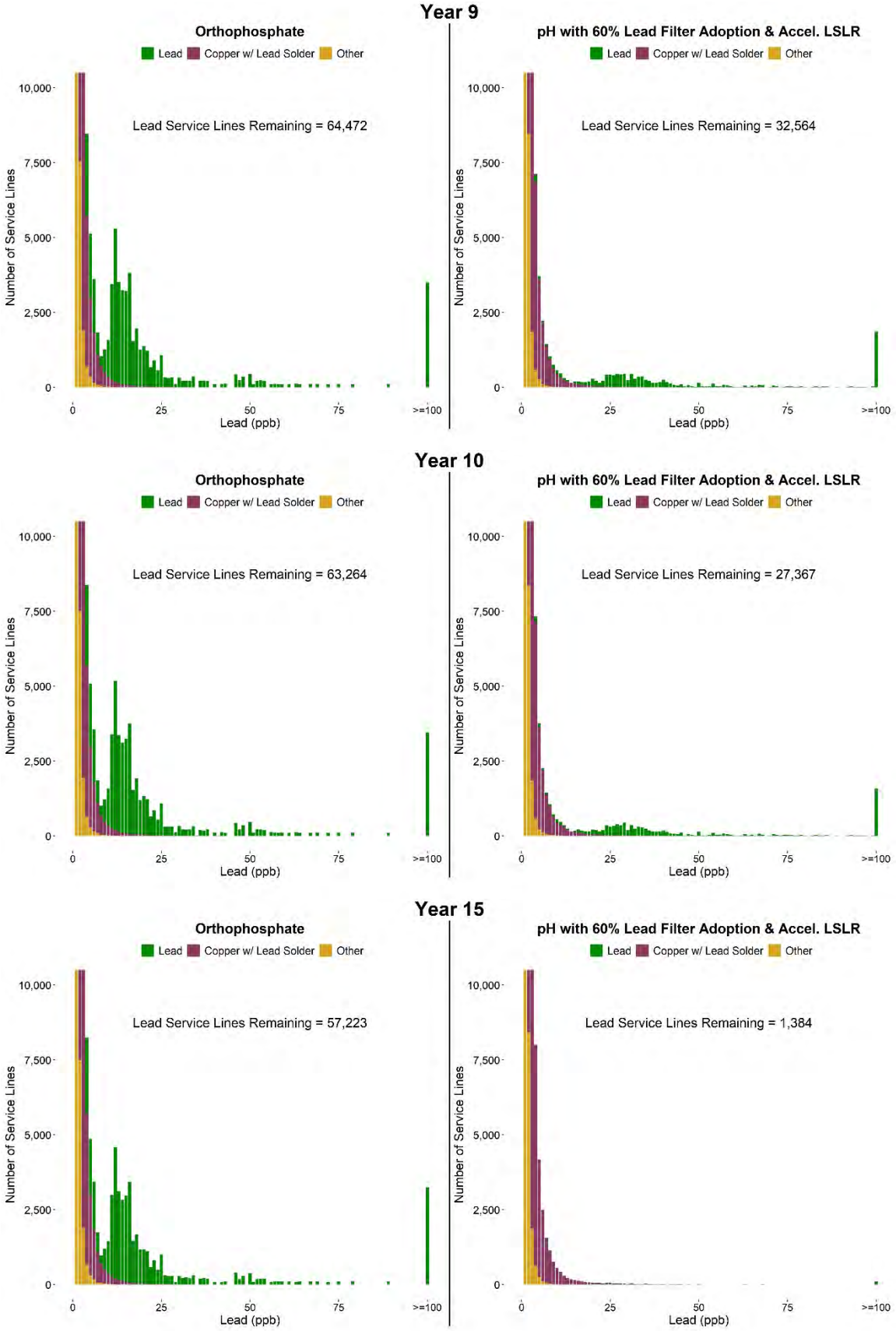

OP 1200 LSLRs/yr
pH 7% LSLRs/yr 50% Lead Filter
pH 7% LSLRs/yr 60% Lead Filter
pH 7% LSLRs/yr 70% Lead Filter
pH 7% LSLRs/yr 80% Lead Filter
pH 7% LSLRs/yr 90% Lead Filter
pH 7% LSLRs/yr 100% Lead Filter
99th Percentile Lead (ppb)
0
40
80
120
160
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
Year

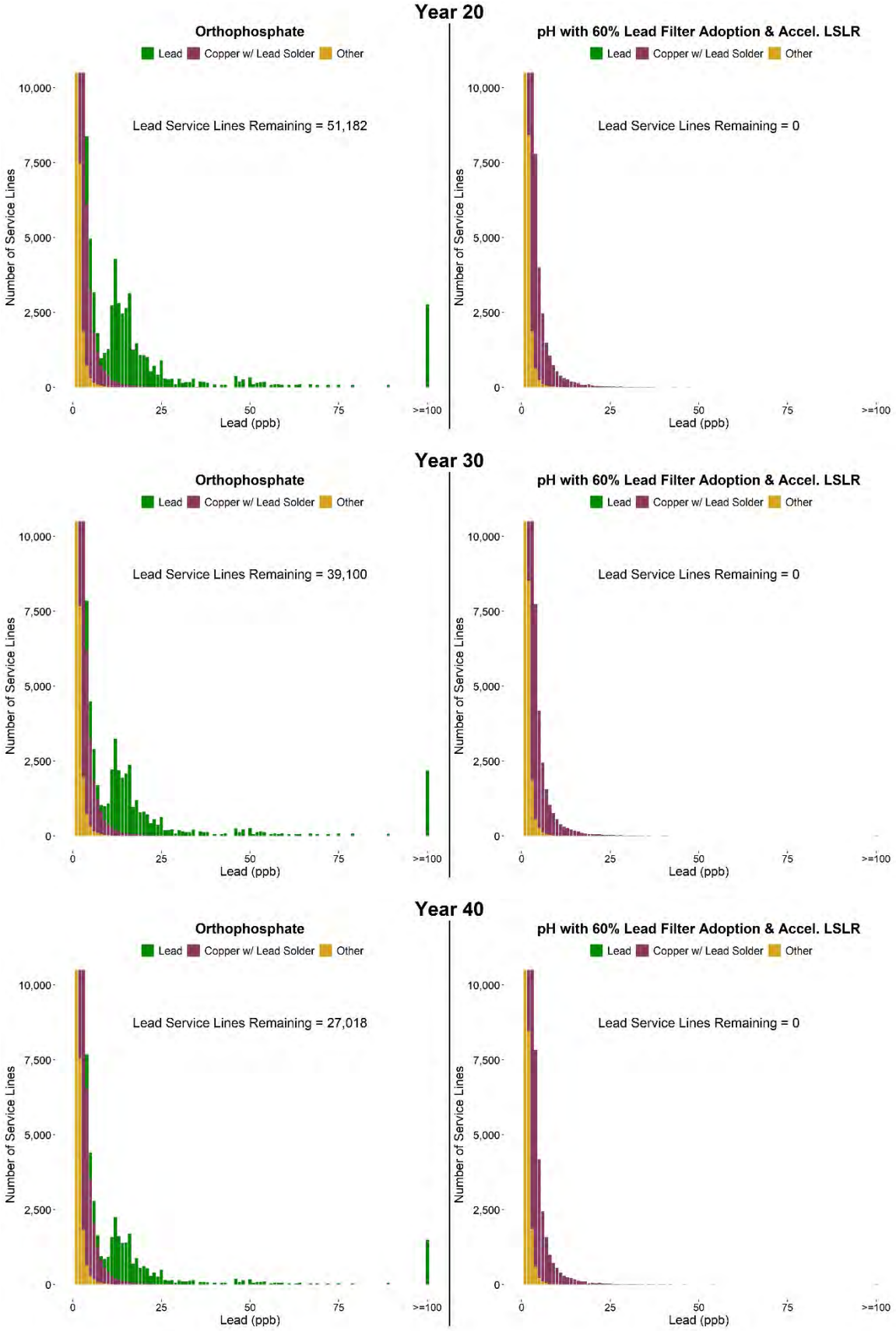
Distribution of lead concentrations by year

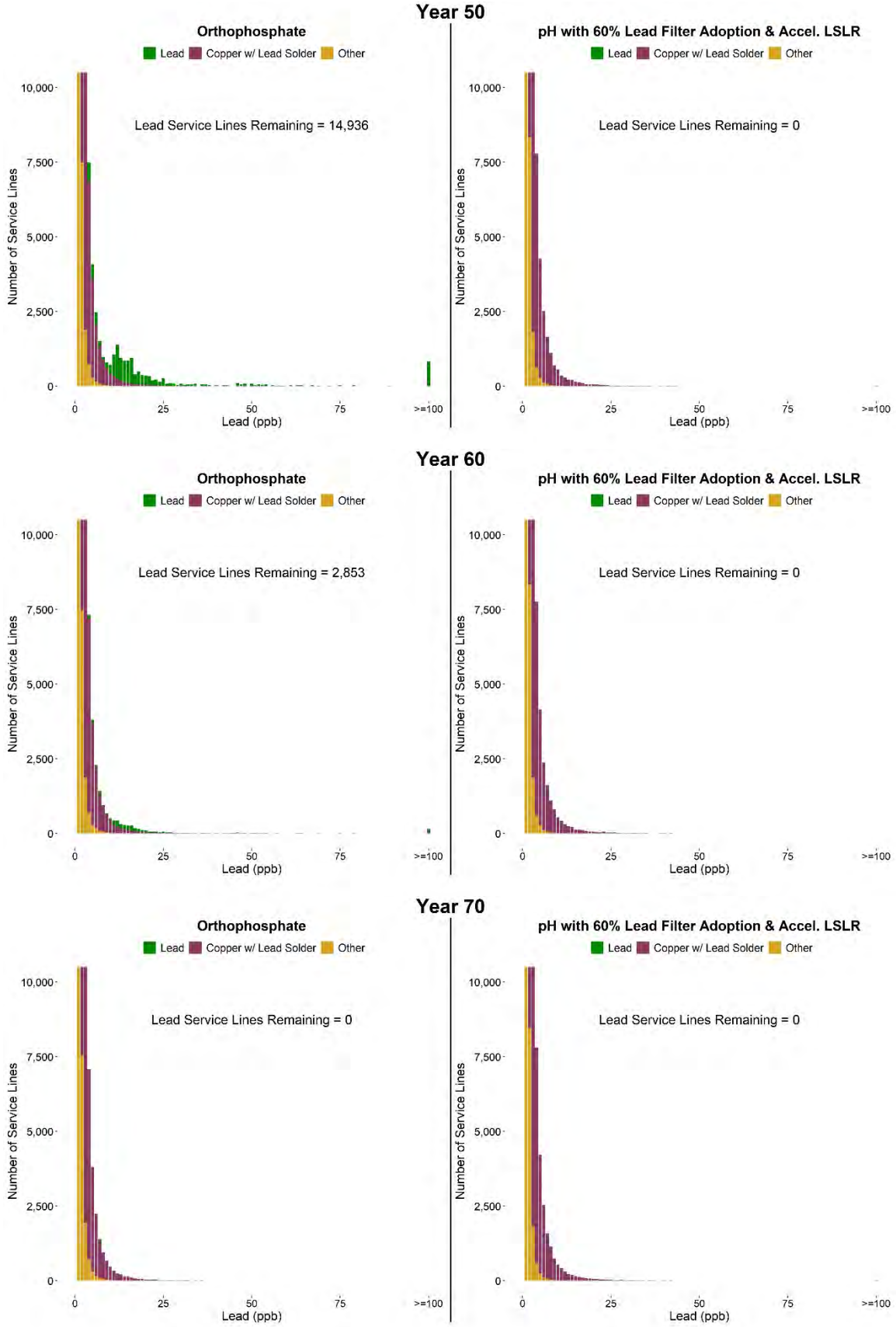



Year 3
Orthophosphate
Lead
Copper w/ Lead Solder
Other
Lead Service Lines Remaining = 71,722
Number of Service Lines
Lead (ppb)
pH with 60% Lead Filter Adoption & Accel. LSLR
Lead Service Lines Remaining = 63,745
Year 4
Lead Service Lines Remaining = 70,513
Lead Service Lines Remaining = 58,548
Year 5
Lead Service Lines Remaining = 69,305
Lead Service Lines Remaining = 53,351
10,000
7,500
5,000
2,500
0
25
50
75
>=100


Year 6
Orthophosphate
Lead
Copper w/ Lead Solder
Other
Lead Service Lines Remaining = 68,097
Number of Service Lines
Lead (ppb)
pH with 60% Lead Filter Adoption & Accel. LSLR
Lead Service Lines Remaining = 48,154
Year 7
Lead Service Lines Remaining = 66,889
Lead Service Lines Remaining = 42,958
Year 8
Lead Service Lines Remaining = 65,681
Lead Service Lines Remaining = 37,761
10,000
7,500
5,000
2,500
0
25
50
75
>=100


Year 9
Orthophosphate
Lead
Copper w/ Lead Solder
Other
Lead Service Lines Remaining = 64,472
Number of Service Lines
Lead (ppb)
pH with 60% Lead Filter Adoption & Accel. LSLR
Lead Service Lines Remaining = 32,564
Year 10
Lead Service Lines Remaining = 63,264
Lead Service Lines Remaining = 27,367
Year 15
Lead Service Lines Remaining = 57,223
Lead Service Lines Remaining = 1,384
10,000
7,500
5,000
2,500
0
25
50
75
>=100


Year 20
Orthophosphate
Lead
Copper w/ Lead Solder
Other
Lead Service Lines Remaining = 51,182
Number of Service Lines
Lead (ppb)
pH with 60% Lead Filter Adoption & Accel. LSLR
Lead Service Lines Remaining = 0
Year 30
Lead Service Lines Remaining = 39,100
Year 40
Lead Service Lines Remaining = 27,018
10,000
7,500
5,000
2,500
0
25
50
75
>=100


Year 50
Orthophosphate
Lead
Copper w/ Lead Solder
Other
Lead Service Lines Remaining = 14,936
Number of Service Lines
Lead (ppb)
pH with 60% Lead Filter Adoption & Accel. LSLR
Lead Service Lines Remaining = 0
Year 60
Lead Service Lines Remaining = 2,853
Year 70

Appendix B: Modeling Approach, Choices, and Assumptions

Introduction

This appendix describes the approach, choices, and assumptions used in Corona's simulations of corrosion control and lead service line (LSL) replacement for Denver Water's (DW's) service area.

Modeling is divided into two major components:

- Immersion study data analysis (bootstrap) conducted to better characterize variability in treatment technique performance, and
- Simulations (Monte Carlo) for lead risk reduction strategies (combinations of treatment strategies and lead service line reduction scenarios).

Models were programmed in the open source R environment.

Simulation Description

Pre-treatment Data Inputs (First Year)

- **Lead Service Lines:**
    - **Marston Source:** For each Denver Water service connection identified as having a lead service line and served by Marston, a random sample is drawn from the Marston pre-treatment pipe rack lead concentration data.
    - **Moffat Source:** For each connection identified as having a lead service line and served by Moffat, a random sample is drawn from the Moffat pre-treatment pipe rack lead concentration data.
    - **Blended Source:** For service connections in the blended region (receiving water from Marston and Moffat), samples are drawn from either Marston or Moffat untreated pipe rack lead concentration data. The fraction of samples drawn from the Marston pipe rack is equal to the number of lead service lines in the Marston zone divided by the total lead service lines in the Marston and Moffat zones. Inversely, the fraction of samples drawn from the Moffat pipe rack is equal to the number of lead service lines in the Moffat zone divided by the total lead service lines in the Marston and Moffat zones.
- **Copper with Lead Solder**:
    - **Marston Source**: For each service connection identified as having copper with lead solder and served by Marston, a random sample is drawn from the lognormal distribution fit to the LCR lead concentration data for taps identified as copper with lead solder served by Marston.
    - **Moffat Source**: For each connection identified as having copper with lead solder and served by Moffat, a random sample is drawn from a lognormal distribution fit to LCR lead concentration data for taps identified as copper with lead solder served by Moffat.
    - **Blended Source**: For each service connection identified as having copper with lead solder in the blended region, a random sample is drawn from a lognormal distribution fit to LCR lead concentration data for taps identified as copper with lead solder in the blended region.
- **Other Material**:
    - For each service connection identified as having other material, a random sample is drawn from the lognormal distribution fit to the LCR data for taps identified as other. A single distribution is used for "other materials" because the number of samples is too low to stratify amongst the Marston and Moffat service areas.

Post Treatment Data Inputs for OCCT (After First Year)

- **Lead Service Lines:**
  - **Marston Source:** For each service connection identified as having a lead service line and served by Marston, a random sample is drawn from the Marston orthophosphate pipe rack lead concentration data during the post-treatment period. During this period, orthophosphate was being dosed at either 3 mg/L or 2 mg/L.
  - **Moffat Source:** For each service connection identified as having a lead service line and served by Moffat, a random sample is drawn from the Moffat orthophosphate pipe rack lead concentration data during the post-treatment period. During this period, orthophosphate was being dosed at either 3 mg/L or 2 mg/L.
  - **Blended Source:** For each service connection identified as having a lead service line in the blended region, a random sample is drawn from either the Marston or Moffat orthophosphate pipe rack lead concentration data during the post-treatment period. The percentages of samples drawn from the Marston pipe rack data and from the Moffat pipe rack data for the post-treatment period are consistent with those for the pre-treatment period, as described above.
- **Copper with Lead Solder:**
  - **Marston Source:** For each service connection identified as having copper with lead solder and served by Marston, a random sample is drawn from a distribution of percent lead reduction data for the CuLS Marston orthophosphate immersion study. The selected percent reduction is then multiplied by the connection's assigned pre-treatment lead concentration to determine the post-treatment lead concentration.
  - **Moffat Source:** For each service connection identified as having copper with lead solder and served by Moffat, a random sample is drawn from a distribution of percent lead reduction data for the CuLS Moffat orthophosphate immersion study. The selected percent reduction is then multiplied by the connection's assigned pre-treatment lead concentration to determine the post-treatment lead concentration.
  - **Blended Source:** For each service connection identified as having copper with lead solder in the blended region, a random sample is drawn from the CuLS blended orthophosphate immersion study. The selected percent reduction is then multiplied by the connection's assigned pre-treatment lead concentration to determine the post-treatment lead concentration.
- **Other Material:**
  - **Marston Source:** For each service connection identified as having other material and served by Marston, a random sample is drawn from a distribution of percent lead reduction data for the CuLS Marston orthophosphate immersion study. The selected percent reduction is then multiplied by the connection's assigned pre-treatment lead concentration to determine the post-treatment lead concentration.
  - **Moffat Source:** For each service connection identified as having other material and served by Moffat, a random sample is drawn from a distribution of percent lead reduction data for the CuLS Moffat orthophosphate immersion study. The selected percent reduction is then multiplied by the connection's assigned pre-treatment lead concentration to determine the post-treatment lead concentration.
- **Blended Source:** For each service connection identified as having other material in the blended region, a random sample is drawn from the CuLS blended orthophosphate immersion study. The selected percent reduction is then multiplied by the connection's assigned pre-treatment lead concentration to determine the post-treatment lead concentration.

- **Lead Service Line Replacement:** Each year, 1,200 lead service line connections are randomly selected for lead service line replacement. For each of these connections, the lead concentration is replaced by a random sample from the pre-treatment copper with lead solder distribution. The line is then categorized as copper with lead solder and follows the post-treatment rules for copper with lead solder described below.

Post Treatment Data Inputs for LRP (After First Year)

- **Lead Service Lines:**
    - **Marston Source:** For each service connection identified as having a lead service line and served by Marston, a random sample is drawn from the Marston pH pipe rack lead concentration data during the post-treatment period. During this period, the target pH was 8.8.
    - **Moffat Source:** For each service connection identified as having a lead service line and served by Moffat, a random sample is drawn from the Moffat pH pipe rack lead concentration data during the post-treatment period. During this period, the target pH was 8.8.
    - **Blended Source:** For each service connection identified as having a non-lead service line in the blended region, a random sample is drawn from either the Marston or Moffat pH pipe rack lead concentration data during the post-treatment period. The percentages of samples drawn from the Marston pipe rack data and from the Moffat pipe rack data for the post-treatment period are consistent with those for the pre-treatment period, as described above.
- **Copper with Lead Solder:**
    - **Marston Source:** For each service connection identified as having copper with lead solder and served by Marston, a random sample is drawn from a distribution of percent lead reduction data for the CuLS Marston pH immersion study. The selected percent reduction is then multiplied by the connection's assigned pre-treatment lead concentration to determine the post-treatment lead concentration.
    - **Moffat Source:** For each service connection identified as having copper with lead solder and served by Moffat, a random sample is drawn from a distribution of percent lead reduction data for the CuLS Moffat pH immersion study. The selected percent reduction is then multiplied by the connection's assigned pre-treatment lead concentration to determine the post-treatment lead concentration.
    - **Blended Source:** For each service connection identified as having copper with lead solder in the blended region, a random sample is drawn from a distribution of percent lead reduction data for the CuLS blended pH immersion study. The selected percent reduction is then multiplied by the connection's assigned pre-treatment lead concentration to determine the post-treatment lead concentration.
- **Other Material:**
    - **Marston Source:** For each service connection identified other and served by Marston, a random sample is drawn from a distribution of percent lead reduction data for the CuLS Marston pH immersion study. The selected reduction is then multiplied by the connection's assigned pre-treatment lead concentration to determine the post-treatment lead concentration.
    - **Moffat Source:** For each service connection identified as other and served by Moffat, a random sample is drawn from a distribution of percent lead reduction data for the CuLS Moffat pH immersion study. The selected percent reduction is then multiplied by the

connection's assigned pre-treatment lead concentration to determine the post-treatment lead concentration.

- **Blended Source:** For each service connection identified as other in the blended region, a random sample is drawn from a distribution of percent lead reduction data for the CuLS blended pH immersion study. The selected percent reduction is then multiplied by the connection's assigned pre-treatment lead concentration to determine the post-treatment lead concentration.

- **All Sources (Lead Filter):** Denver Water will provide each household with a lead service line with a lead filter. The model is run with lead filter adoption rates, *p*, of 50%, 60%, 70%, 80%, 90% and 100%. For each adoption rate scenario, *p*% of the lead service line connections are randomly sampled and the assigned lead concentration is replaced with 1 ppb to account for the lead reduction achieved by the lead filter.
- **Lead Service Line Replacement:** Each year, 7% of the total lead service lines (7% of 74,138 lead service lines = 5,190 replacements per year) are randomly selected for lead service line replacement. For each of these connections, the post-treatment lead concentration is replaced by a random sample from the pre-treatment copper with lead solder distribution. The line is then categorized as copper with lead solder and follows the post-treatment rules for copper with lead solder described below.

Estimating the Reduction in Lead Release (Immersion Study Data Analyses)

Approach

1. Data used in the bootstrap analysis are immersion study data for periods of stable operation. All immersion study data for CuLS coupons from these periods are retained.
   1.1. The immersion study included CuLS coupons for the Marston plant and for the Moffat plant. For both Marston and Moffat CuLS coupons, data from June 7, 2019 through July 5, 2019 were used. The CuLS coupons included control coupons, coupons with orthophosphate treatment, and coupons with pH treatment.
2. For each plant, draw a sample from the control coupon lead concentration data and a sample from the treatment, either orthophosphate treatment or pH treatment, coupon lead concentration data. The size of the control sample is equal to the number of control data and the size of the treatment sample is equal to the number of treatment data.
3. Calculate the reduction in lead concentration for the control and treatment samples for the coupon. Reduction calculated as the difference in the expected values for a lognormal distribution of the control and treatment samples as a percent of the expected value of the lognormal distribution of control samples.
4. In some case, negative reductions were observed. Because increases in lead concentrations observed in the pilot rack and immersion study were assumed to due to other factors and not as a result of CCT, these values were changed to zero.
5. Steps 2 - 4 were repeated 1,000 times for each treatment.
6. The distribution of reductions for a given treatment is given by the combination of reductions for the 1,000 reduction estimates for a given plant and a given treatment. This resulted in 4 output files, each with 1,000 potential reduction and all used in the Monte Carlo analysis:
   6.1. Moffat plant, OP treatment
   6.2. Moffat plant, pH adjustment
   6.3. Marston plant, OP treatment
   6.4. Marston plant, pH adjustment

Choices and Underlying Assumptions

1. Assume coupons and operating conditions for coupons are representative of pipes and operating conditions for a given service area (Moffat or Marston).
2. Assume that sufficient data were collected from immersion study to account for seasonal differences in corrosion control performance.
3. Assume data are lognormally distributed and calculate reduction based on the difference in the expected value for lognormal distribution for control and treatment data.
4. 1,000 samples per plant and treatment is sufficient for establishing the range of reductions that might have been observed for a pipe carrying water from that plant with the specified treatment.

Lead Risk Reduction Strategy Simulations

Approach

1. Create virtual customers/connections
   1.1. 74,138 lead service lines, distributed following source of supply ratios throughout the service area. (Marston only, Moffat only and Blend).
2. Lead concentration for a given service connection is sampled randomly from the appropriate distribution every year.
   2.1. For lead service line connections, lead concentration is sampled from pipe rack data.
      2.1.1. For connections served exclusively by the Marston or Foothills plant, lead service line lead concentration is sampled from the Marston plant pipe rack data. The following data are sampled:
         2.1.1.1. All post-stabilization control pipe data (both the pre-treatment and post-treatment period)
         2.1.1.2. All post-stabilization, pre-treatment data (all pipes)
      2.1.2. For connections served exclusively by the Moffat plant, lead service line lead concentration is sampled from the Moffat pipe rack data. The following data are sampled.
         2.1.2.1. All post-stabilization control pipe data (both the pre-treatment and post-treatment period)
         2.1.2.2. All post-stabilization, pre-treatment data (all pipes)
      2.1.3. For connections in blended areas, the connection is randomly assigned a “dominant” plant based on the proportion of connections serving each service area in the compliance and customer requested sample data. Lead concentration is drawn from pipe rack data for the assigned plant as described above.
   2.2. For CuLS and other connections, lead concentration is drawn from a random distribution corresponding to the distribution that fit the compliance data for the corresponding service area (Marston, Moffat or Blend) and material. Best fit distributions were developed separately from the Monte Carlo simulation and via maximum likelihood estimation (mle). The median lead concentration was used for addresses with more than one lead concentration in the compliance and customer requested data set.
3. In each simulation year, lead service lines can be removed, lead filters can be adopted, and treatment can be applied. There are two treatment options: orthophosphate addition and pH adjustment.
   3.1. Orthophosphate treatment is assumed to be fully implemented by March 20, 2020, which is the start of year 1 of the simulation. Under the orthophosphate treatment option, the annual lead service line replacement rate is N=1,200 and no lead filters are provided by Denver Water.
   3.2. pH addition is assumed fully implemented by the start of year 1 of the simulation. Under pH treatment option, the annual lead service line replacement rate is 7% of the total 74,138 lead service lines at the start of the simulation, N=5,190. Lead filters are provided to all addresses

with a lead service line. The lead filter adoption rate is equal to *p*%, which is varied from 50% to 100%.

3.3. Lead service line replacement is assumed to begin in year 1 of the simulation.

4. Lead concentrations are assigned or calculated for each virtual service connection for each simulation year.
   4.1. Before initiation of treatment, there is no reduction in lead concentration (i.e., the lead concentration is the same as the concentration assigned in step 2) for any connection.
   4.2. After treatment:
      4.2.1. Lead concentrations for lead service lines are sampled from the post-treatment, post-stabilization pipe rack data for the chosen treatment strategy and for the plant serving the address.
      4.2.2. Lead concentrations for non- lead service line connections are estimated as the pre-treatment lead concentration (from 2.2) minus a percent reduction drawn from the distribution of reductions from immersion study data for the plant serving the address and treatment type (i.e., from the results of the bootstrap analysis described above).
5. Lead service lines are removed at a specified rate at the beginning of each simulation year. In the simulation, lead service line addresses are reassigned as CuLS addresses.
   5.1. Addresses are converted from lead service lines to CuLS at random. At the beginning of each simulation year, a random value from a uniform distribution between 0 and 1 is assigned to each lead service line, and the N addresses with the highest random values are converted from a lead service line to a CuLS, where N is the annual replacement rate.
   5.2. Pre-treatment lead concentration for lead service line addresses converted to CuLS are drawn from the appropriate distribution (as described in 2.2). Post-treatment lead concentration for lead service line addresses converted to CuLS are assigned in the same way as for other CuLS addresses (as described in 4.2.2).
6. Lead filter adoption is randomly assigned, based on the lead filter adoption rate (*p*%), to addresses with lead service lines. A random value from a uniform distribution between 0 and 1 is assigned to each address with a lead service line and the *p*% of the addresses with the highest random values are assumed to have an adopted lead filter. The lead concentration for these addresses are reassigned as 1 ppb.
7. The simulation continues for 70 years. Statistics are output for each simulation. Those statistics include median, 75th, 90th, 95th and 99th percentile lead concentrations, the number of addresses with lead concentration exceeding some threshold (typically 15 ppb) and the proportion of addresses exceeding the threshold.

Choices and Assumptions

1. Assume that lead concentrations observed in pipe racks are indicative of worst-case concentrations that could be observed (and ingested) for connections with lead service lines.
2. Assume that distributions fit to first-draw compliance sample data adequately characterize the distribution of lead concentrations for CuLS and other connections and provide a realistic indication of lead concentrations in water that could be ingested (brass fittings and lead solder are closer to taps and lead releases from them are more likely to be caught in a first-draw sample).
   2.1. For addresses with multiple observations, assume that median lead concentration for that address is representative.
3. Assume that reductions in lead observed in immersion studies for CuLS also apply to other materials and real service connections and plumbing.
4. Lead filters are provided to all Denver Water customers with lead service lines and if adopted, the lead filter removes the customers' lead exposure (i.e. lead concentration = 1 ppb at addresses with

lead service lines and adopted lead filters). Lead filters distributed to non- lead service line customers will occur but are not considered in the analysis.

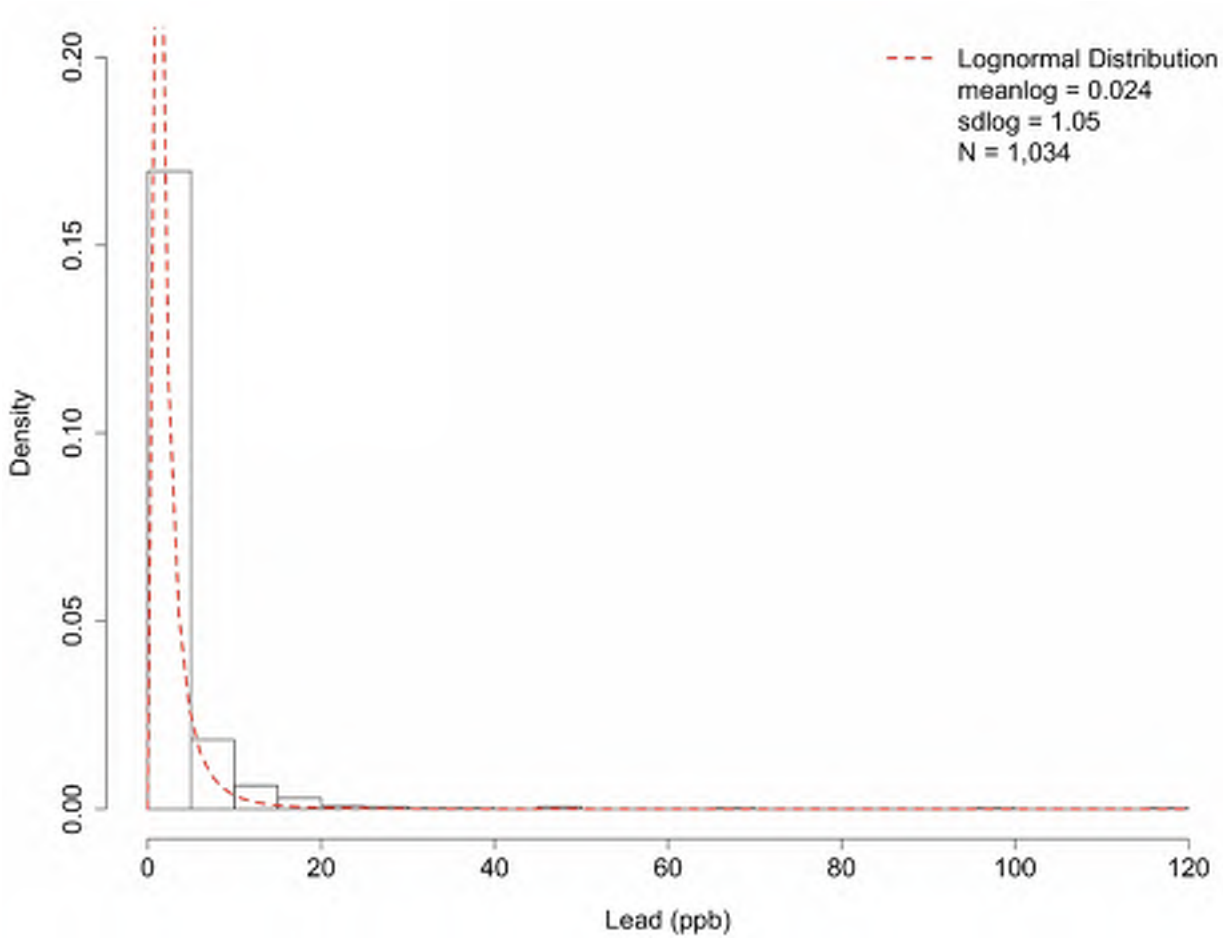
5. Choices:
   5.1. Treatment strategy (none, OP addition, pH adjustment)
   5.2. Lead service line replacement rate (# pipe/year)
   5.3. Lead filter adoption rate (% of addresses where customers adopt lead filter)

Appendix C: Model Input Data Distributions

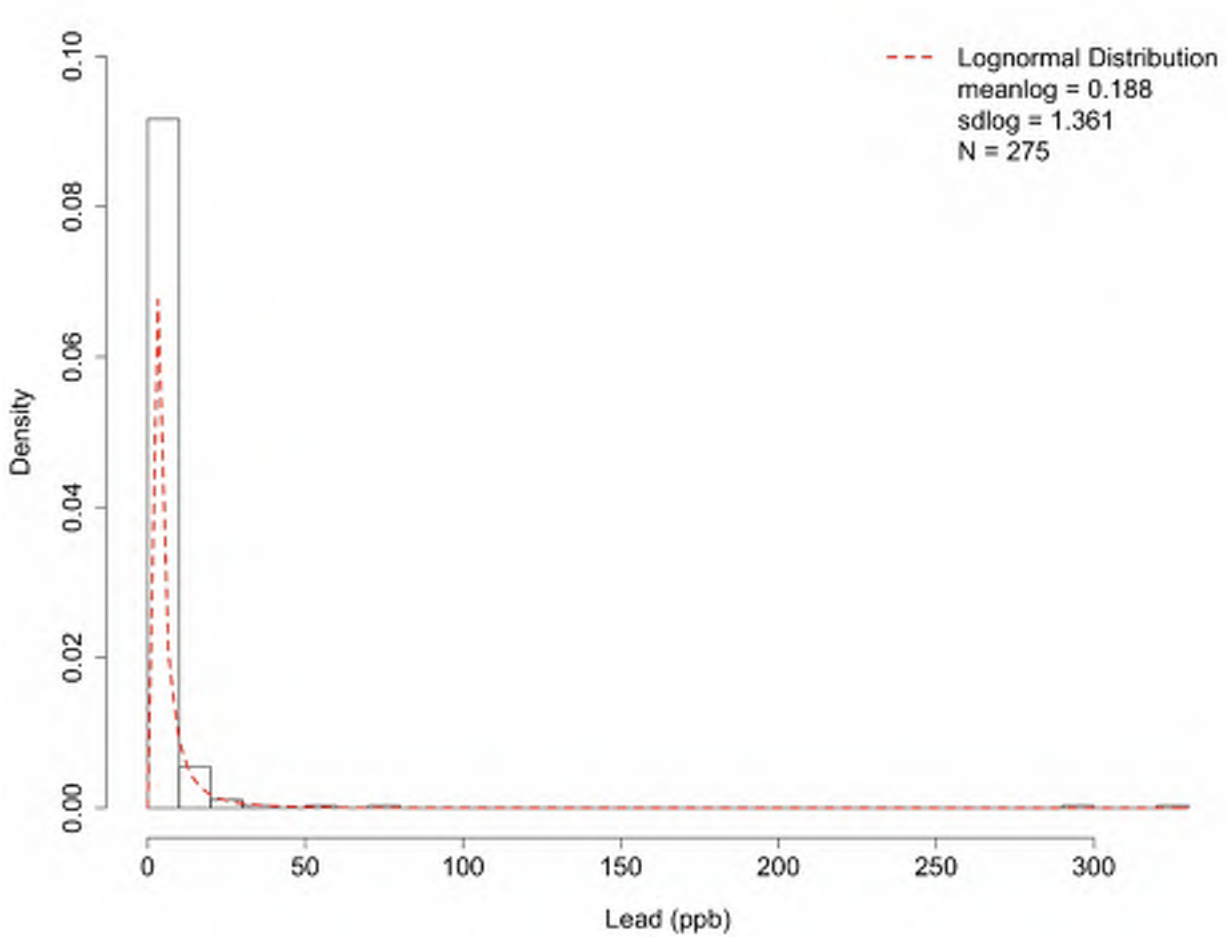
Input Data for CuLS

For CuLS, the model uses lead concentrations drawn from a distribution fitted to the lead concentrations sampled in the distribution system from CuLS. In the LCR data set, there are a total of 2,403 lead concentrations data records for 1,243 addresses over a period from June 2000 through July 2019. A subset of these data was created by taking the median lead concentration for each address. Distributions were fit to the subset of median lead concentrations for each service area (Marston, Moffat or Blend). The following figures show histograms of the median lead concentration data for each address with the best-fit distribution.

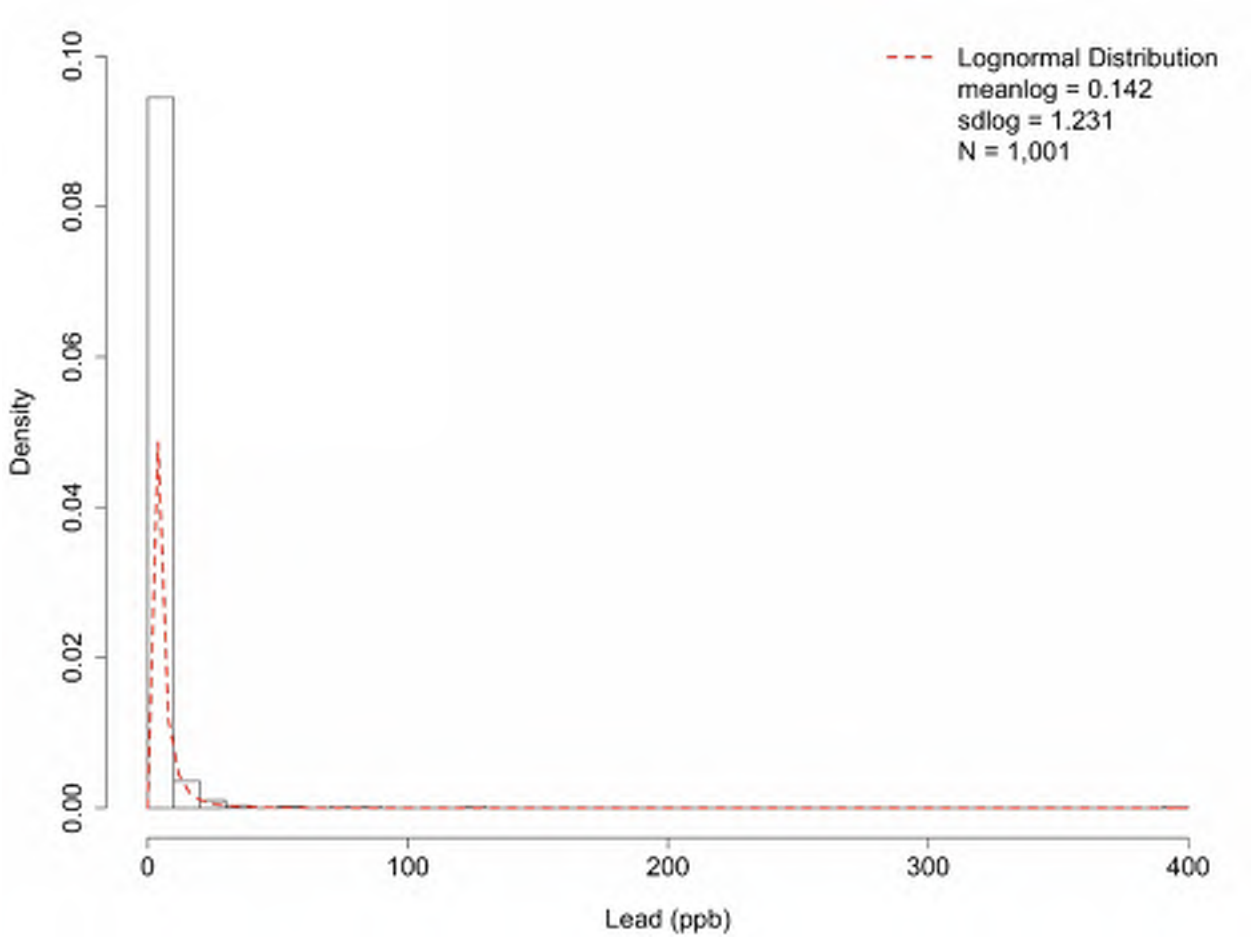
Marston Service Area



Moffat Service Area



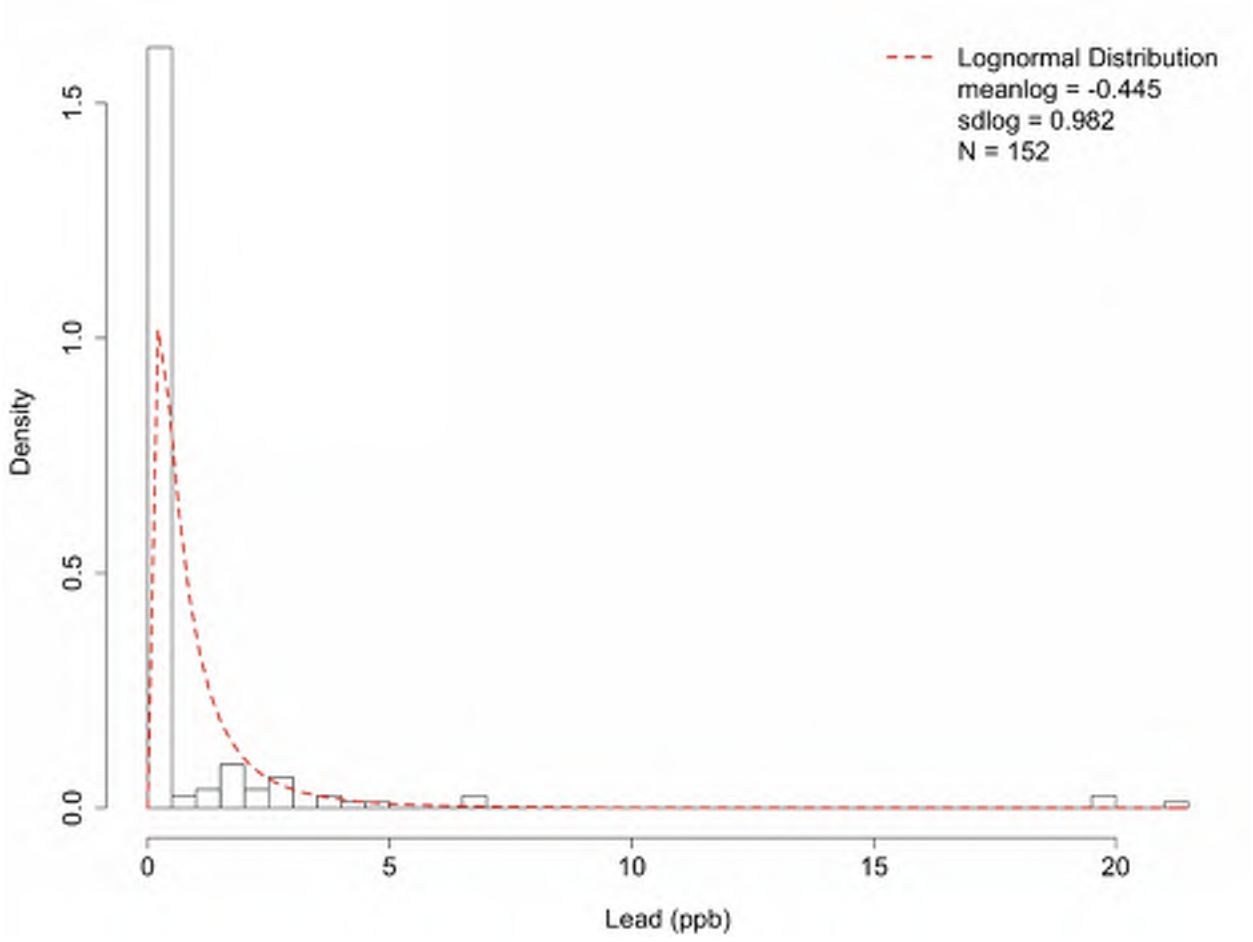
Blend Service Area



Input Data for Other Service Lines

For other service lines, the model uses lead concentrations drawn from a distribution fitted to the lead concentrations sampled in the distribution system from other service lines. In the LCR data set, there are a total of 152 lead concentrations data records for 133 addresses over a period from August 2010 through July 2019. A subset of these data was created by taking the median lead concentration for each address. Distributions were fit to the median lead concentrations for the entire distribution system. Distributions were not fit separately for different service zones (Marston, Moffat, Blend) due to limited data availability. The following figure shows a histogram of the median lead concentration data for each address with the best-fit distribution.

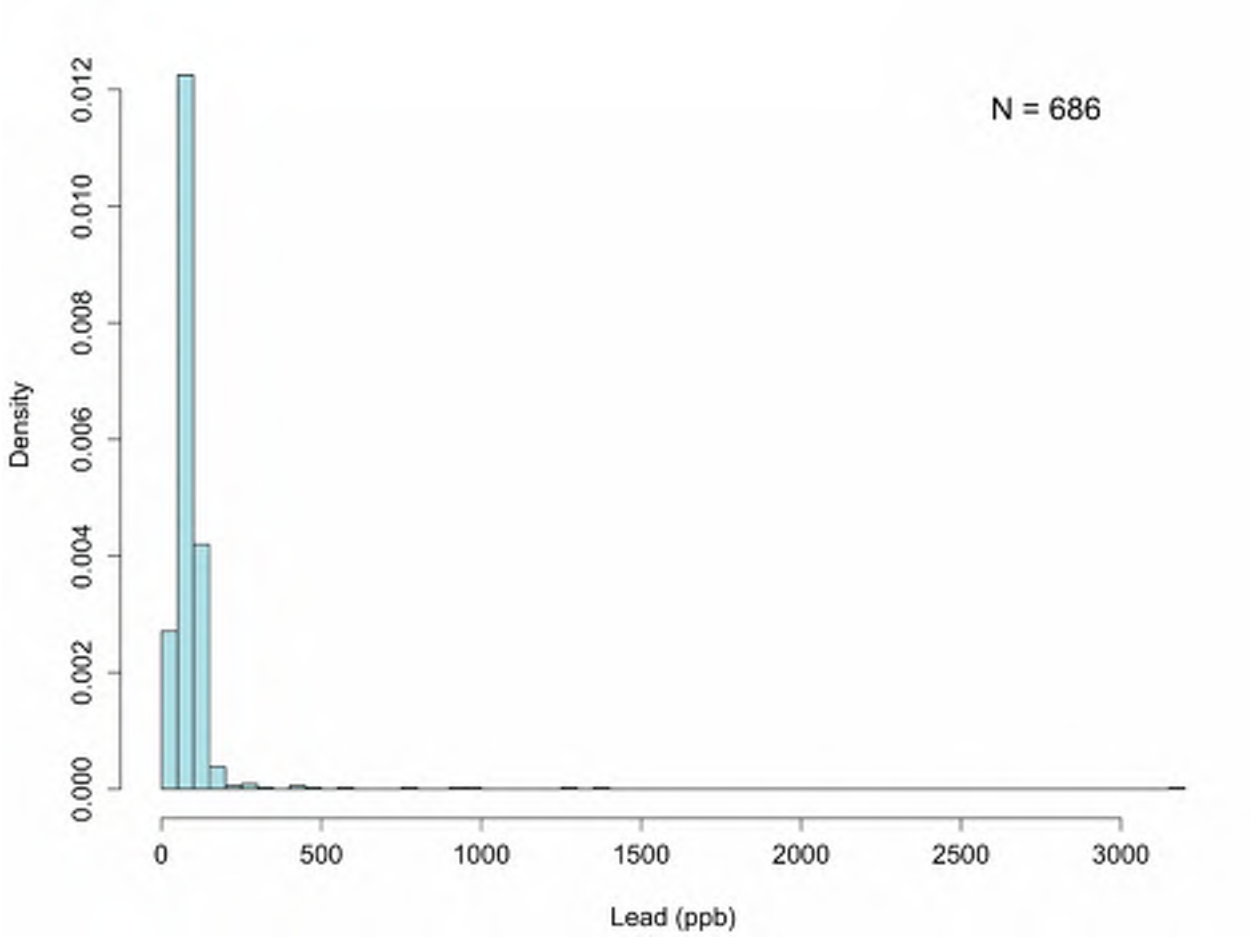
Entire Distribution System



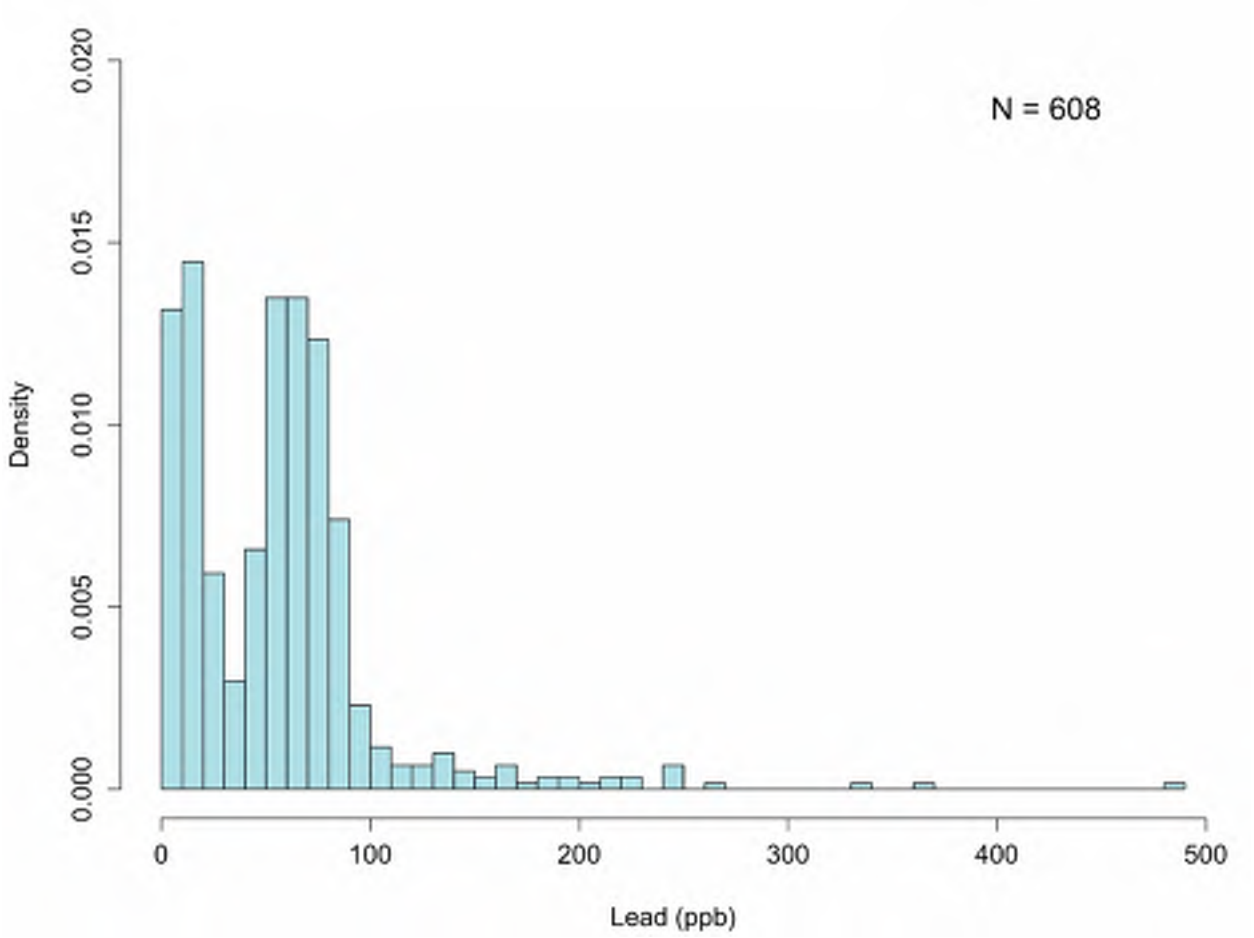
Input Data for Lead Service Lines

For lead service lines, the model uses lead concentration data from the pipe racks. For the first year, prior to the start of treatment, the model uses pipe racks lead concentration data from the Pre-Treatment period for the Control, Orthophosphate, and pH racks. To model lead concentrations after orthophosphate or pH treatment are implemented, the model uses input data from the pipe racks during the Post-Treatment period from the Orthophosphate racks and the pH racks, respectively.

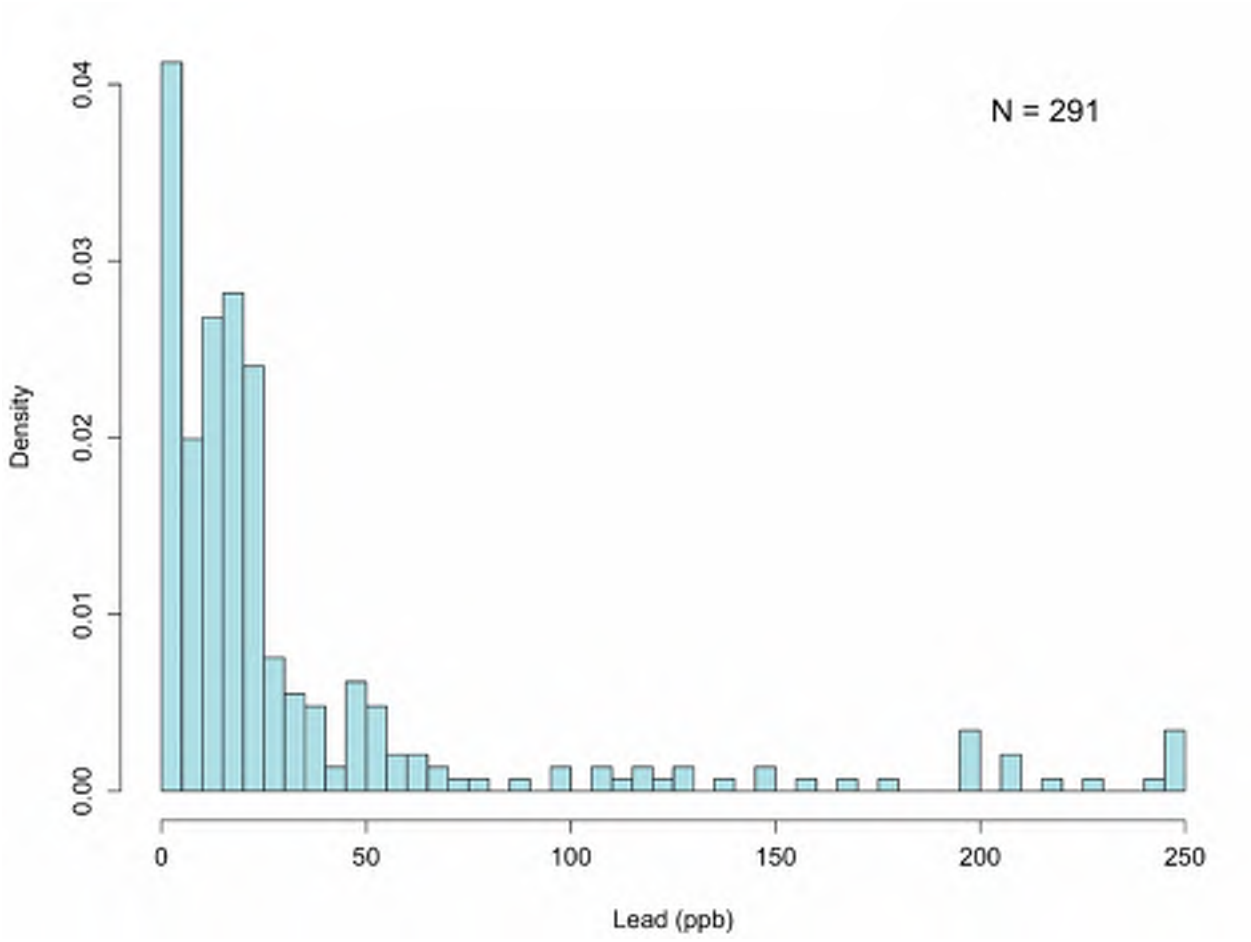
Marston No Treatment (Pre-Treatment):



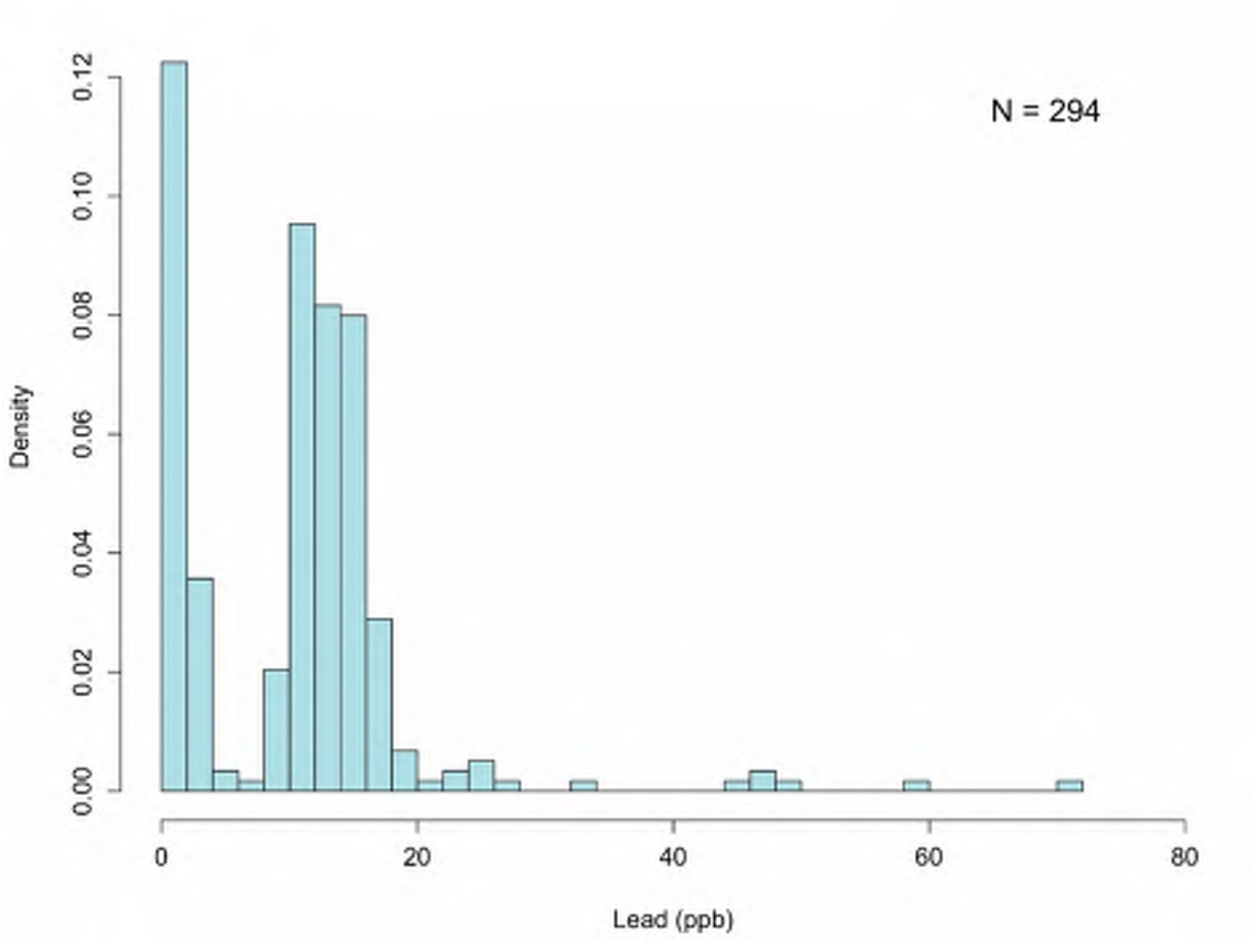
Moffat No Treatment (Pre-Treatment):



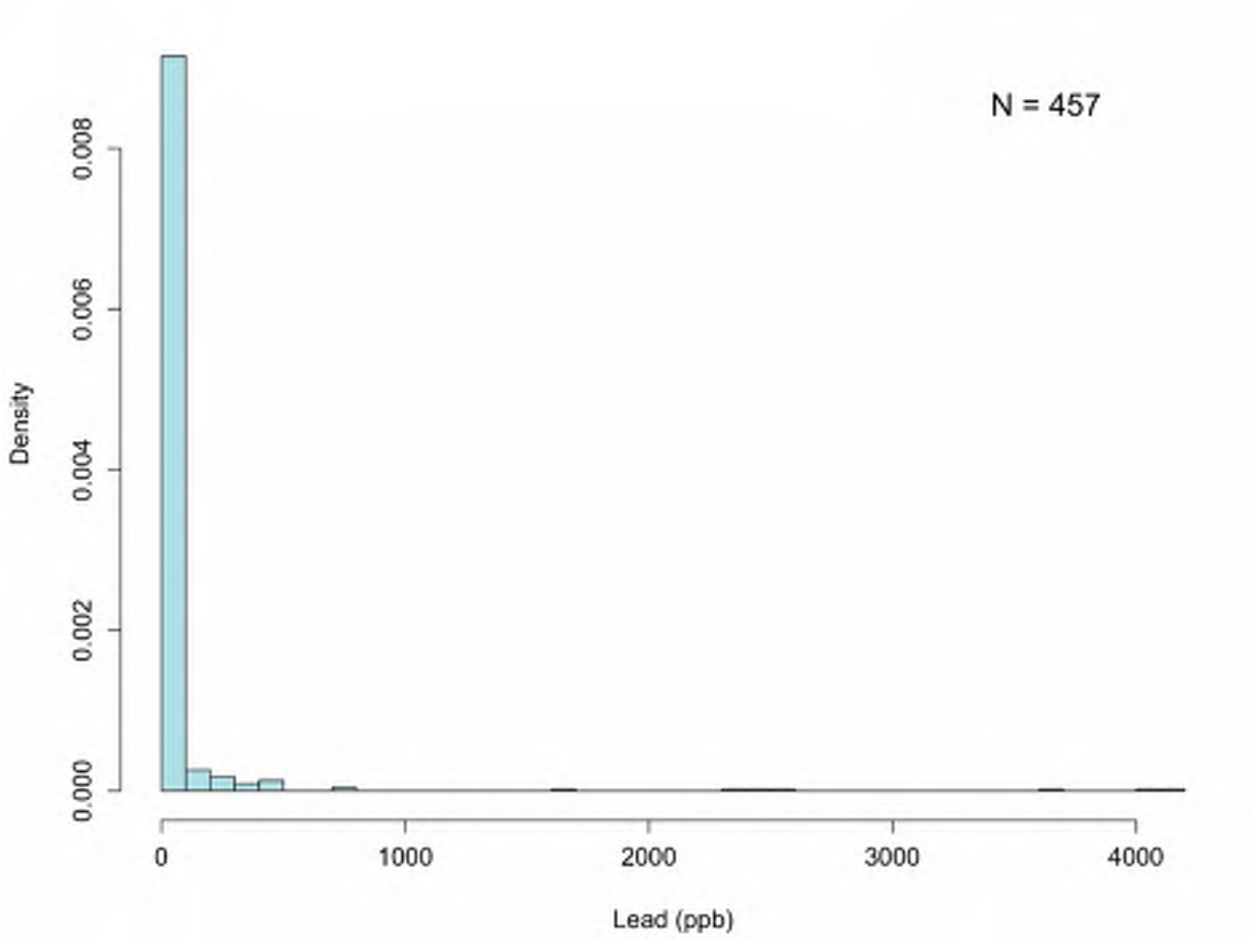
Marston Orthophosphate Treatment:



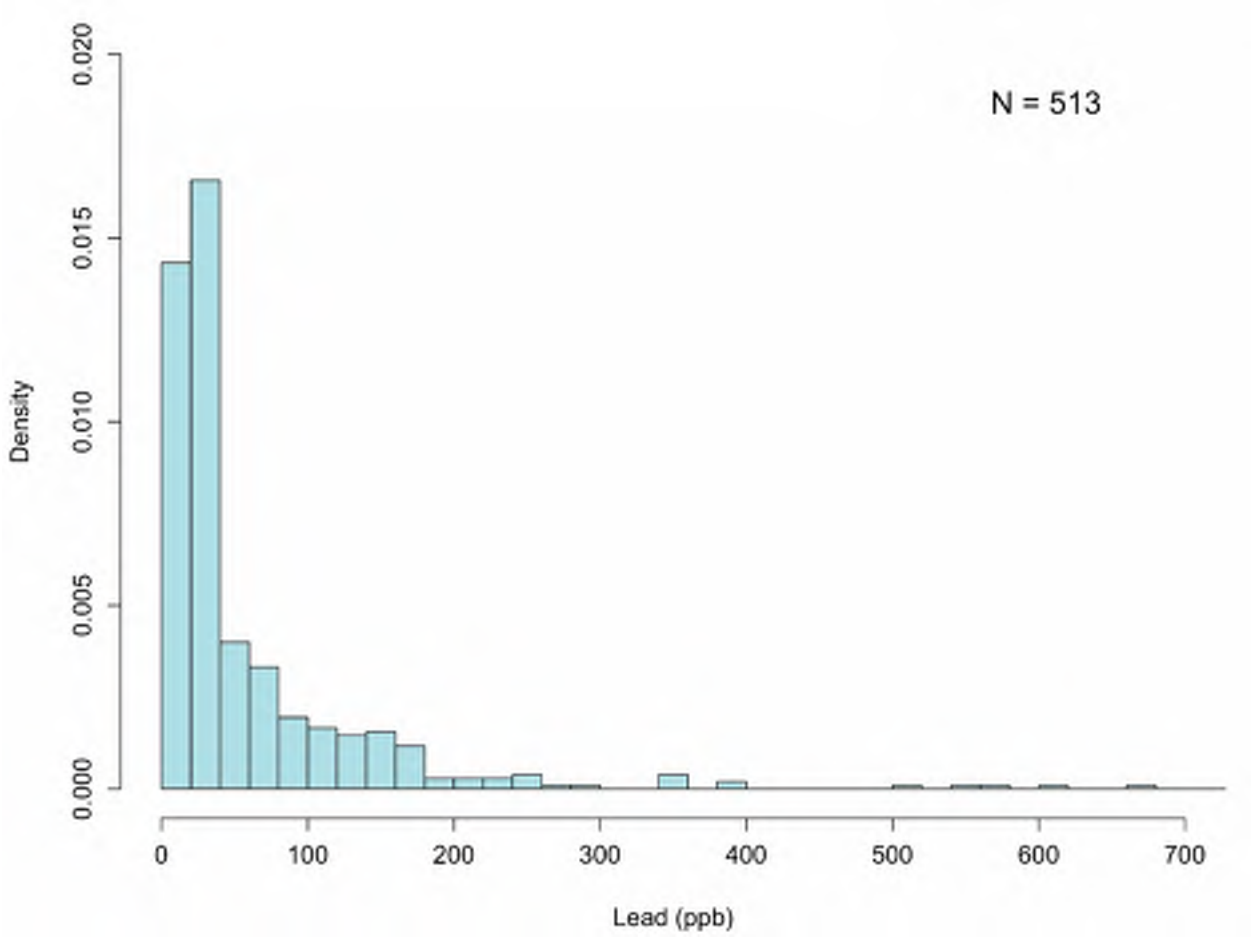
Moffat Orthophosphate Treatment:



Marston pH Treatment:



Moffat pH Treatment:



APPENDIX II.B - LEAD PILOT RESULTS

September 2019

DENVER WATER

Appendix II.B:

Lead Pilot Results

Date: Revised August 16, 2019
May 15, 2019

To: Denver Water

From: Corona Environmental Consulting, LLC

This appendix reports data from the two lead service line pilots located at Marston and Moffat treatment plants. These two sites were chosen to represent the South Platte River and the Fraser River which are the two major water supplies to the Denver Water system. Although the Foothills plant produces the most water, it is also located on the South Platte Supply with very similar water quality to Marston. Detailed information on the design and initial operation of the pilots can be found in Denver Water's "Optimal Corrosion Control Treatment Report," dated September 20, 2017.

The Marston pilot started operation in October of 2015, Moffat in May of 2016 with both plants continuing in operation at the time of this report. Average and ranges of influent water quality parameters over the period of operation are presented in Table 1.

Table 1. Summary of Influent Water Quality.

Parameter	**Marston Influent** Avg. (range)	**Moffat Influent** Avg. (range)
Temperature (°C)	13 (4-25)	12 (5-21)
pH	7.8 (7.4-9.1)	7.8 (7.2-8.3)
Alkalinity (mg/L as $CaCO_3$)	64 (36-83)	39 (14-70)
Calcium (mg/L)	30 (7-41)	16 (1-36)
Magnesium (mg/L)	8.0 (1.7-10.8)	2.9 (0.3-9.2)
Conductivity (µS/cm)	325 (35-450)	152 (92-330)
Total Chlorine (mg/L)	1.34 (0.03-8.00)	1.40 (0.12-1.78)

Each pilot consists of four racks of three whole lead service lines (and one segmented service line not included in sampling). Each pipe is run for three flow and stagnation cycles each day. The flow period is two hours, followed by a 5-hour stagnation period, then a 1-hour sampling period. Feedwater is supplied from the distribution system and piped back to the pilot rigs.

The Rack 1 is the control rack, which has no adjustment to water quality. The Rack 2 tests corrosion control using orthophosphate addition which was started at 3 mg/L as PO_4 and reduced over time. Orthophosphate was dosed as phosphoric acid and the pH was returned to match the existing distribution system of 7.8 with caustic soda. Rack 3 originally tested silicate addition but was later

transitioned to an additional orthophosphate test where the test began at 1 mg/L as PO_4. Only the orthophosphate data are included in this report for Rack 3. Rack 4 uses pH modification for corrosion control. Target pH of 8.8 and 9.2 were tested using caustic soda as the base.

Rack 3 data through April 25, 2019 and Rack 4 data through May 2, 2019 are included. After this date, pilot operation was modified to begin testing other conditions. These tests are currently underway testing low dose orthophosphate at high pH and transitioning from high pH to orthophosphate should it be necessary in the future. Rack 1 and 2 data through July 18, 2019 are included.

Summaries of the lead release for each pilot are shown in Figure 1 and Figure 2. Lead was analyzed by the ICP/MS direct method EPA 200.8 with a minimum reporting level of 1 ppb (µg/L). Each pipe was run for a conditioning period to stabilize operation after the disturbance of harvesting the lead service lines. These are indicated by the "pre-treatment" gray box. Lead removal is calculated by dividing the median lead during treatment by the median lead during the pretreatment period for each pipe. The three pipes on each rack were averaged to get the values used in the summary figures. The only data excluded from the analysis were periods where the operational targets could not be maintained (i.e. the orthophosphate dose or pH were out of range). These are noted as upset periods indicated with gray rectangles and are discussed in further detail later.

Both plots show that orthophosphate and high pH reduce lead release, with orthophosphate performing better for lead control. An orthophosphate dose of 2 mg/L appears to be equal in performance to 3 mg/L, assuming dosing starts at 3 mg/L. See Corona Technical Memorandum "Reducing Orthophosphate Dose from 3 mg/L to 2 mg/L does not Result in Increased Lead Release in Denver Water Pilot Study" dated 5/24/2019 for additional information. While testing continues, an orthophosphate dose of 1 mg/L does not appear to result in equivalent reduction.

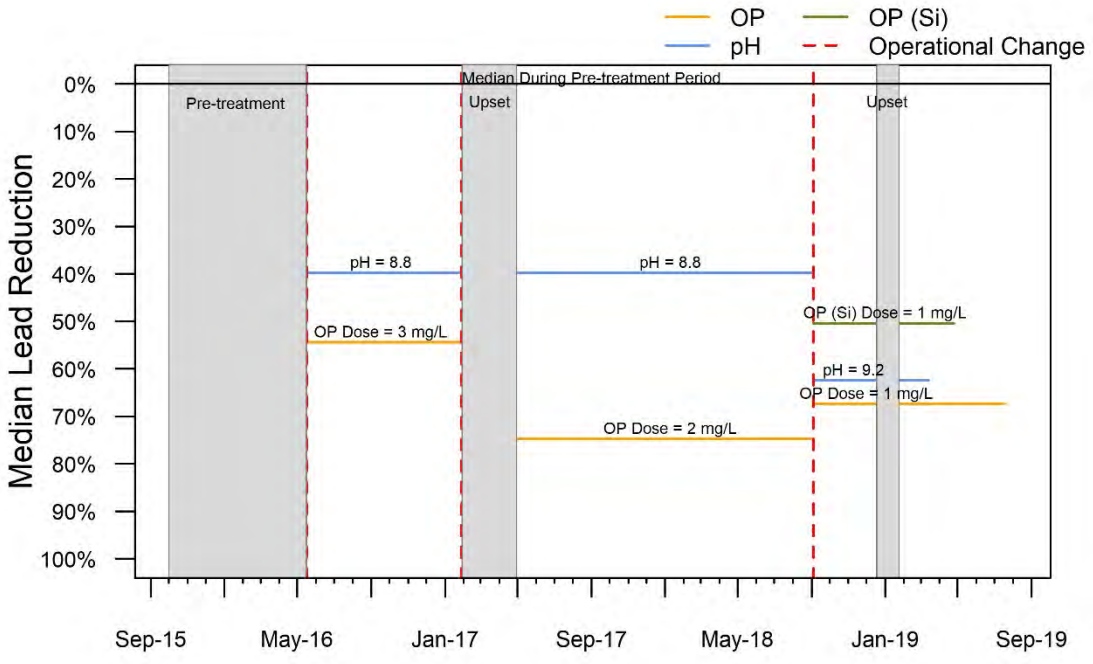


Figure 1: Marston Pilot Summary of Lead Reduction (orthophosphate doses shown measured as PO_4)

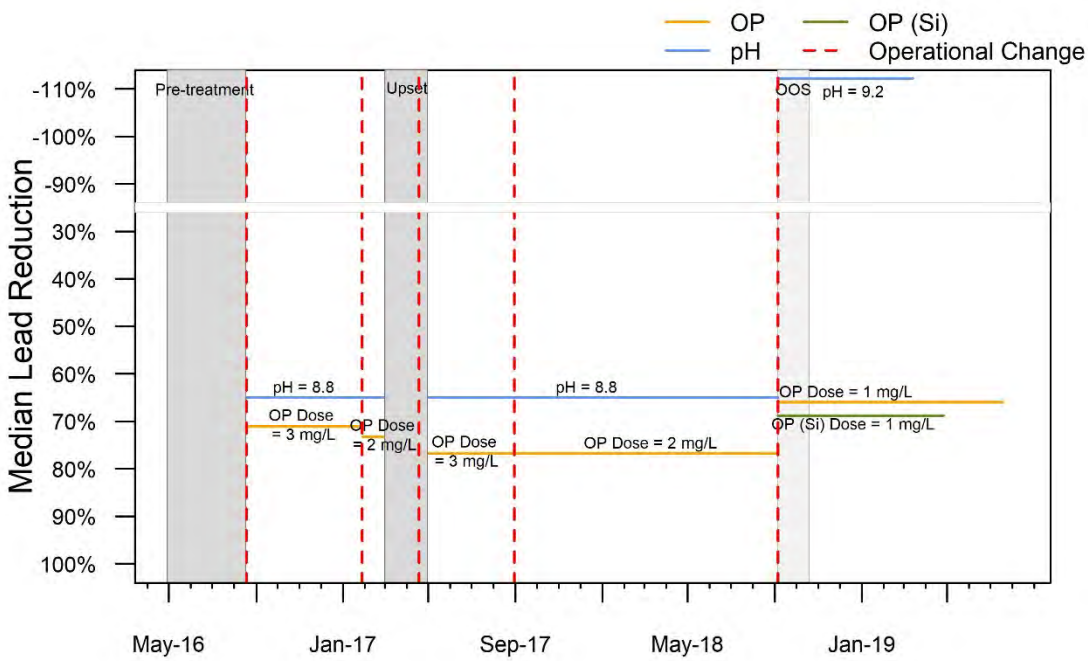


Figure 2: Moffat Pilot Summary of Lead Reduction (orthophosphate doses shown measured as PO_4)

Time series plots of lead release for all treatment conditions for both pilots are shown in Figure 3 through Figure 12. These plots include all data as distinct points with the y-axis in a log scale for lead concentrations to display all the data and demonstrate the pipe-to-pipe variability. Where appropriate, target orthophosphate dose and target pH are shown with a dashed red line.

The Marston pre-treatment period is shown with a gray rectangle in Figure 3 through Figure 7; during this time no chemical was being added. For the orthophosphate racks, shown in Figure 4 and Figure 5, the orthophosphate dose was started at 3 mg/L and stepped down to 2 mg/L then 1 mg/L. The dose was stepped down to determine whether a lower dose provided equivalent corrosion control to the 3 mg/L dose. The former silica orthophosphate racks stepped directly from no orthophosphate to a dose of 1 mg/L. This condition was selected to determine whether starting with a high dose and lowering the dose was equivalent to starting with a lower dose. The pH racks, shown in Figure 6 and Figure 7, ran with a pH setpoint of 8.8 and increased the setpoint to 9.2. The pH was increased to see whether a higher setpoint would provide further corrosion control.

Marston experienced two upset periods, shown with gray rectangles. Both upsets caused increased lead release. Both upsets were due to several minor electrical faults that prevented the pilot from running correctly as scheduled. As shown in the plots, many of the pipes have not returned to pre-upset conditions. This is especially true for pH pipe 4.

Figure 5 shows the orthophosphate measured in the sample after stagnation. This may not be representative of the applied dose early in the test where pipe scales are forming and consuming some phosphate. Overall, the orthophosphate results indicate it was fed consistently and accurately after the initial range finding. Figure 7 shows the measured pH in the sample after stagnation. Results indicate a drop in pH of about 0.3 units over the stagnation period.

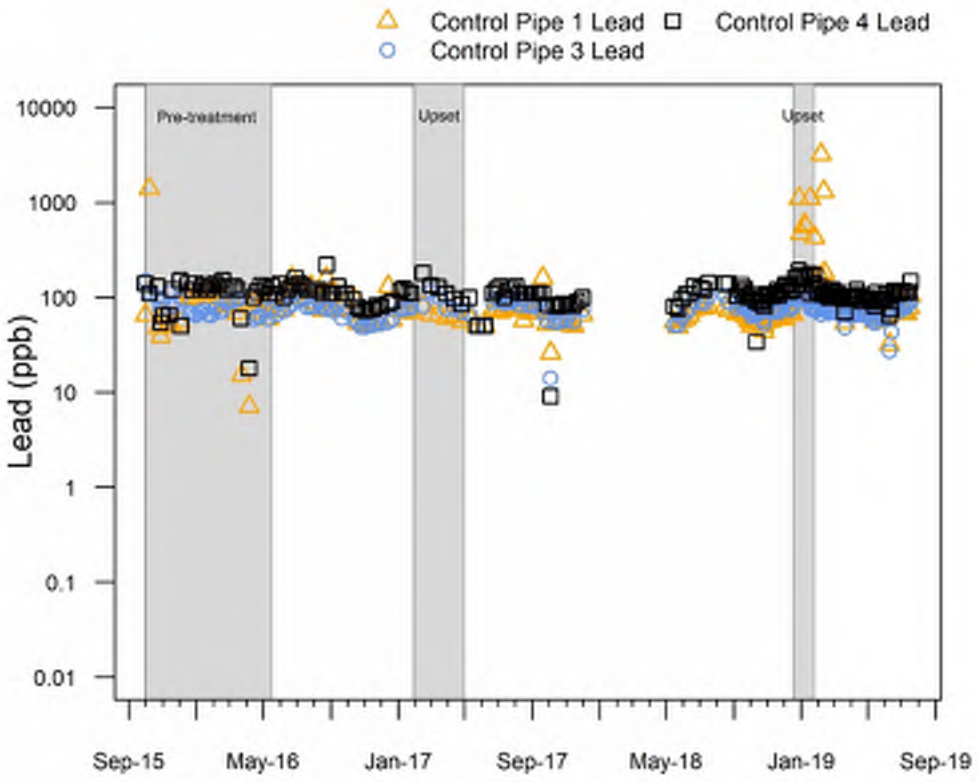


Figure 3: Marston Control Rack - Lead

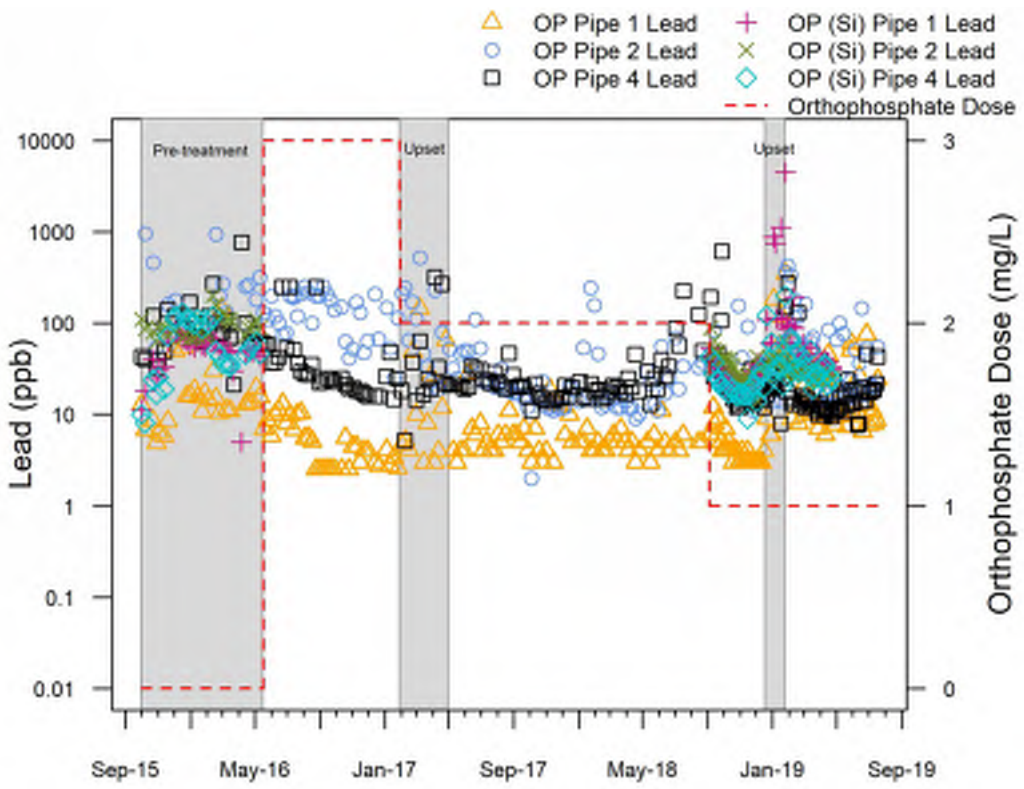


Figure 4: Marston Orthophosphate Racks - Lead

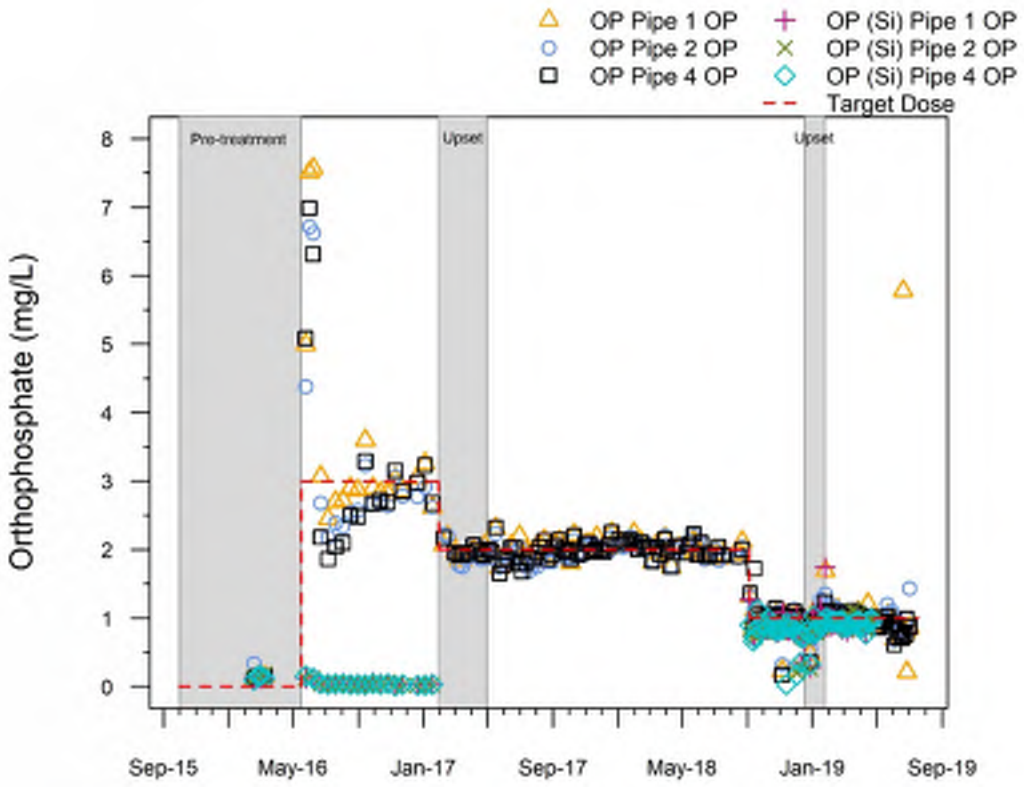


Figure 5: Marston Orthophosphate Racks - Orthophosphate Target Dose and Measured Residual

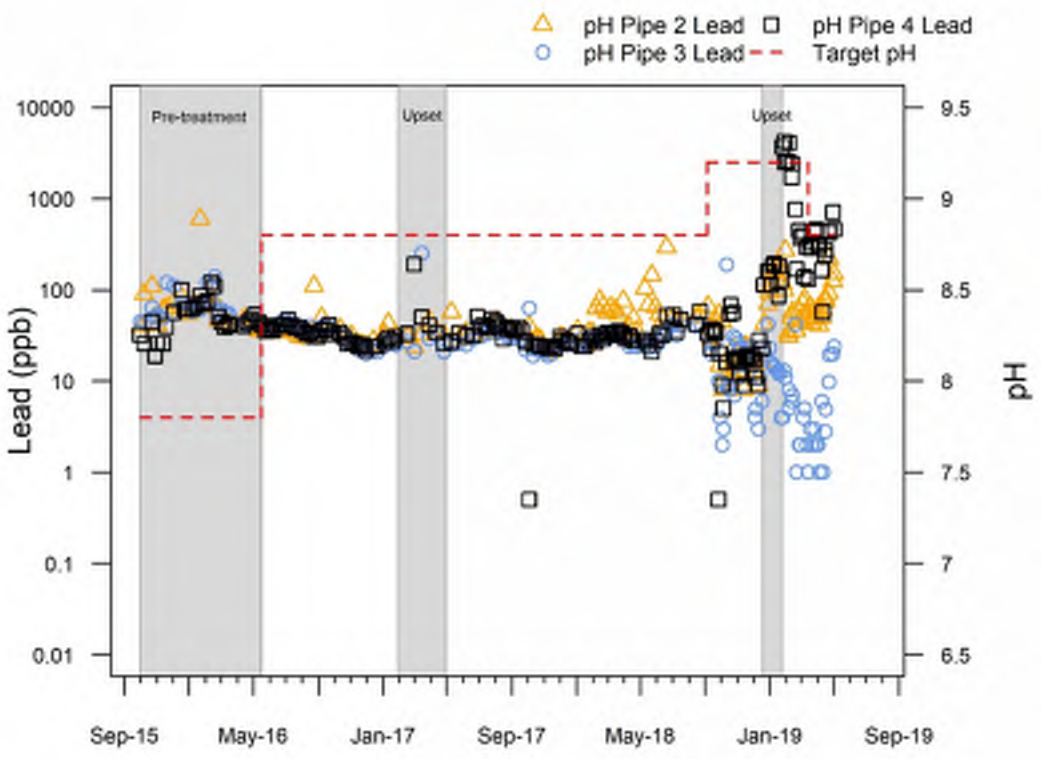


Figure 6: Marston pH Rack - Lead

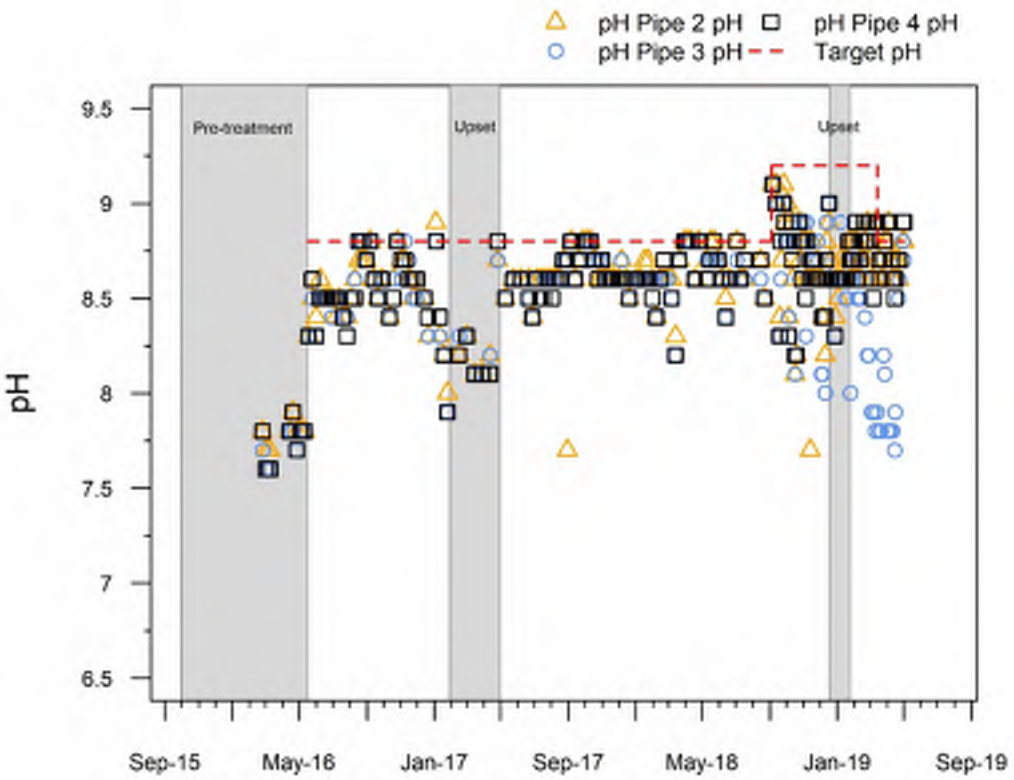


Figure 7: Marston pH Rack – pH Measured Post-stagnation

The Moffat pretreatment period is shown with a gray rectangle in Figure 8 through Figure 12. For the orthophosphate rack, dose was stepped down in a similar manner to Marston. The former silica rack and the pH rack were both controlled the same as Marston. Moffat experienced one upset due to a series of pump failures that resulted in the target conditions not being met. The orthophosphate dose was increased back to 3 mg/L to help stabilize lead release. A second area is highlighted in a light gray box when the Moffat plant was out of service. During this time, the pilot was being fed a water from the distribution fed by the Marston plant. The change in water quality caused a large response in lead release. All pipes (including the controls) saw an increase in lead release during the out of service period and some maintained the higher levels when the out of service period ended. Pipe 1 in the pH rack was affected most drastically. Because all operational parameters were maintained during this period and this is a normal occurrence, these data were included in the analysis.

Figure 10 shows the orthophosphate measured in the sample after stagnation. Like the Marston pilot, the orthophosphate results indicate it was fed consistently and accurately after the initial range finding. Figure 12 shows the measured pH in the sample after stagnation. Results also show some drift in pH but pH was more stable than at Marston.

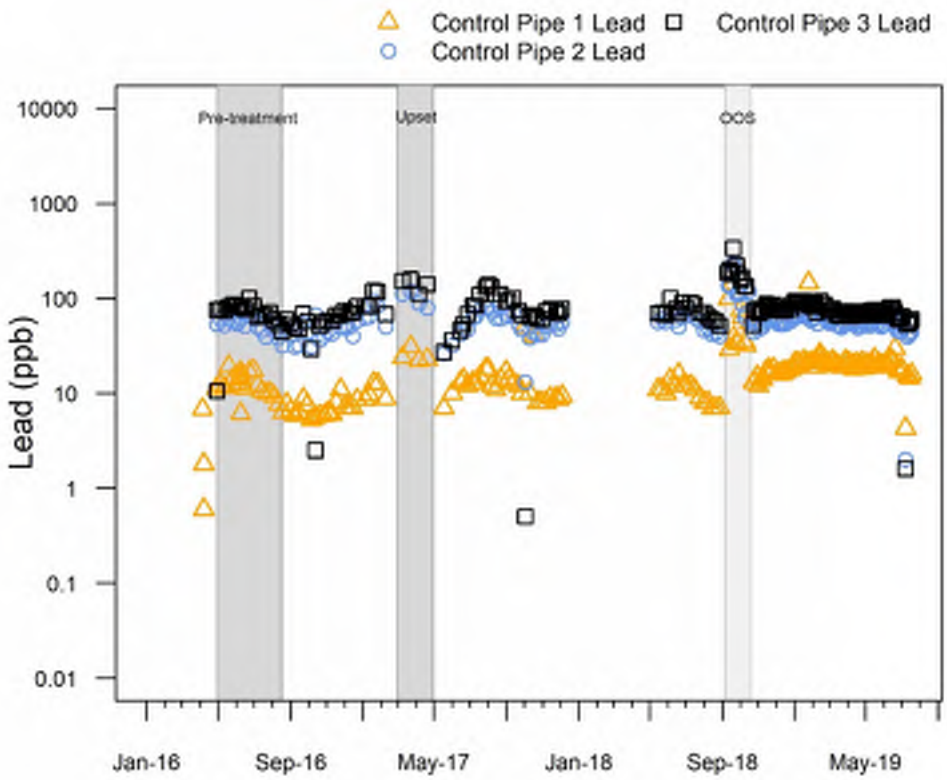


Figure 8: Moffat Control Rack - Lead

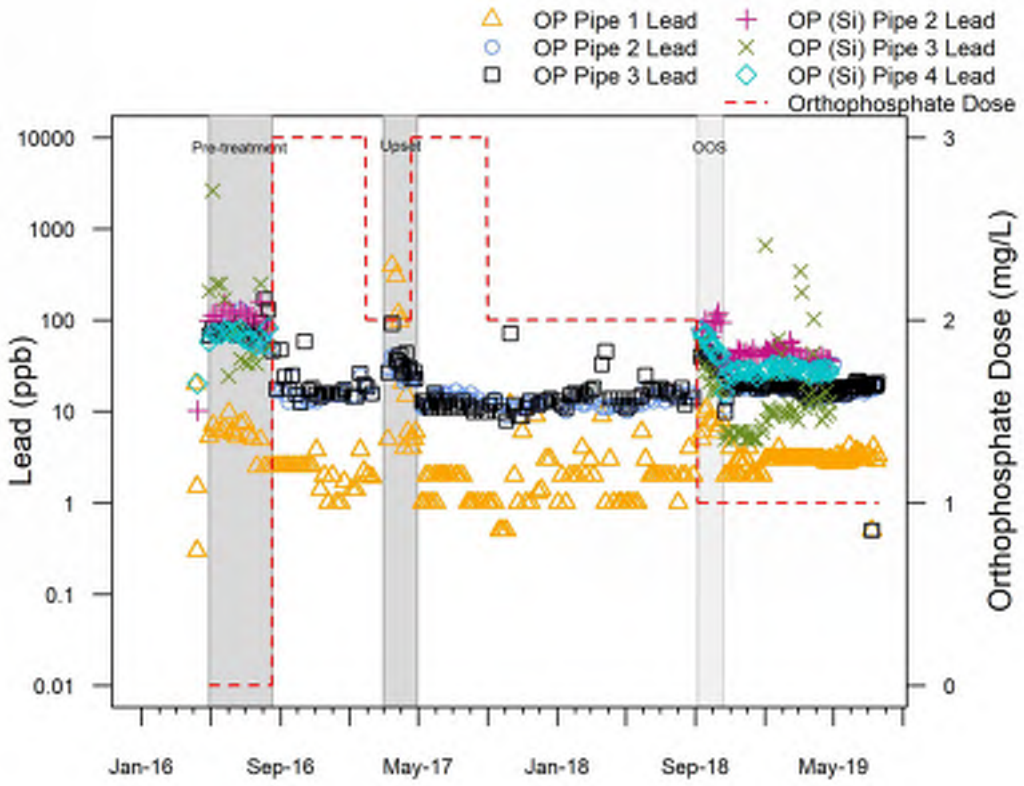


Figure 9: Moffat Orthophosphate Racks - Lead

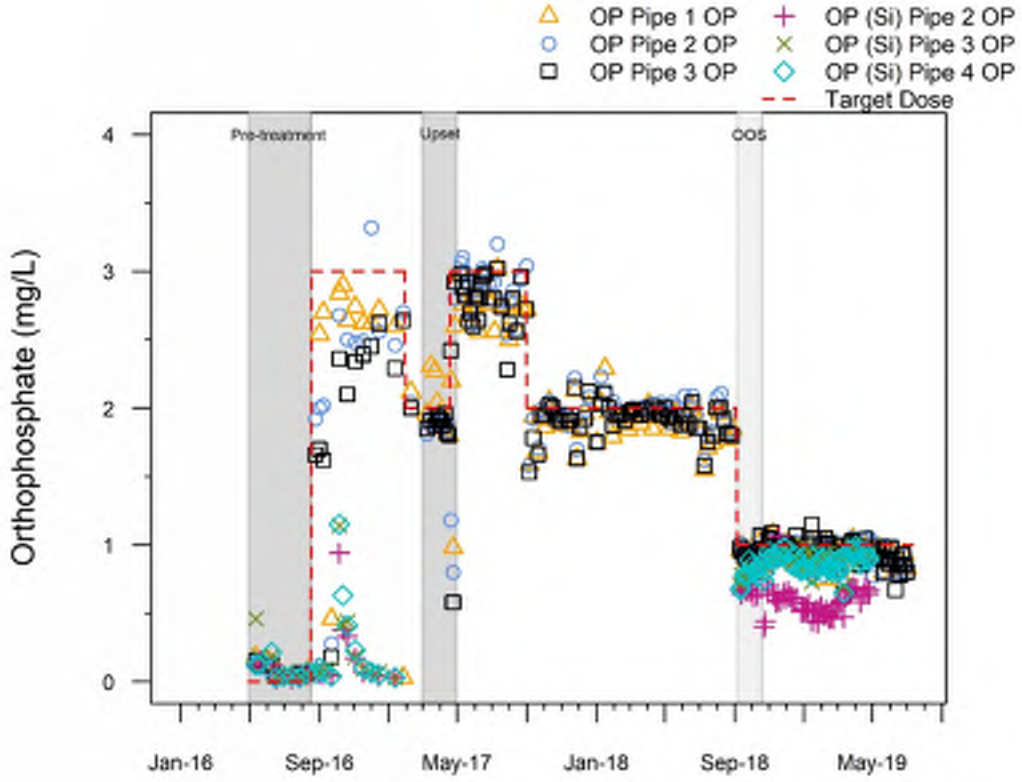


Figure 10: Moffat Orthophosphate Racks - Orthophosphate Target Dose and Measured Residual

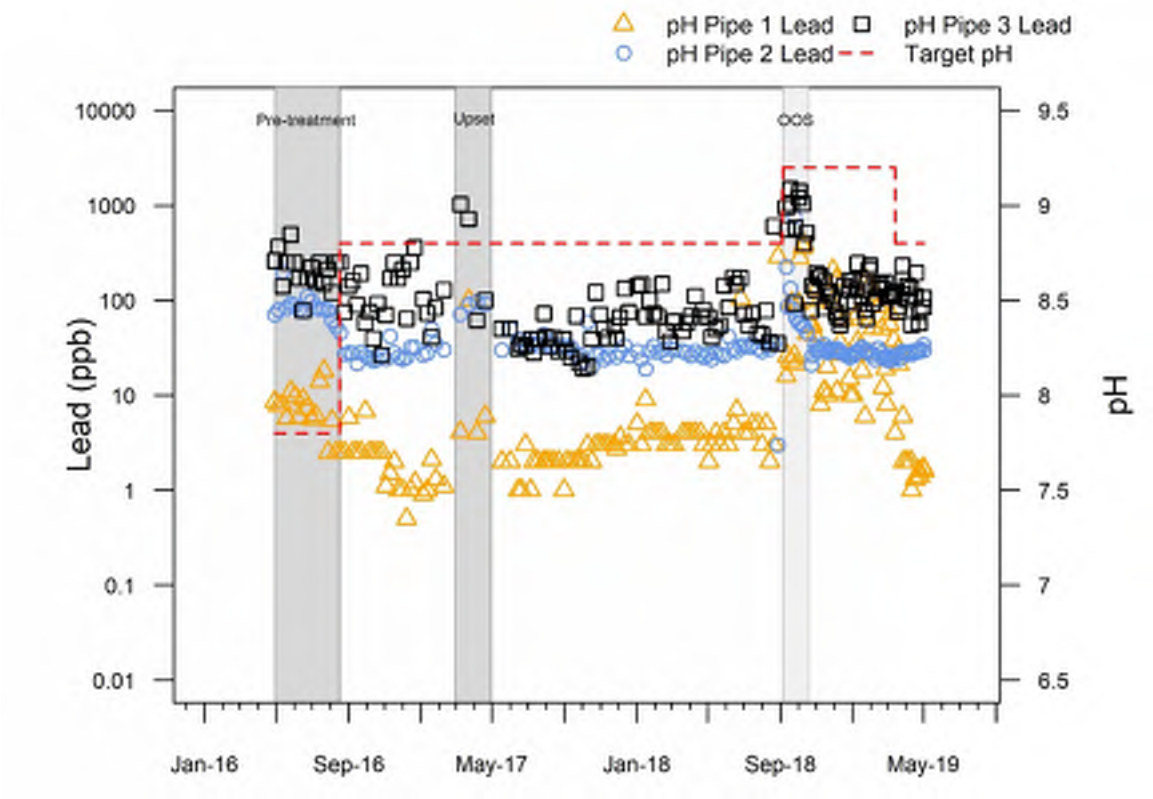


Figure 11: Moffat pH Rack - Lead

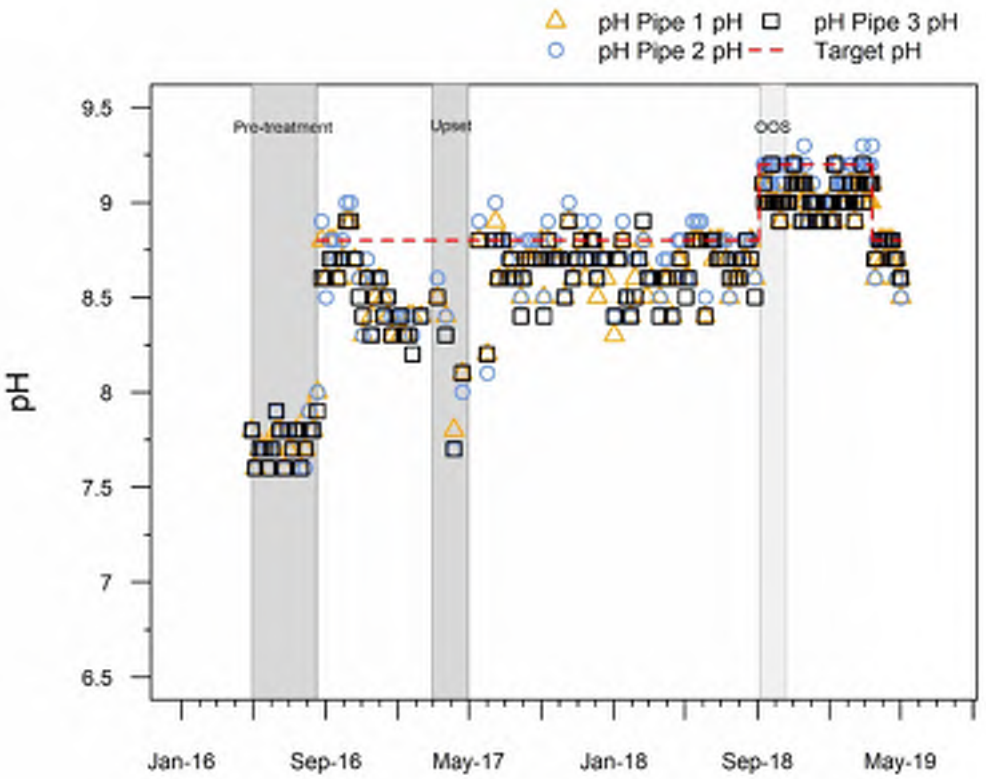


Figure 12: Moffat pH Rack – pH Measured Post-Stagnation

Box plots of lead release under the different treatment conditions are shown in Figure 13 through Figure 24. The quartiles are shown with horizontal lines; the mean is shown with a diamond. The whiskers represent the 5th and 95th percentile. Dots outside the whiskers show individual data points outside this range. The counts for each range of data are shown below the box. All plots use the same y-axis range of 0 to 250 µg/L. Because of high measurements, not all data are shown. Each treatment condition has a matching control box plot. All control box plots use the same data, but the data are split across the different boxes to match the times at which the corresponding treatment conditions were varied. For example, Figure 13 shows the control rack behavior when the OP rack was at 3 mg/L, 2 mg/L, and 1 mg/L.

The box plots are also divided by individual pipe, each shown in a separate pane, which shows the variability in lead release between different pipes under the same conditions. For example, as shown in Figure 14, OP Pipe 1 has always had low lead release in comparison to the other pipes in the pilot, even during pretreatment. Therefore, plotting individual pipes allows comparison of treatment conditions to pretreatment lead release, with each treatment condition shown as a separate box plot. The matching control plots are shown to account for the variability in pilot feed water affecting lead release.

The upset periods were removed from the calculations for all box plots because target operational conditions were not maintained.

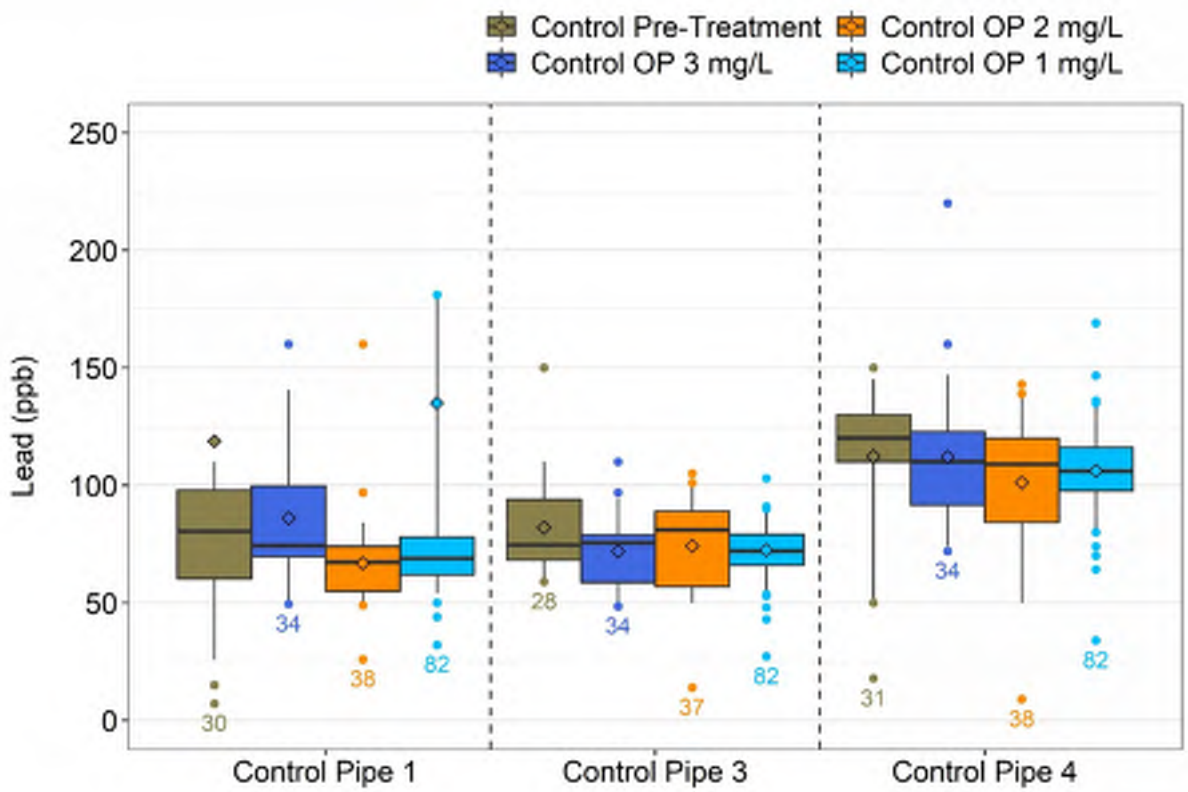


Figure 13: Marston Control Rack - Matching Orthophosphate Operation

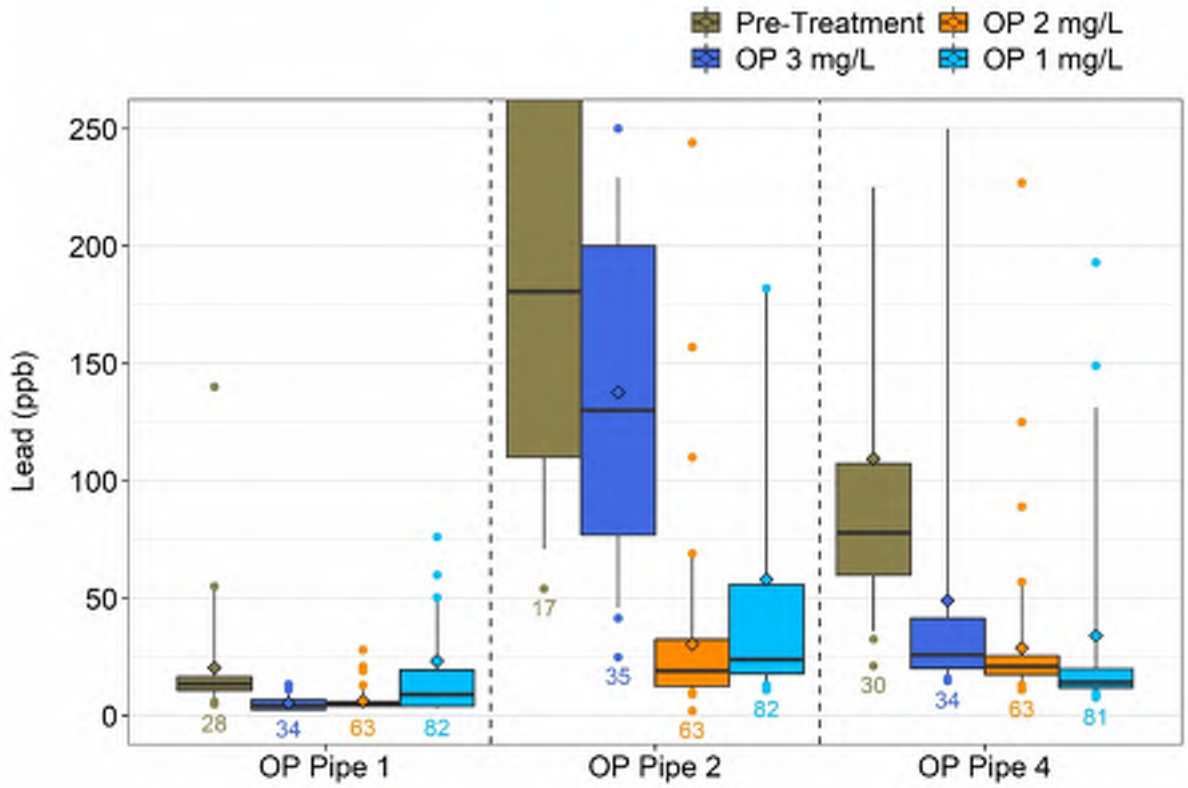


Figure 14: Marston Orthophosphate Doses Tested

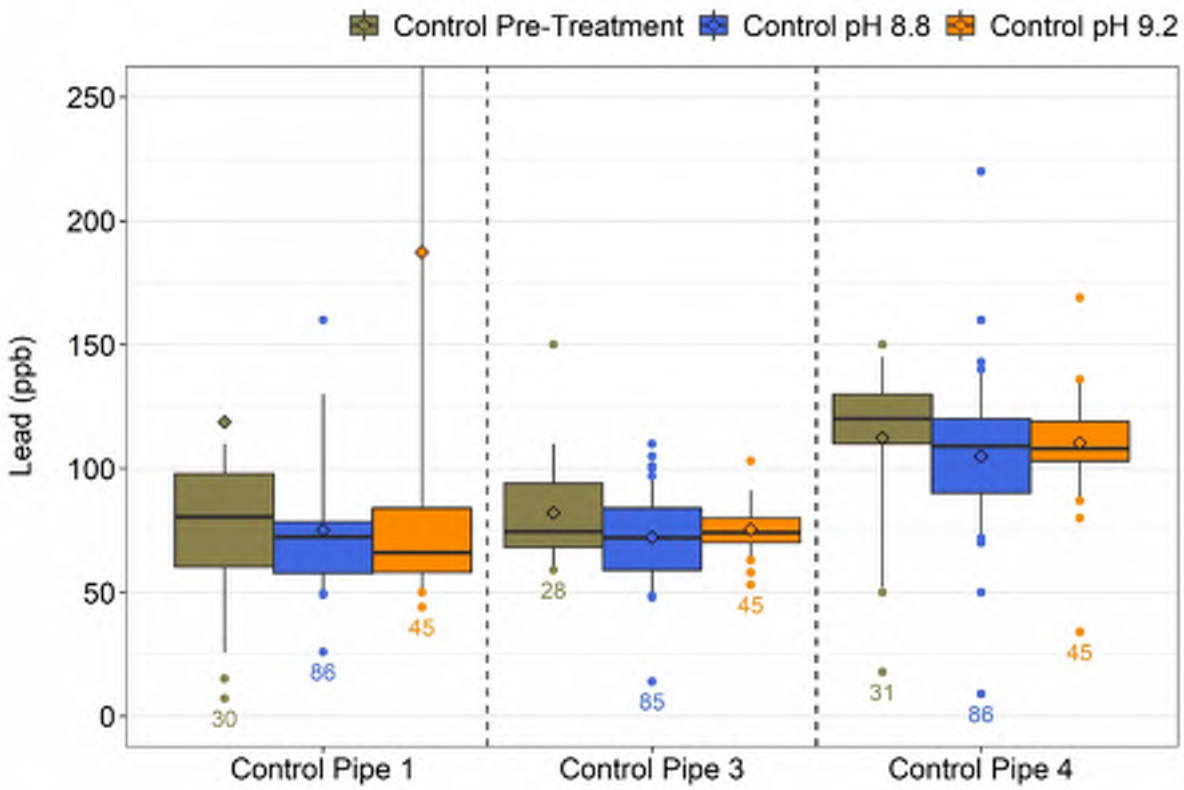


Figure 15: Marston Control Rack - Matching pH Rack Operation

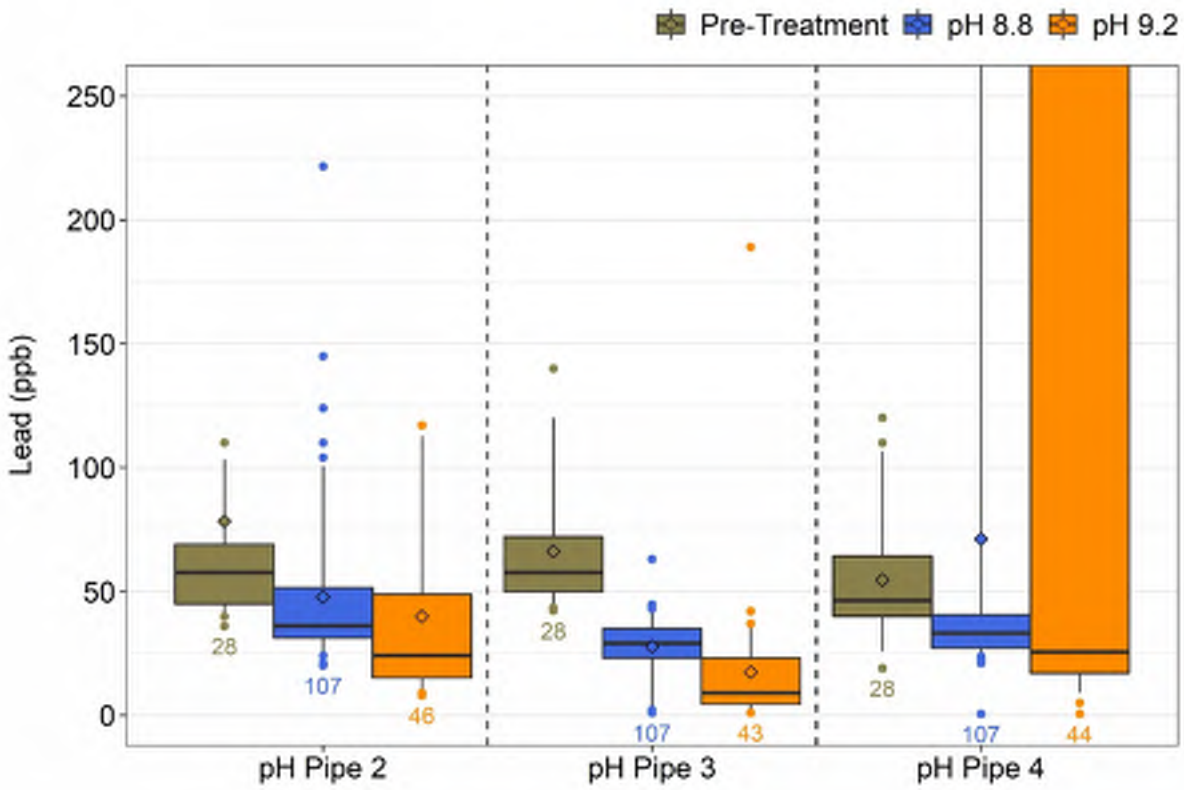


Figure 16: Marston pH Rack Conditions Tested

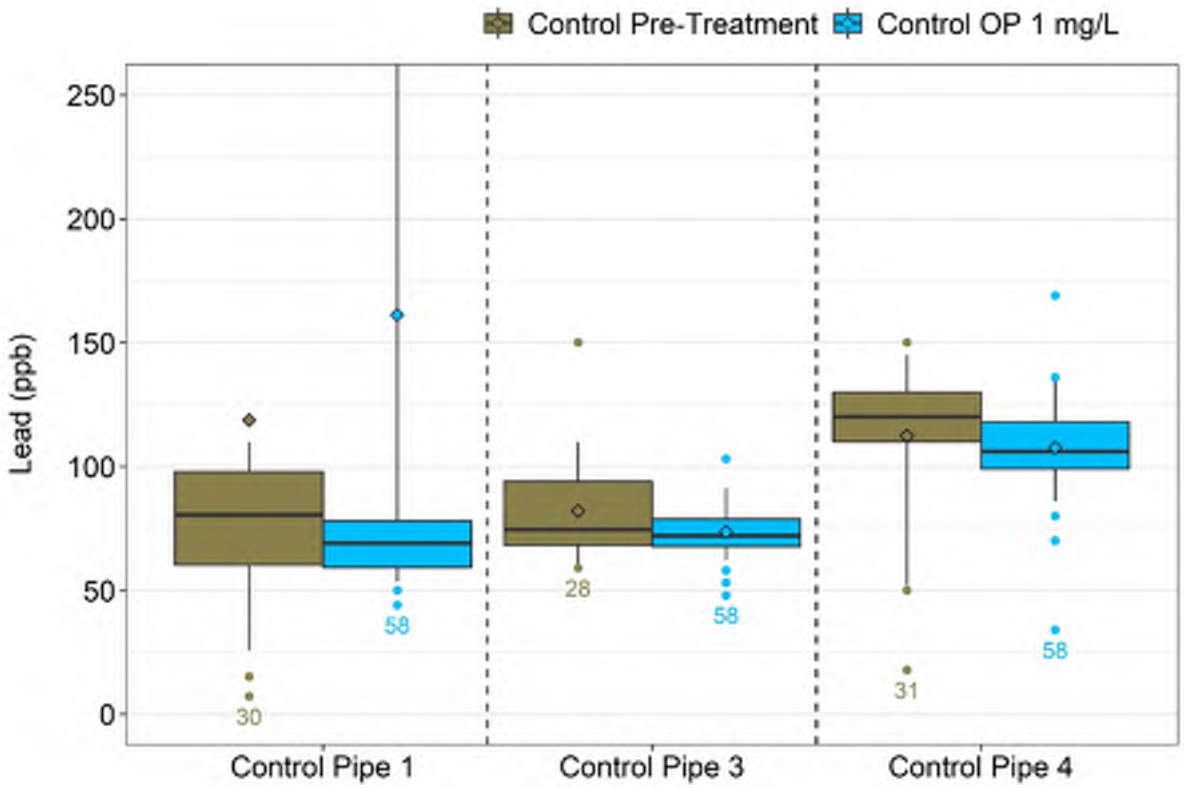


Figure 17: Marston Control Rack - Matching (Si) OP Rack Operation

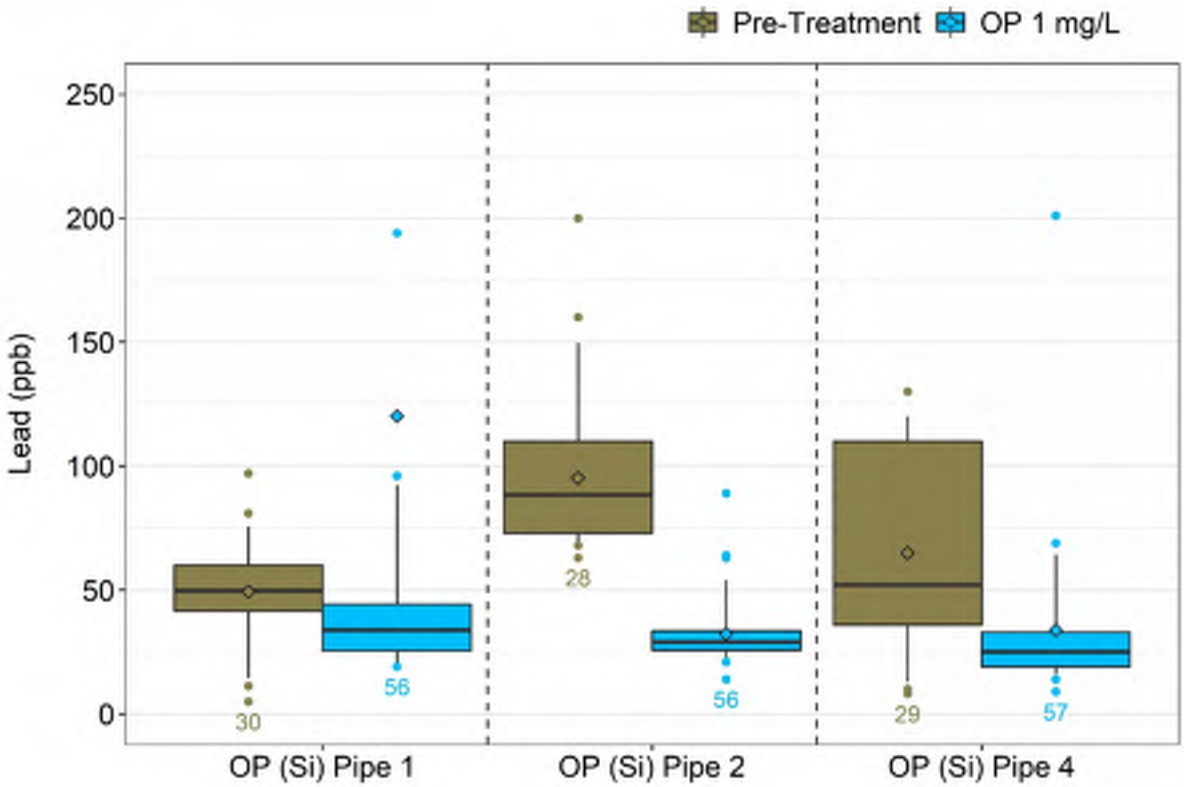


Figure 18: Marston (Si) Orthophosphate Rack Testing Going Directly to a Low Dose

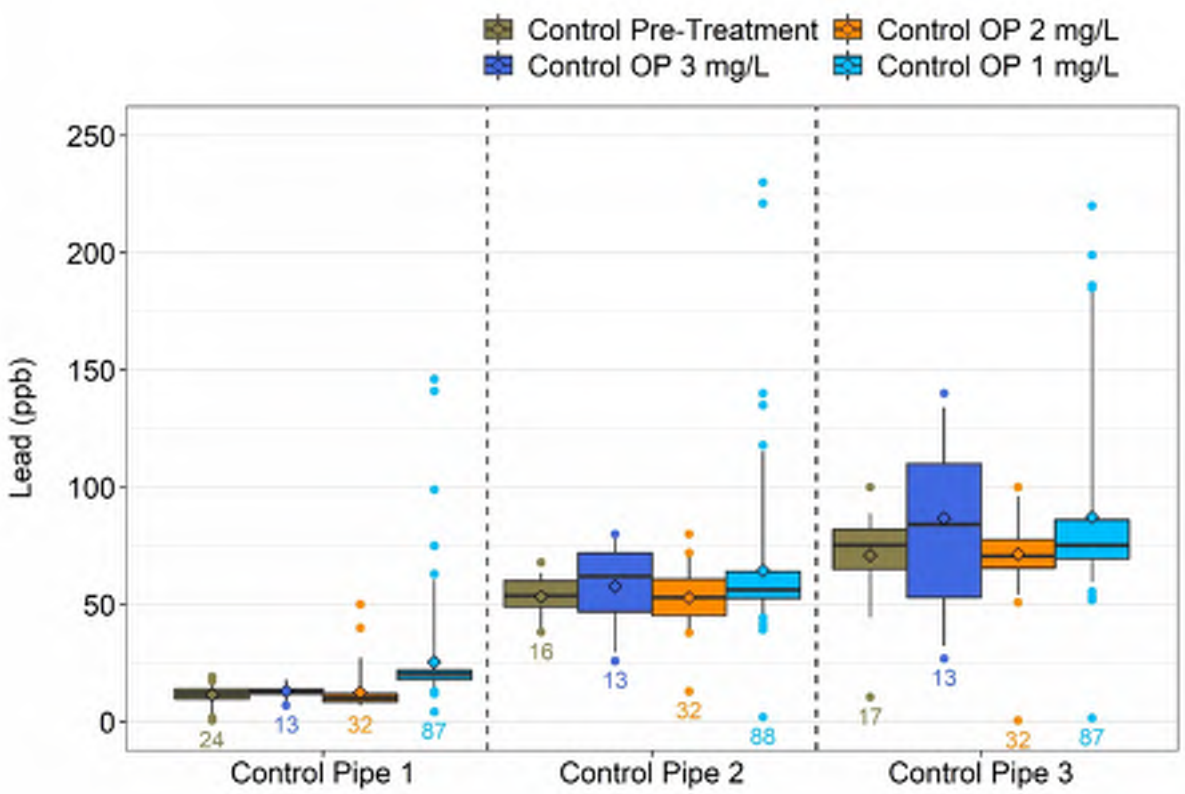


Figure 19: Moffat Control Rack - Matching Orthophosphate Rack Conditions

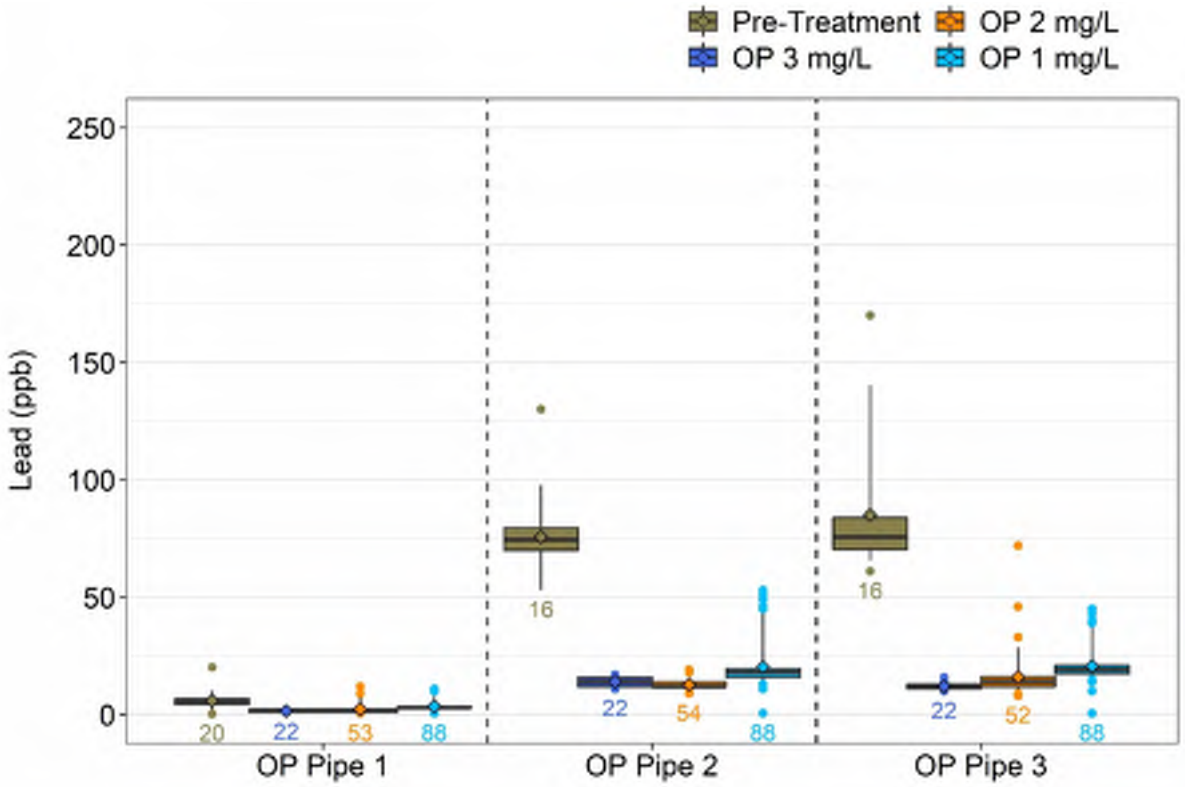


Figure 20: Moffat Orthophosphate Rack Doses Tested

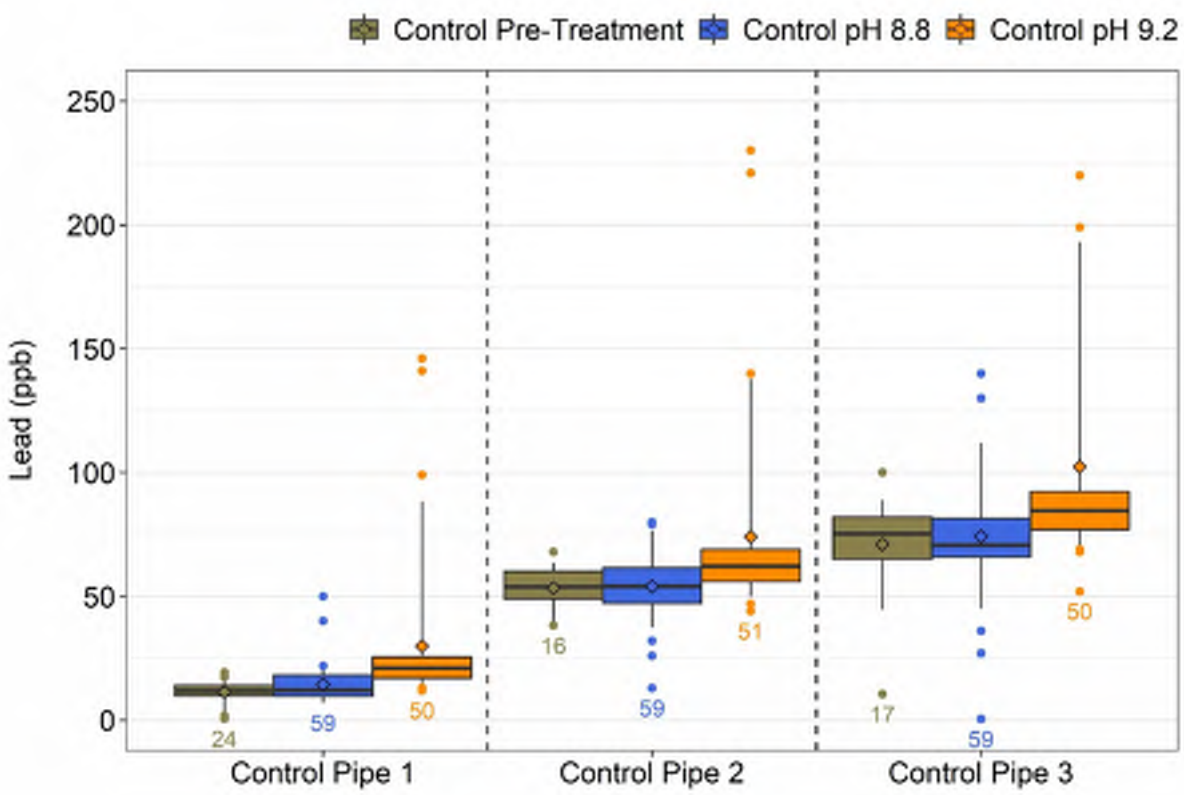


Figure 21: Moffat Control Rack - Matching pH Rack Conditions

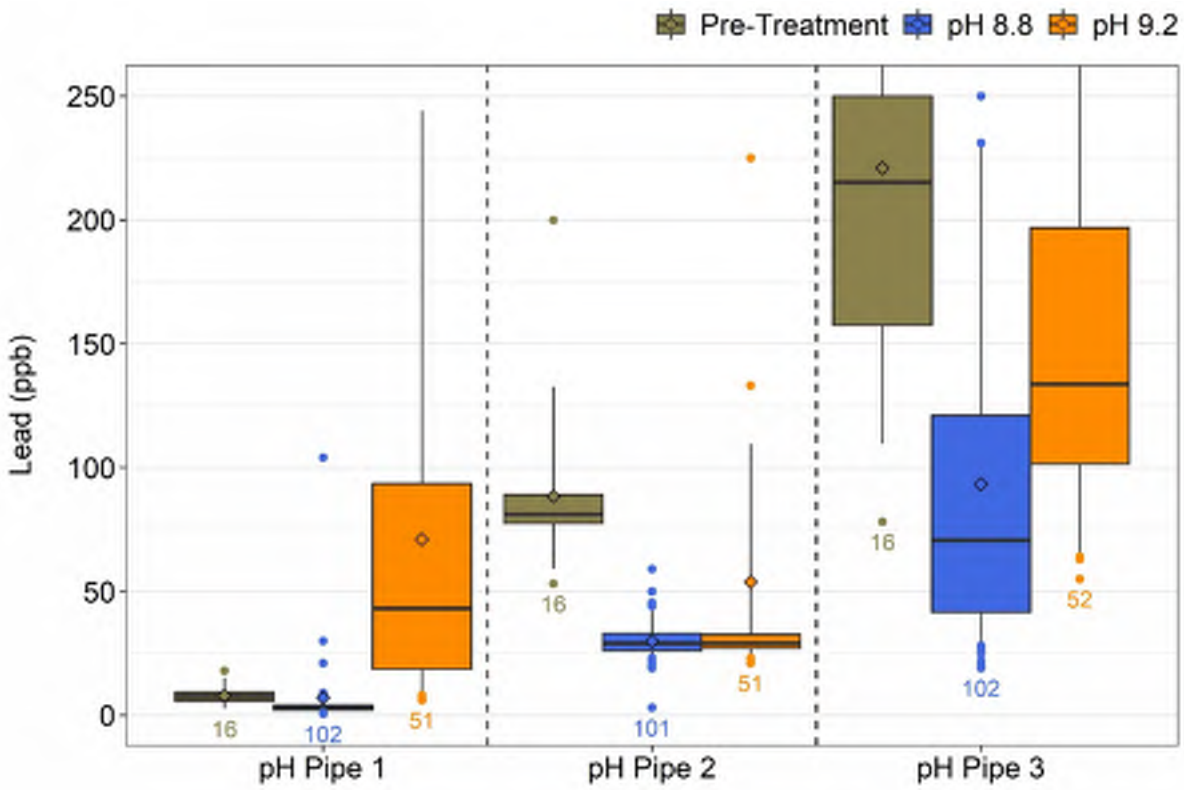


Figure 22: Moffat pH Rack Conditions Tested

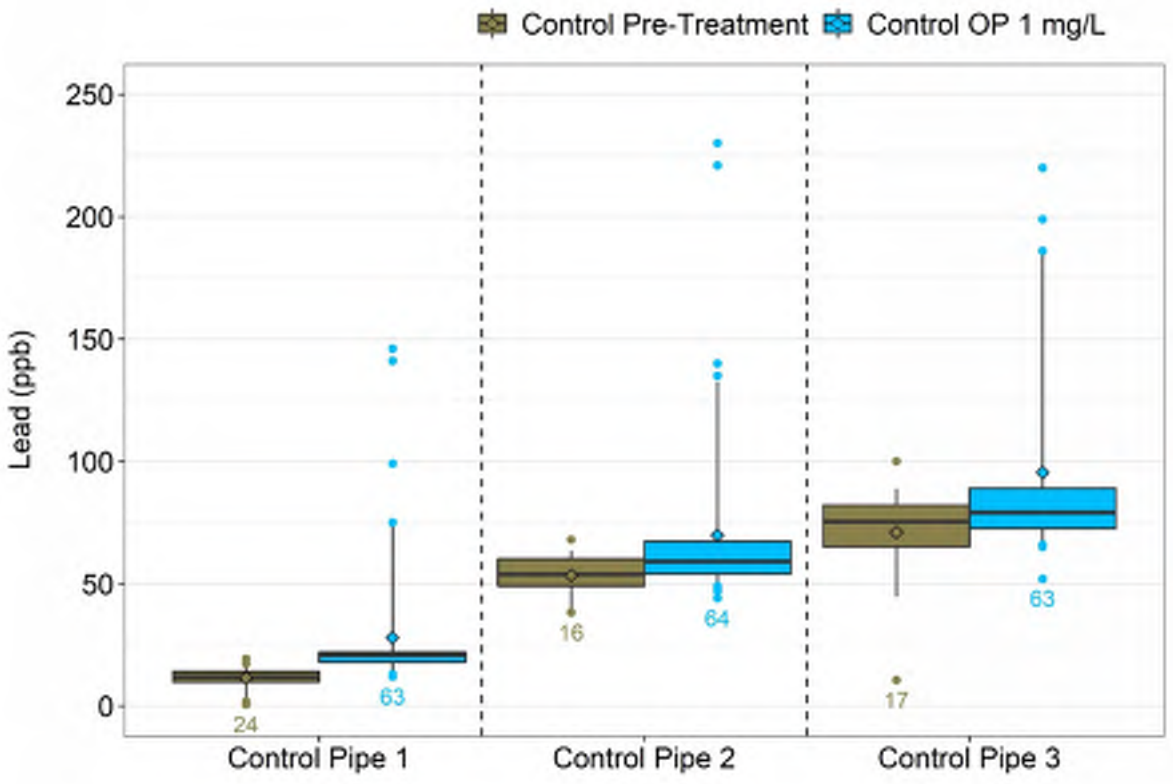


Figure 23: Moffat Control Rack - Matching (Si) Orthophosphate Rack Conditions

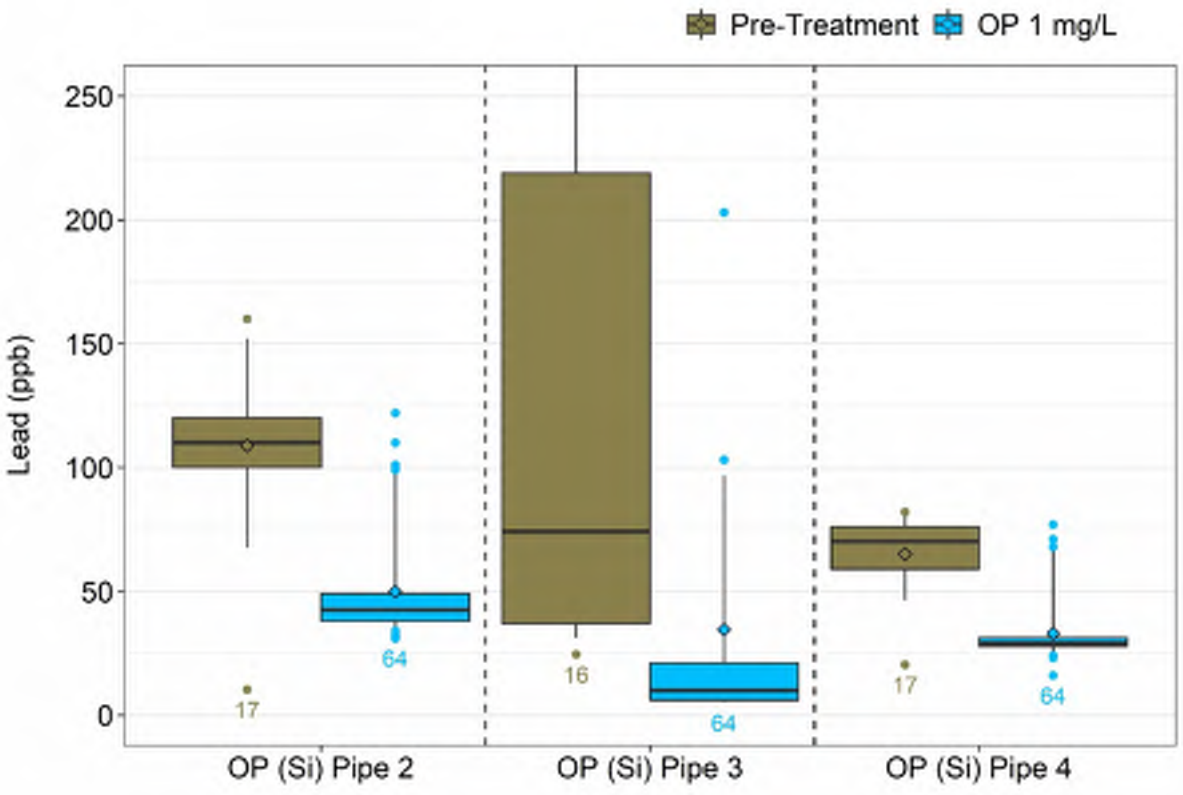


Figure 24: Moffat (Si) Orthophosphate Rack Testing Going Directly to a Low Dose

APPENDIX II.C - REVIEW OF LEAD CONCENTRATION OUTLIERS

September 2019

DENVER WATER

Appendix II.C

Review of Lead Concentration Outliers

Background:

Data from Denver Water's Lead and Copper Rule monitoring efforts at Tier 1 properties with copper piping and lead solder include some results above the action level of 15 ppb. Results from profile testing using a sequential testing protocol[1] confirmed that properties with copper piping and lead solder typically have lead measured up to 5 ppb in the first 1 L sample, followed by lead measured near the method detection limit in subsequent sample volumes. Please refer to Appendix III.E.1 for a detailed discussion of profile testing at copper piping with lead solder homes compared with lead service lines.

Denver Water has an extensive database of results for lead measured from properties with copper piping with lead solder. The purpose of this technical memorandum is to analyze the results from LCR compliance sampling and customer requested sampling to better understand typical lead release at properties identified as copper piping with lead solder homes. Of interest is the frequency with which outliers occur (i.e., when higher than expected lead concentrations are measured) and whether a higher lead concentration is indicative of a source of lead in addition to lead solder. If the source of the lead levels can be better understood, recommendations for follow up sampling and potential mitigation can be identified.

Methods:

Approximately 2,300 samples were included in the analysis of potential outliers:

- LCR compliance sampling at Tier I properties with copper piping and lead solder:
    - 1,184 samples were collected from 1997 through the first half of 2019
    - As these are LCR sites, many properties were sampled repeatedly over this time
    - A 1 L sample was collected after a minimum stagnation period of 6 hours
- Customer requested sampling:
    - All customer requested samples collected from 2016 through the first half of 2019 were reviewed against the Lead Service Line Inventory (see Appendix III.B.2) to identify likely properties with copper piping with lead solder; properties were selected based on the year that the property was constructed (1,196 have a build date from 1952 to 1987)
    - The 3-bottle test was used, with samples collected after a minimum stagnation period of six hours

As the customer is responsible for sample collection, the duration of the stagnation period used before the sample is collected can vary. For this analysis a stagnation period of six hours is assumed.

[1] See Appendix III.E.1. More than 20 aliquots of varying sample volume (125 mL to 1 L) were collected from 16 homes.

The Denver Water lab is certified by the Colorado Department of Public Health and Environment to test lead. All samples for lead are measured using method EPA 200.8. To perform the analysis, half the method detection limit was used for samples where the lead concentration was reported below the method detection limit (i.e., 50% of 1 ppb or 0.5 ppb).

The use of control charts is a commonly used to identify potential outliers in a given dataset. The assumption is that the data follow the behavior of a normally distributed dataset. Results can be used to identify results outside three standard deviations as outliers. Denver Water's LCR compliance data were analyzed using a control chart to identify an outlier result based on exceeding the sum of the average and 1 standard deviation, providing a more conservative approach than the customary three standard deviations.

Both data sets were reviewed to identify properties where:

- Lead was measured greater than 15 ppb in at least one sample at a given property; for customer requested sampling, data for the first bottle (or first draw) were used.
- Lead was measured greater than 5 ppb in at least five samples, where lead was measured on more than one sampling date; this applies mostly to the LCR data set as there were very few sites included in the customer requested sampling for which samples were obtained on multiple sampling.

The sub-set of data were subsequently reviewed for the:

- Build date, to identify homes built from 1951 to 1987.
- Tap date, to identify properties connected to a water main from 1951 to 1987.
- Original water main installation year.
- Additional data on service line material type (original material or an indication that the service line was replaced).

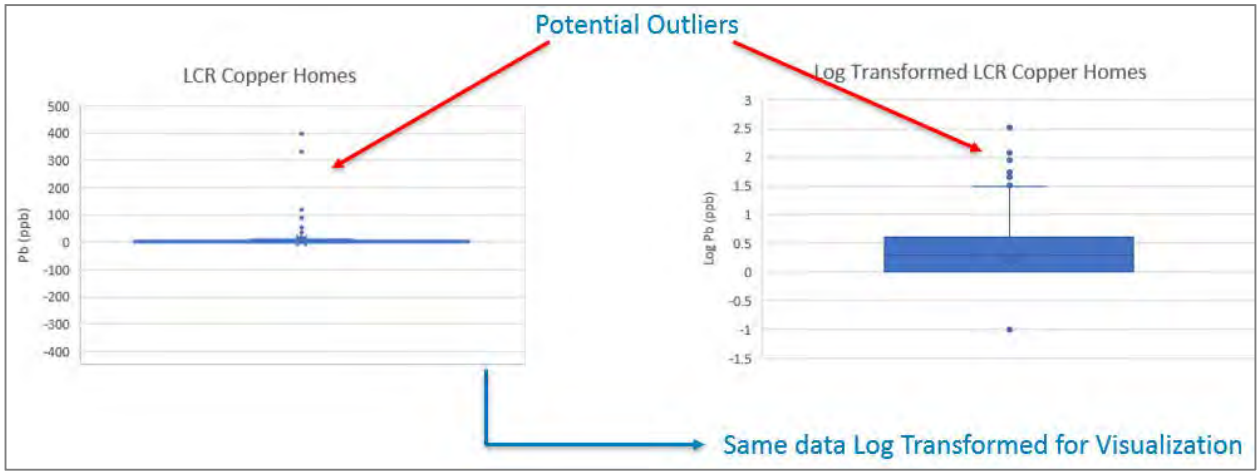
Analysis of LCR Compliance Samples from 1997 to 2019, Copper Piping with Lead Solder

The variability observed in the data available from LCR compliance sampling is shown in Figure 1, with a logarithmic scale used on the vertical axis on the right to exaggerate the details. Of the 1,184 Tier I copper piping with lead solder samples analyzed, 2.5 percent, or 25 samples were above the LCR action level of 15 ppb with the highest concentration reported was 400 ppb.[2] The average was calculated as 4.3 ppb and the standard deviation was 16.6 ppb.

Additional sampling occurred at several of these homes both before and after the reported testing, with lead level results reporting lower, particularly with some of the very high sample results that were originally reported.

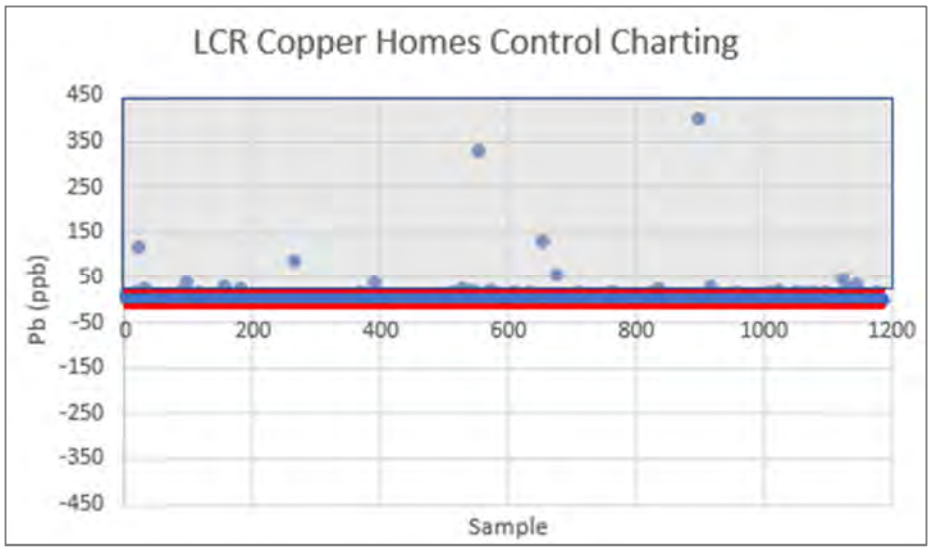
[2] This property was re-sampled and follow-up investigations and it was determined that the original sample had been collected from a tap that had been used for more than six months. Therefore, this outlier can be attributed to sample collection error. With one exception, lead was measured at less than 5 ppb in all other samples collected from 2013 through 2019.

Figure 1: Variability of LCR Compliance Samples Tier 1 Copper Piping with Lead Solder (1997 – 2019)



The same data set is presented using a control chart in Figure 2, based on the application of Gussain Curves which are usually set at ± 3 standard deviations from the mean. However, in this analysis, the control chart was prepared using ± 1 standard deviation.

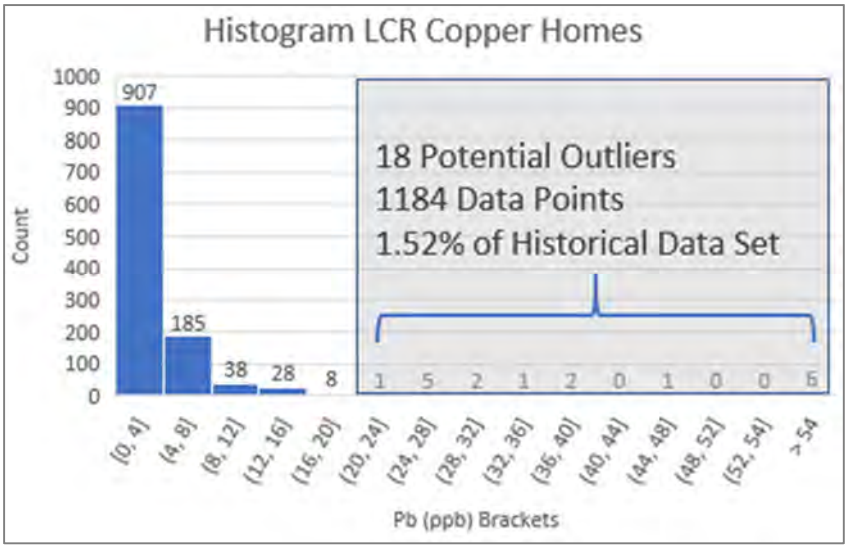
Figure 2: Control Chart Applied to LCR Compliance Samples Tier 1 Copper Piping with Lead Solder (1997 – 2019)



Note: The red lines represent the upper and lower control limits, based on ± 1 standard deviation.

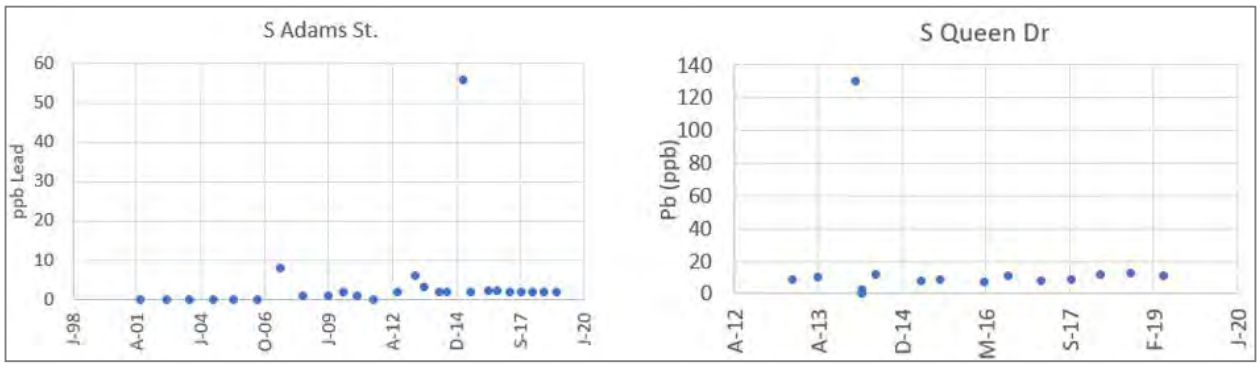
Using ± 1 standard deviation to define the upper and lower control limits is interpreted to mean that the chance is 68.3 out of 100 that the random uncertainty of any single measurement is no more than 1 standard deviation. For the 1997 to 2019 LCR compliance data, the upper control limit is 20.8 ppb, and any result measured greater than this is considered an outlier. Using this definition of outlier, the LCR compliance samples include 18 results greater than 20.8 ppb, or about 1.5% of the dataset. The LCR compliance samples are presented as a histogram in Figure 3 and reveal that the data do not follow a normal distribution (see Figure 3).

Figure 3: Histogram of LCR Compliance Samples Tier 1 Copper Piping with Lead Solder (1997 – 2019)



An example comparing two sites, each with at least one result for which lead was measured above 20 ppb, is presented in Figure 4 to show how the results were interpreted and the proposed follow-up steps to confirm the source of lead at the property. In the example from South Adams Street (shown on the left of Figure 4), only one result out of 26 samples was measured above 20 ppb and all but two of the remaining samples were measured below 5 ppb. The result from this site is considered an outlier, the property appears to be correctly identified as having copper piping with lead solder, and therefore not follow-up action is recommended.

Figure 4: Interpreting Data with at Least One Potential Outlier (Concentration > 20 ppb)

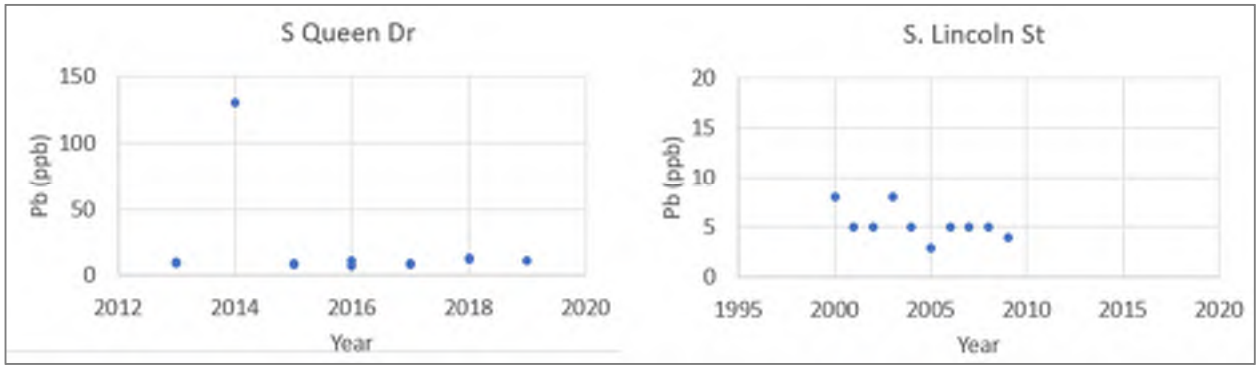


In contrast, the results for the South Queen Drive property shown on the right of Figure 4 prompted a recommendation for additional water quality sampling and field investigations to better understand the source of lead at this property. With one sample measured above 120 ppb, 12 of the 15 samples shown on the right of Figure 4 had lead measured between 7 and 13 ppb.

An example comparing two sites, each which have at least five results greater than 5 ppb, is presented in Figure 5 to show how the results were interpreted and the proposed follow-up steps to confirm the source of lead at the property. For the South Queen Drive results (on the left in Figure 5A), one outlier was measured but lead above 5 ppb was also measured on at least five occasions. In the case of the

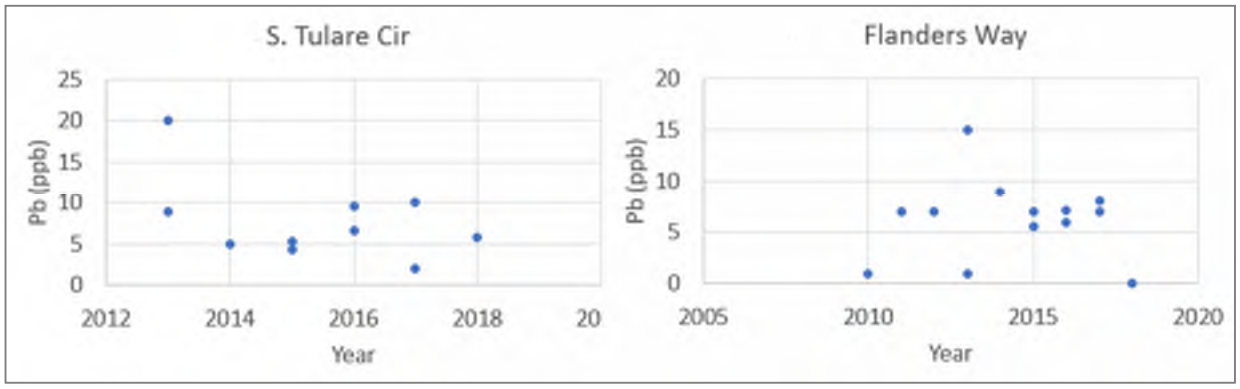
South Lincoln Street property shown in Figure 5A, multiple samples above 5 ppb, were measured. The presence or extent of lead at either of these properties cannot be confirmed from the available data and therefore additional water quality sampling and field investigations are recommended at both properties to better understand the source of lead.

Figure 5A: Interpreting Data with Persistent Lead (Concentration ≥ 5 ppb in at least Five Results)



Two additional sites with persistent lead release are provided as an example in Figure 5B. Persistent lead was measured at both properties and despite a build date of 1984, a source of lead in addition to solder is suspected at the Flanders Way property. Additional water quality sampling and field investigations are recommended for both properties to better understand the source of lead.

Figure 5B: Interpreting Data with Persistent Lead (Concentration ≥ 5 ppb in at least Five Results



In summary, several of the samples collected, analyzed and submitted to CDPHE are suspected to be anomalies, as follow up sampling produced sampling results much lower than the reported sample. Other sites may have full or partial lead service lines given the tap date, home age or main installation year. Water quality testing and filed investigations (such as pot holing and/or visual inspections) are recommended to confirm the service material. While not clearly conclusive, further sampling may confirm that high lead levels at these homes are unusual and can be explained. The homes that had follow up sampling should be contacted to try and gain an understanding as to why the submitted sample yielded such high lead concentrations.

Analysis of Customer Requested Samples from 2016 to 2019, Copper Piping with Lead Solder

Data available from customer requested sampling were also reviewed for outliers and persistent lead release. It is noted that the samples included in this analysis were selected based on historical data

available to describe the characteristics of the property and visual or field investigations have not been performed to confirm the service line material type.

Of the 1,196 customer requested samples included in this review:

- 14 properties were identified for having lead measured that appeared to be an outlier or an indicator of persistent lead.
- Of the 14, 12 properties appeared to have a source of lead in addition to (or instead of) lead solder; additional water quality sampling and field investigations are recommended for these properties.

Analysis when the Two Datasets are Combined:

The results from sampling from both datasets were considered together to better understand the occurrence of outliers, based on all samples collected from customer requested sampling and a sub-set of the LCR compliance samples (2011 to 2019). Although Denver Water has data from LCR compliance sampling dating back to 1997 (1,184 samples), only results from samples collected since 2011 were included in the analysis (635 samples). Results from sampling prior to 2011 are considered less robust: Denver Water may have used different analytical methods with different detection limits, Denver Water's own procedures may have varied, and/or treatment objectives (and the resulting performance) at the three water treatment plants may have changed between 1997 and 2011.

From this, 40 properties were highlighted due to:

- outlier value > 15 ppb (LCR compliance data).
- at least five results ≥ 5 ppb at the same address (LCR compliance data).
- at least one draw from the 3-bottle test with lead > 5 ppb (customer requested data).

Of these 40 properties, 18 appeared to have a source of lead in addition to solder. This includes 6 out of the 26 LCR compliance sampling properties and 12 out of the 14 of the customer requested sampling properties.

Table 2: Outliers Analysis from Copper Piping with Lead Solder Properties

Sample Source	Number of Samples included in Analysis	Estimated Number of Outliers	Samples with Potential Lead Source in Addition to Solder
LCR Compliance Samples (2011 to 2019)	635 samples included in Tier I sampling (1983 to 1987)	26 (or 4.1%)	6* (or 1.0%)
Customer Requested Sampling (2016 to 2019)	1,196 total samples with a build date from 1951 to 1987	14 (or 1.2%)	12* (or 1.0%)
Total	1,831	40 (or 2.2%)	18* (or 1.0%)

* This number is included in the total number of outliers in the column to the left.

In general, both datasets are susceptible to outliers: some samples are true outliers, but some also appear to come from a property with a lead source other than lead solder. For these, additional water quality testing and/or field investigations are needed to confirm the source of lead at the property.

Discussion:

The LCR compliance sampling includes properties built from 1983 to 1987 in Tier 1 sampling to capture the impact of lead solder. However, all homes in the Denver Water service area built from 1952 to 1987 potentially have lead solder, unless updates were made to plumbing inside the home. An understanding of the typical release of lead from the 1983 to 1987 homes compared with all homes that potentially have lead solder (1952 to 1987) was evaluated. The results from this analysis was used as part of the equivalency test of the Lead Reduction Program compared with orthophosphate addition to drinking water for corrosion control.

The build date of all homes included in the Denver Water service area was reviewed based on decade of construction (see Table 3). The number of service connections built between 1983 and 1987 is relatively low, representing less than 5% of all connections in the Denver Water service area.

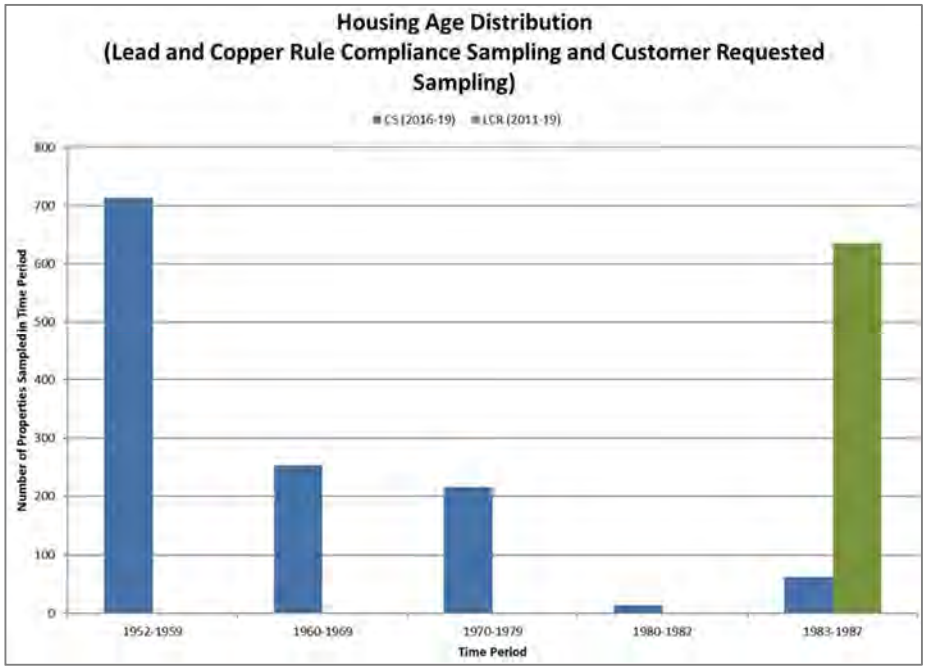
Table 3: Estimated Number of Service Lines by Housing Age, by Decade

Service Line Material Type	Estimated Build Date	Estimated Number of Service Lines
Lead Service Lines	≤ 1951	63,955
Copper Piping with Lead Solder	1952 - 1959	46,429
	1960 - 1969	37,699
	1970 - 1979	49,427
	1980 - 1982	11,961
	1983 - 1987	14,089
	Total 1952 - 1987	159,605
Non-Lead Service Line	≥ 1988	96,140

*Source: See Appendix III.B.2 and Tables 6, 8 and 9 in the Lead Reduction Program Plan.

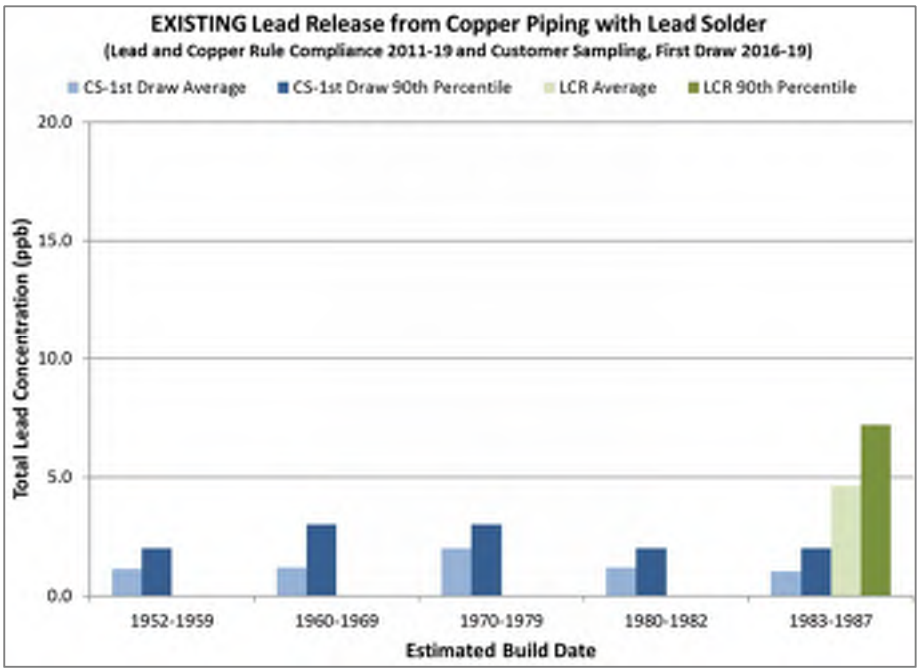
Water quality data from all properties identified as having copper with lead solder that are included in the LCR compliance dataset (collected 2011 to 2019) and customer requested sampling (2016 to 2019) dataset were reviewed as a function of the build date of the property. A summary of the number of properties included in this analysis by decade is shown in Figure 6, with a build date of 1983 to 1987 assumed for samples included in LCR compliance sampling.

Figure 6: Distribution of Available Water Quality Samples, by Decade



The analysis by decade of lead concentrations measured at homes with copper piping with lead solder are presented in Figure 7. Most results for lead concentration are relatively low and typically below 5 ppb, although higher lead release (8.0 ppb) is observed from homes constructed between 1983 and 1987. Although this group contributes less than 5% to the total housing stock in the Denver Water service area, the elevated lead that has been reported for the 1983 to 1987 properties warrants the further investigation of outliers to better understand the source of lead. If a property currently included in the 1983 to 1987 LCR compliance sampling set is found to have a lead service line it should be added to the list for replacement and a request to remove the property from the LCR compliance sampling set should be made to CDPHE.

Figure 7: Analysis of Lead Release from Copper Piping with Lead Solder with Existing Corrosion Treatment, by Decade



Recommendations:

There are several reasons why elevated lead is measured higher than would be expected at a property classified as having copper piping with lead solder, such as:

- Faucet material
- Incorrect sampling location and/or sample collection protocol by customer
- Contamination of sample in the field
- ICP-MS Matrix effects during analyses
- Inappropriate classification of property due to inconsistencies with build date and tap date

Additional water quality sampling and field investigations are recommended to better understand the source of lead and the service line material used, to allow the appropriate remediation strategy to be employed to reduce lead as measured at the tap. The choice of follow-up method for additional sampling (3-bottle test or sequential profile testing) and/or field investigations (visual, potholing, excavation) will depend on the availability of results from water quality sampling completed to date as well as historical information to characterize the property. Development of a standard operating procedure to capture potential follow-up steps is recommended.

APPENDIX III.A - OVERALL COMMUNICATIONS, OUTREACH AND EDUCATION PLAN

September 2019

DENVER WATER

APPENDIX III.A.1

OVERALL COMMUNICATIONS, OUTREACH & EDUCATION PLAN

Version 3.0: August 19, 2019

Presented by: Denver Water External Affairs

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EXECUTIVE SUMMARY

There is no lead in the water Denver Water sends to customers. But lead can get into water as it moves through lead-containing household plumbing and service lines. When it comes to lead in drinking water, no levels are considered safe. Therefore, the intent of the Lead Reduction Program is to ultimately replace customer lead service lines outside the home, while controlling/reducing lead exposure until the lead lines can be replaced and reducing lead release associated with lead solder inside a home's premise plumbing.

In 2012, Denver Water's routine testing of homes with known lead services lines and plumbing to comply with the federal Lead and Copper Rule had results that exceeded the action level for lead, prompting the utility to implement its largest public health education campaign and initiate follow-up action. Since 2012, Denver Water's ongoing lead campaign has involved sharing information with customers, stakeholders and community leaders about lead service lines, solder and fittings, proactive lead identification and replacement programs, offering free water quality testing and informing customers about what they can do to minimize their lead exposure.

In addition to those actions, Denver Water conducted detailed studies and analyses to evaluate corrosion control treatment methods to reduce lead exposure for customers with lead service lines or plumbing. In 2018, CDPHE designated orthophosphate as the Optimal Corrosion Control Treatment, or OCCT, for reducing lead exposure in homes with lead service lines or plumbing as required per the Safe Drinking Water Act. Denver Water requested an Environmental Protection Agency variance from this decision in order to implement a multipart Lead Reduction Program designed to maximize public health for customers while minimizing impacts to the environment. Both options will benefit public health by improving water quality and protection from lead. Also, in 2018, Denver Water and several parties (including Denver Water and CDPHE) entered into a collaborative agreement to address lead via an ongoing technical and stakeholder (public) workgroup process. Specifically, this group is working toward long-range regional solutions that protect public health and the environment per the Safe Drinking Water Act and the Clean Water Act, while additionally minimizing impacts to water supplies, wastewater treatment plants and watersheds.

Communications, outreach and education is a critical foundation for successful implementation of the LRP. Denver Water will continue to communicate proactively and transparently to help define relevant information for customers and provide a foundation for a well-informed public dialogue.

CURRENT AND ONGOING ACTIVITIES

Delivering safe water to 1.4 million people in the metro area is Denver Water's most important responsibility, and the utility long ago adopted a proactive approach that includes adapting its ongoing communications, operations and monitoring efforts as science and regulations have evolved. When it comes to lead in drinking water, no levels are considered safe.

The utility has tested water from inside customer homes with known lead service lines or lead solder once a year since 1992, per the EPA's Lead and Copper Rule. Information about lead is included as part of the sample collection process. In 2012, Denver Water's routine testing turned up results that exceeded the Action Level for lead, prompting the utility to implement its largest public health education campaign and initiate follow-up action, which included testing two times a year.

Since 2012, Denver Water's ongoing lead campaign has involved sharing information with customers, stakeholders and community leaders about lead service lines, solder and fittings, proactive lead identification and replacement programs, and what customers can do to minimize their lead exposure. The utility has used a variety of strategies and tactics, including direct mailings to customers, bill inserts, sharing information at community gatherings, meeting annually with elected officials and using traditional and social media for mass communications and engagement on the issue.

Denver Water communications, outreach and educations efforts include free water quality testing for customers who want to know if the water from their taps contains lead. Information about the testing program, as well as general issues surrounding lead, is included on Denver Water's website, in bill inserts, on social media, in presentations to groups touring Denver Water's facilities, and is the focus for discussions at Denver Water's water trailer, which supports numerous neighborhood events throughout the metro area. Denver Water also has a youth education program that reaches thousands of local families and Denver-area youth by directly engaging with schools in Denver Water's service area every year.

Denver Water has tested more than 15,000 samples of water from schools within its service area for lead and are working with the school districts on their remediation efforts. Starting in 2016, Denver Water partnered with Denver Public Schools and conducted multiple rounds of sampling and testing, developed strategies to remediate different sources of lead (plumbing, faucets, water fountains), and replaced the only two lead service lines remaining at their schools. Results from testing were posted on the Denver Public Schools website, along with the description and timeline of the school district's remediation efforts.

Additional coordination efforts with Denver Public Schools included developing sampling procedures adapted from EPA's 3Ts (Training, Testing, and Taking Action) tool kit, as well as communications and signage, which were then offered to other utilities in the country. Denver Water performed a single round of testing for Littleton Public Schools and helped with the communications and signage to parents and teachers. Douglas County Schools, Clayton Early Learning, and Children's Colorado KidStreet were three additional partnerships that included sample testing, communications and other efforts on a much smaller scale. The procedures, signage examples, and other protocols were provided to CDPHE and other utilities and schools both in Colorado (Loveland, Byers, Thompson School District and Colorado Springs) and elsewhere in the United States (Maryland and New York).

Denver Water has adapted its information campaign as technology has evolved. As the use of social media has increased in the community, Denver Water has augmented its ongoing

communications efforts to include new platforms and strategies, including using its own Facebook and Twitter accounts to share information and call customers to action.

For example, in fall 2018, Denver Water's community relations staff posted an informational message about lead on Nextdoor, the neighborhood social media platform. The message included links to additional information on Denver Water's website and TAP news site. Since then, that Nextdoor post has garnered more than 15,000 views and continues to gather comments, indicating customers are reading and reacting to the information. Denver Water also highlighted the issue of lead in plumbing in a Facebook live interview in November 2018 via a partnership with 9Health, a highly respected local nonprofit group. The segment to date has received more than 7,300 views.

Moving forward, Denver Water will deploy tactics the utility has used successfully for years, and adapt as new strategies emerge, to communicate with people, families, neighborhoods and communities in Denver Water's service area. Tools and tactics include direct mail notification letters and postcards, website postings, video instructions, traditional and social media outreach and engagement, news sites stories, videos and infographics and advertisements. Outreach and engagement will include ongoing dialogue with diverse community groups, community members, as well as local and state government officials through a wide variety of variety of stakeholder engagement activities, such as town hall meetings, neighborhood meetings, community events and presentations, small group and one on one meetings, etc.

GOALS, OBJECTIVES, STRATEGIES AND TACTICS

Phase I: Pre-Variance (June 2019–October 2019)

Detailed communications, outreach and education plans for the pre-variance phase laid the foundation for the development of future communications, outreach and education plans. EPA, CDPHE and Denver Water agreed on goals and objectives for this phase. The group has also finalized key messages and a commonly asked questions document to serve as the foundation for communication materials.

Goal(s)

Denver Water, CDPHE and EPA agree on the benefits of carrying out education and outreach prior to the OCCT variance decision. More specifically, the agencies will:

- Educate, engage and seek input/feedback from residents, customers, local public health agencies, local government stakeholders and other targeted audiences about ways Denver Water could address reducing lead exposure (OCCT designation and variance alternative).
- Develop a framework that will create a shared understanding of lead education and reduction efforts to help ensure consistent information is being shared and distributed among stakeholders and the broader community.

Objectives

- Develop outreach strategies and tactics to educate, engage and seek feedback from target audiences. Educate residents on the following:
    - A historical overview leading up to the 2012 exceedance.
    - The Lead and Copper Rule, 2012 exceedance and Denver Water programs currently in place.
    - CDPHE's March 2018 decision regarding OCCT and subsequent Denver Water activities.
    - Clear communication on the impacts of lead exposure and what can be done to lower risk in the short-term.
    - Denver Water's Lead Reduction Program proposal, study plan and impacts to residents.
    - Milestones timeline for addressing the problem.
    - Use of filters through the Filter Pilot.
- Engage and seek input and feedback on the following one of two paths forward to address lead — state decision re: OCCT and variance.
    - Designation: Orthophosphate treatment spoken in layman's terms.
    - Alternative: Denver Water's Lead Reduction Program (accelerated lead service line replacement, filter program).
- Gather input and feedback to be used in the following ways:
    - Inform CDPHE and EPA of public sentiment regarding the alternative path forward.
    - Inform Denver Water on methods to increase engagement and implementation of the Lead Reduction Program. In particular the Filter Pilot will begin to educate customers on and encourage filter use, gathering input and lessons learned to apply to the full-scale filter program.

Strategies

- Develop communications and outreach plan.
    - Target audience analysis which includes those listed in the table.
    - Key messaging points developed in tandem with CDPHE and EPA for any agency that comes into contact with the public.

    - Refine strategies as needed and identify tactics for communications and outreach.
    - Identify multicultural outreach services needed (documents, meetings, etc.).[1]
- Communications and education outreach for internal staff.
    - Determine audience(s).
    - Organizational communication.
    - Training for Denver Water Call Center, Customer Service Field, Water Quality, and Safety and Security staff.
    - Support documents and communication materials.
- Implement external communications, outreach and education.
    - Implement filter and potholing pilot programs.
    - Industry Day for contractors interested in bidding on project to proactively answer questions and ensure these individuals know where to direct inquiries they may receive.
        - Coordinate with various City and County of Denver departments, Council Members and Mayor's office to prepare their offices for inquiries.
- Initiate public outreach and input opportunities.
    - Detailed outreach plan incorporated into separate document.
    - Provide pilot study participants with feedback opportunities for participants to share their thoughts on the process and filter preferences.

Phase II: Post-Variance Stakeholder Outreach (October 2019–January 2034)

Goals

The overarching goals for communications will be to scale up education and outreach efforts to achieve the following:

[1] Denver Water is using multiple sources of information to identify language and cultural needs for communications and translation services. Those include the federal interagency Limited English Proficiency webpage, CDPHE Community Health Equity Online Map and Denver Public Schools language information by neighborhood and zip code as well as information from peer cities. All documents include translation into Spanish and are available upon request into additional languages. Denver Water's call center and communications team have Spanish speakers.

- Inform customers and stakeholders of EPA's final decision.
- Raise awareness among all customers of the change and its impacts.
- Emphasize the outcome of implementation of the LRP, namely improved water quality and reduced risk of exposure to lead in drinking water for those with lead service lines and plumbing.
- Provide clear and consistent messaging and branding.

Objectives

Denver Water will further aim to:

- Build a platform for communitywide education and engagement regarding the Lead Reduction Program that includes communications and outreach, and gathers feedback to improve the program as it moves forward.
- Facilitate training for contractors, employees and vendors to educate these groups on where to direct customer inquiries and to support consistent communications on the program.
- Provide clear, accurate and timely information and messaging about the Lead Reduction Program to target audiences.

- Educate and engage with customers, residents, families and communities in order to create a common understanding of and instill confidence in the Lead Reduction Program.
- Support a specific communications, outreach and education program targeted at expectant and existing families with formula-fed infants/children up to age 2 living in homes with copper piping with lead solder built 1983-1987.
- Educate customers to encourage consistent, proper and ongoing filter usage.
    - Develop materials that easily demonstrate how to use the filters.
- Encourage customers to consider in-home plumbing updates and to flush the tap before drinking, cooking or preparing infant formula after prolonged periods during which water is not used, such as first thing in the morning or when returning home from work or school.

- Seek feedback from customers and others about the Lead Reduction Program to learn best practices and effective ways to implement program activities.
- Incorporate the Learning by Doing approach to improve outcomes during the life of the Lead Reduction Program.

Strategies

- Develop communications, outreach and education plans.
    - Target audience analysis including those listed in the table.
    - Key messaging points developed in tandem with CDPHE and EPA.
    - Identify translation services needed (e.g., documents, meetings).

    - Develop customized tools and techniques.[2]
- Communications, outreach and education for distributors.
    - Share customizable outreach materials to support distributors' customer communications.
- Communications, outreach and education for internal Denver Water staff.
    - Determine stakeholders.
    - Organizational communication.
    - Intranet.
    - Training for Call Center, Water Sales, Customer Service Field, Water Quality and Water Distribution staff.
    - Support and standard procedure documents.[3]
- Communications, outreach and education for contractors.
    - Training.[4]
    - Support documents and communication materials.
- Implement external communications, outreach and education.
    - Notification to all customers.
    - Targeted notifications to impacted customers (e.g., with known or suspected LSLs).
    - Target outreach campaign to impacted customers.

LEAD REDUCTION PROGRAM COMPONENTS

Each component requires clear goals, strategies, objectives and tactics specific to the component. For example, the strategies and tactics will differ for the Accelerated Lead Service Line Replacement and the Filter Program.

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[2] Tools and Techniques will be customized by target audiences to include direct mail notification letters and postcards, website postings, video instructions, traditional and social media outreach and engagement, news site stories, videos and infographics, advertisements, public engagement activities, such as town hall meetings and neighborhood meetings, as well as collaborative efforts with community organizers, Spanish-speaking community groups and government officials.

[3] Documents include FAQs about the program, fact sheets, brochures, website information, maps, customer surveys for filter program, newsletters, news site stories, videos and infographics and bill inserts.

[4] Denver Water will offer seminars for contractors for education on best practices for replacement, following our standards and post-replacement flushing protocol.

There are several phases for all program components phases, including development, initial launch and implementation and sustained program management that incorporates course corrections along the way (i.e., learning by doing). Components vary in the timing of when each phase begins or ends which has implications for overall messaging and engagement.

Lead Service Line Inventory (In progress)

Goal

Continuously update and publish the inventory of lead service lines throughout the service area to improve estimate of number of lines that require replacement.

Objectives

- Inform and educate customers about their service lines — ownership, material types and plumbing.
- Engage suburban distributors to assess lead service lines within Denver Water's integrated system.
- Work with municipalities to develop better records regarding service line material.

Strategies

- Develop communications plan.
    - Target audiences (e.g., customers in homes with known or suspected lead service lines, local governments, elected officials, public health agencies). As lead inventory is updated, follow up and messaging differs by group.
    - Key messaging points.
    - Translate documents.
    - Tools and techniques.
- Communications, outreach and education for distributors.
    - Share customizable outreach materials to support distributors' customer communications.
- Communications, outreach and education for internal Denver Water staff.
    - Determine stakeholders.
    - Organizational communication.
    - Training for Call Center, Water Sales, Customer Service Field, Water Quality and Water Distribution.
    - Support and standard procedure documents.
- Communications, outreach and education for contractors collecting inventory data.

    - Training on service line inspection and identification including photo documentation.
    - Support documents and communication materials.
- Implement external communications, outreach and education.
    - Direct mail marketing and outreach.
    - Utilize existing internal resources to engage with distributors.
    - Mapping tool to show:
        - Unknown, suspected and known lead service line locations.
        - Known copper service line locations.
    - Links to water quality test requests and filter program.
    - Website information about service line verification techniques.
    - Training resources for plumbers.
- Review, revise and reinforce components of communications, outreach and education.

Filter Program (October 2019)

Goal

Provide customers with known or suspected lead service lines with a filter and educational materials to encourage consistent, ongoing and proper use of filters.

Objectives

- Inform and educate customers about the Filter Program.
- Engage with customers with known or suspected lead service lines to ensure they receive a filter.
- Work with property owners, local housing authorities and tenants to share information and encourage filter use with residents in rental and multi-family properties.
- Encourage filter use for drinking, cooking and when preparing infant formula.
- Encourage changing the filter cartridge according to the manufacturer's instructions.
- Educate customers about flushing and provide flushing instructions to encourage flushing the tap before drinking, cooking or preparing infant formula after prolonged

periods during which water is not used, such as first thing in the morning or when returning home from work or school.

Strategies

- Develop communications plan.
    - Target audiences, including those listed in the table.
    - Key messaging points.
    - Translate documents.
    - Tools and techniques.
- Develop a specific communications, outreach and education program targeted at expectant and existing families with formula-fed infants/children up to age 2 living in homes with copper piping with lead solder built 1983-1987. The program will:
    - Work with area healthcare providers to deliver educational material.
    - Encourage people to run the cold water tap before drinking, cooking or preparing infant formula after long periods of stagnation (per recommendation from profiling studies).
    - Encourage households to get their water tested.
    - Provide free filters and replacement cartridges for households with formula-fed infant/children up to age 2, where lead level results exceed 3 ppb, per CDPHE guidance.
- Communications, outreach and education for distributors.
    - Share customizable outreach materials to support distributors' customer communications.
- Communications, outreach and education for internal staff.
    - Determine stakeholders.
    - Organizational communication.
    - Training for Call Center, Water Sales, Customer Service Field, Water Quality and Water Distribution.
    - Support and standard procedure documents.
- Communications, outreach and education for contractors performing filter distribution work to ensure they can direct customers to appropriate resources and channels to get questions answered.
    - Training on flushing, filter types, installation methods and replacement protocols.

    - Support documents and communication materials.
- Implement external communications, outreach and education.
    - Notify impacted residents.
    - Complete distribution (mail and door-to-door delivery).
    - Ensure implementation of registration, tracking (i.e., QR code).
    - Utilize local opportunities to engage with residents.
    - Implement feedback surveys on filter adoption.
    - Initiate replacement filter process including how-to videos and use verification.
    - Implement voucher program, if used, for replacement cartridges.
- Review, revise and reinforce components of communications, outreach and education plan.

Accelerated Lead Service Line Replacement Program (December 2019)

Goal

Replace customer-owned lead service lines and provide information on post-replacement flushing procedures.

Objectives

- Inform and educate customers about their service lines — ownership, material types and plumbing.
- Inform and educate customers about their premise plumbing – sources of lead, known potential health risks, and options or strategies to reduce the risk of lead exposure from premise plumbing.
- Obtain property-owner consent to replace their lead service line and share information with the owner and residents of the property on what to expect from service line replacement.
- Provide support and information on post-replacement filter use and flushing.
- Provide customers with appropriate education and resources on water quality testing and the results of testing following lead service line replacement.
- Offer Denver Water staff and contractors strategies to obtain the consent of property owners who have refused to have their lead service line replaced.

Strategies

Communications efforts for this part of the program will build on work done during the inventory and filter programs. As part of the replacement segment of the program, customers will be supplied educational materials on how to eliminate additional sources of lead from premise plumbing, will be provided with lead filter cartridges for an additional six months and be offered a water quality test following replacement of the LSL. This will include the best practices found for post-replacement flushing to minimize lead particles.

- Develop communications plan.
    - Target audiences, including those listed in the table.
    - Key messaging points.
    - Translation.
    - Tools and Techniques.
- Communications, outreach and education for distributors.
    - Share customizable outreach materials to support distributors' customer communications.
- Communications, outreach and education for internal staff.
    - Determine stakeholders.
    - Organizational communication.
    - Training for Call Center, Water Sales, Customer Service Field, Water Quality and Water Distribution.
    - Support and standard procedure documents.
- Communications, outreach and education for contractors.
    - Training on replacement standards and flushing guidelines.
    - Training to provide talking points and business cards to direct customer inquiries.
    - Support documents and communication materials.
- Implement external communications, outreach and education.
    - Develop messaging around lead service line identification and inventory process.
    - Before LSL replacement.
        - Website information, direct mail and educational materials.

        - Notify impacted property owners via letter in advance of construction.
        - Carry out appointments with property owners to discuss construction and gain property-owner consent for LSL replacement.
        - Notify within 24 hours of service shut-off for construction activities.
- During and post LSL replacement.
    - Encourage continued filter use through the first six months following LSL replacement.
    - Educate customers on flushing protocol.
    - Offer water quality testing for follow-up.
        - If water quality results remain above the action level, walk through educational materials with the customer on how to reduce lead in their premise plumbing and refer them to community organizations and funding programs that can assist with investigating and removing lead from their home.
- If LSL replacement is declined, provide customers with educational information and follow appropriate protocols for documentation, notification and escalation if needed.
- Review, revise and reinforce components of communications, outreach and education plan.

Corrosion Control Treatment (CCT)

Goal

Educate and inform customers about how Denver Water treats water to help minimize the release of lead into water from lead service lines and household plumbing and fixtures that contain lead.

Objectives

- Provide information on the Lead and Copper Rule and metal corrosion for general audiences.
- Inform and educate residential and commercial customers about the sources of lead in plumbing.
- Raise awareness among customers of the upcoming water treatment change and how it will or will not impact water quality, including little-to-no noticeable impacts to Denver Water customers, their plumbing and appliances; no anticipated changes to taste and odor; and specific considerations for chemistry dependent uses.

- Emphasize the outcome of increasing the pH — improved water quality and reduced risk of lead exposure in drinking water for customers with lead service lines and lead plumbing.
- Educate customers about flushing and provide flushing instructions to encourage flushing the tap before drinking, cooking or preparing infant formula after prolonged periods during which water is not used, such as first thing in the morning or when returning home from work or school.
- Provide clear and consistent messaging and branding.

Strategies

- Develop communications plan.
    - Target audiences, including those listed in the table.
    - Key messaging points.
    - Translation.
    - Tools and Techniques.
- Communications, outreach and education for distributors.
    - Share customizable outreach materials to support distributors' customer communications.
- Communications, outreach and education for internal staff.
    - Determine stakeholders.
    - Organizational communication.
    - Training for Call Center, Water Sales, Customer Service Field, Water Quality and Water Distribution.
    - Support and standard procedure documents.
- Communications, outreach and education for contractors.
    - Training on replacement standards and flushing guidelines.
    - Support documents and communication materials.

- Implement external communications, outreach and education.
    - Outreach to industrial commercial customers whose processes may be impacted by water chemistry changes.
    - Educate customers about flushing and provide flushing instructions for best water quality practices.

- Review, revise and reinforce components of communications, outreach and education plan.

APPENDICES

Appendix A: Pre-Variance Stakeholder Outreach

Goal

Denver Water, CDPHE and EPA agree on the benefits of carrying out education and outreach prior to the optimal corrosion control treatment variance decision. More specifically:

- The agencies will educate, engage and seek input/feedback from residents, customers, local public health agencies and providers, local government stakeholders, distributors and other targeted audiences about ways Denver Water could address reducing lead exposure (OCCT and variance paths).

Objectives

- Develop outreach strategies and tactics to educate, engage and seek feedback from target audiences. Educate audiences on the following:
    - The scope and history of the problem
        - The Lead and Copper Rule, 2012 exceedance and Denver Water programs currently in place.
        - CDPHE's March 2018 decision regarding OCCT and subsequent Denver Water activities.
    - Risk communication on the impacts of lead exposure and what can be done to lower risk in the short-term.
    - Denver Water's Lead Reduction Program proposal, study plan and impacts to residents.
    - Timeline for addressing the problem.
- Engage and seek input and feedback on the alternative path forward to address lead — state decision re: approval of the variance.
    - OCCT designation: Orthophosphate treatment spoken in layman's terms.
    - Alternative path (variance): Denver Water's Lead Reduction Program (accelerated lead service line removal, Filter Program).
- Gather input and feedback to be used in the following ways:
    - Inform CDPHE and EPA of public sentiment regarding the alternative path forward

- Inform Denver Water on methods to increase engagement and implementation of the Lead Reduction Program (e.g., filter program).

Introduction

EPA, CDPHE and Denver Water agree that seeking stakeholder feedback regarding the alternative path to reduce lead is critically important to the success of the communication, education and outreach efforts related to the full Lead Reduction Program.

This document outlines various components required to educate and gather feedback about the OCCT designation and alternative path to reduce lead exposure before a variance decision (October 2019) including:

- Timeline — provided below (updates happening frequently).
- Outreach framework including audiences — complete.
- Key messages — in a separate document.

Outreach Framework (Target audiences and timeline)

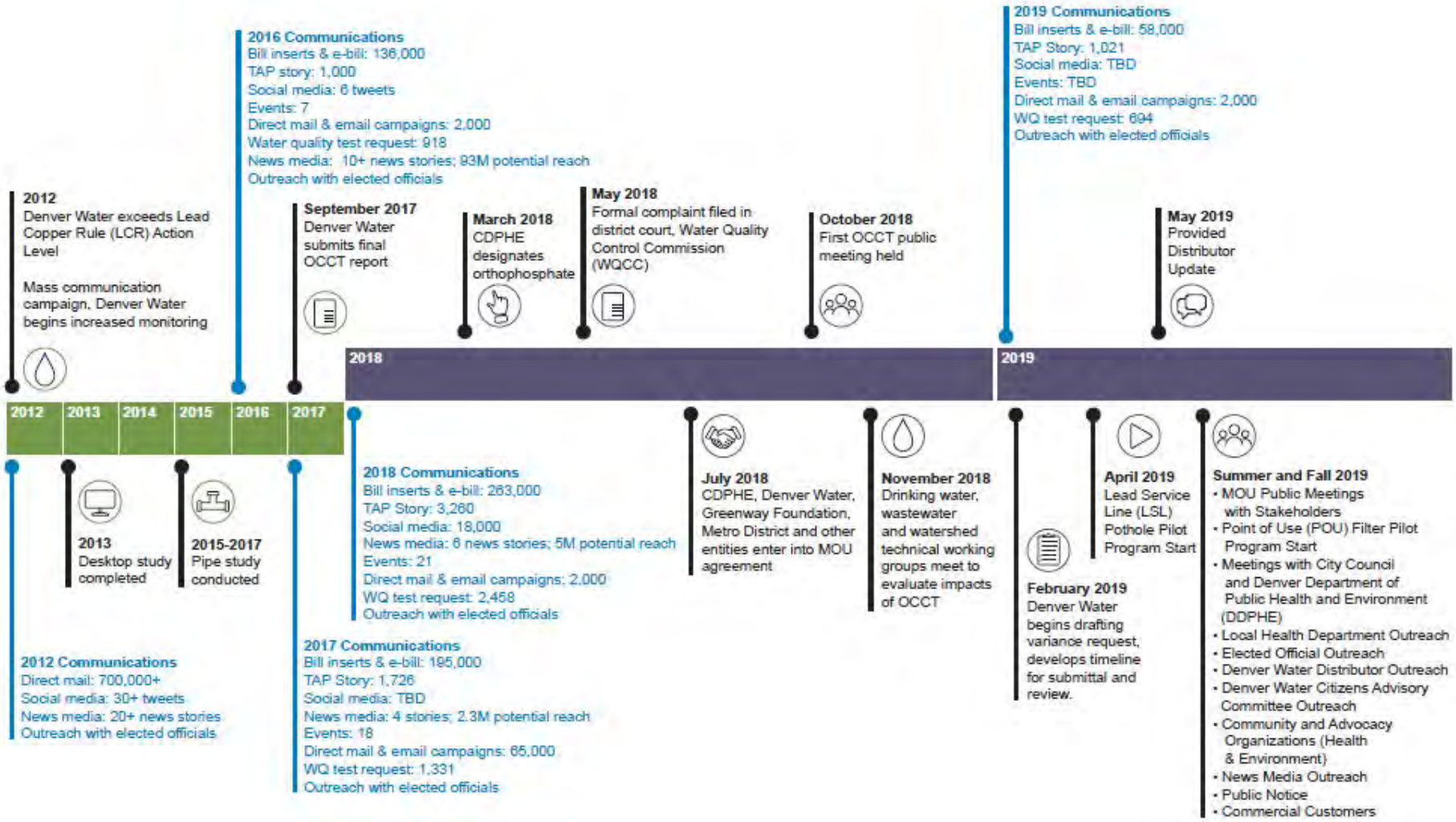
Communication strategies relate to program audiences, which have been placed in categories based on associated influences and communication goals. Timeline column denotes when the activity was or will be completed.

Timeline	Target Audience	Agency lead	Objectives	Method of Communication
Beginning 2/2019 and ongoing.	**Denver Water customers (Pre-1951 homes)**	Denver Water	Create awareness about LSLs. Provide information to learn more (e.g., water quality testing, loans for service line replacement).	Direct mail, and others as identified through communications plans.
Quarterly	**Denver Mayor's Office**	Denver Water	Provide information to elected officials and staff about the reason for implementing OCCT. Provide assistance for handling citizen calls. Obtain input and guidance on approach to council districts.	Meetings. Informational materials.
Beginning 6/2019 and ongoing.	**Denver City Council**	Denver Water	Provide information to elected officials and staff about the reason for implementing OCCT. Provide assistance for handling any citizen calls. Obtain input and guidance on approach to council districts.	Meetings. Informational materials. Presentations as requested.
Beginning 7/2019 and ongoing.	**City and County of Denver departments** (includes Planning, Public Works, Engineering, Office of Environmental Justice and Health Equity, etc.)	Denver Water	Create awareness about CCT variance request. Determine areas requiring coordination for construction and community affairs.	Meetings. Informational materials. Presentations as requested.

Timeline	Target Audience	Agency lead	Objectives	Method of Communication
Beginning 5/2019 and ongoing.	**Public health agencies and public health providers**	Denver Water	Enlist support for water quality improvements for the benefit of public health. Inform about the benefits of CCT. Inform about the impacts of any change in water quality. Gain support from the health department as a communications partner with special, targeted audiences, including general public, physicians, etc.	Meetings. Informational materials. Presentations as requested. Others as identified through communications plans.
6/2019 7/10/2019 7/16/2019 8/2/2019 8/5/2019 others pending.	**Denver Water Distributors (wholesale/retail large account holders)**	Denver Water	Create awareness. Obtain input.	Meetings. Informational materials. Presentations as requested. Others as identified through communications plans.
6/2019 6/20/19 7/18/2019 others pending.	**Denver Water - Citizens Advisory Council**	Denver Water	Create awareness. Obtain input.	Meetings. Informational materials.
7/2019 – 8/2019	**Customers/participants in filter pilot**	Denver Water	Educate and engage to gauge viability of a filter distribution program and adoption rates by Denver Water customers that have known or suspected lead service lines.	Letters, informational materials, phone calls, door-to-door outreach.
Beginning 6/2019 and ongoing.	**Advocacy organizations: public health, children's health advocacy, environmental groups**	CDPHE & Denver Water for public health and children's health; EPA & Denver Water for enviro groups.	Create awareness. Build interest. Obtain input.	Meetings. Informational materials. Presentations as requested. Others as identified through communications plans.

Timeline	Target Audience	Agency lead	Objectives	Method of Communication
Monthly	**MOU stakeholder group**	CDPHE	Present overview of variance option and input requested.	Meetings.
Beginning 7/2019 and ongoing.	**Customers and residents**	Denver Water	Implement a comprehensive, strategic, integrated public communication and outreach program. Create awareness about program approach. Obtain input.	Various, including those listed above and others identified through communications plans.
Beginning 7/2019 and ongoing.	**Commercial customers**	Denver Water	Create awareness about program approach. Obtain input.	Various, including those listed above and others identified through communications plans.
Beginning 7/2019 and ongoing.	**Impacted customers (with known or suspected LSLs)**	Denver Water	Educate and engage with customers about LSLs, coordinate LSL removal.	Various, including those listed above and others identified through communications plans.

Outreach Timeline


2012
Denver Water exceeds Lead Copper Rule (LCR) Action Level
Mass communication campaign, Denver Water begins increased monitoring
2016 Communications
Bill inserts & e-bill: 136,000
TAP story: 1,000
Social media: 6 tweets
Events: 7
Direct mail & email campaigns: 2,000
Water quality test request: 918
News media: 10+ news stories; 93M potential reach
Outreach with elected officials
September 2017
Denver Water submits final OCCT report
March 2018
CDPHE designates orthophosphate
May 2018
Formal complaint filed in district court, Water Quality Control Commission (WQCC)
October 2018
First OCCT public meeting held
2019 Communications
Bill inserts & e-bill: 58,000
TAP Story: 1,021
Social media: TBD
Events: TBD
Direct mail & email campaigns: 2,000
WQ test request: 694
Outreach with elected officials
May 2019
Provided Distributor Update
2018
2019
2012
2013
2014
2015
2016
2017
2013
Desktop study completed
2015-2017
Pipe study conducted
2012 Communications
Direct mail: 700,000+
Social media: 30+ tweets
News media: 20+ news stories
Outreach with elected officials
2018 Communications
Bill inserts & e-bill: 263,000
TAP Story: 3,260
Social media: 18,000
News media: 6 news stories; 5M potential reach
Events: 21
Direct mail & email campaigns: 2,000
WQ test request: 2,458
Outreach with elected officials
2017 Communications
Bill inserts & e-bill: 195,000
TAP Story: 1,726
Social media: TBD
News media: 4 stories; 2.3M potential reach
Events: 18
Direct mail & email campaigns: 65,000
WQ test request: 1,331
Outreach with elected officials
July 2018
CDPHE, Denver Water, Greenway Foundation, Metro District and other entities enter into MOU agreement
November 2018
Drinking water, wastewater and watershed technical working groups meet to evaluate impacts of OCCT
February 2019
Denver Water begins drafting variance request, develops timeline for submittal and review.
April 2019
Lead Service Line (LSL) Pothole Pilot Program Start
Summer and Fall 2019
• MOU Public Meetings with Stakeholders
• Point of Use (POU) Filter Pilot Program Start
• Meetings with City Council and Denver Department of Public Health and Environment (DDPHE)
• Local Health Department Outreach
• Elected Official Outreach
• Denver Water Distributor Outreach
• Denver Water Citizens Advisory Committee Outreach
• Community and Advocacy Organizations (Health & Environment)
• News Media Outreach
• Public Notice
• Commercial Customers

APPENDIX III.B.1 - INTEGRATED AND CONSECUTIVE SYSTEMS

September 2019

DENVER WATER

Appendix III.B.1: Integrated and consecutive systems

DENVER WATER DISTRIBUTORS

Denver Water provides water to two types of systems: integrated and consecutive. Consecutive systems are entities that receive some of their water supply from Denver Water and blend it with other sources, examples include Broomfield, Inverness and East Cherry Creek Valley. Consecutive Systems are not included in the lead service line inventory because they do not conform to Integrated System requirements defined by Denver Water.

Integrated System Agreements include three distinct types of districts: Master Meter, Read and Bill and Total Service. These districts have a total of over 160,000 service lines with approximately 6,000 pre-1951 taps, which have been included in the lead service line inventory. Additional factors, as spelled out in lead service line inventory section and Appendix III.B.2, may result in more homes being included in the final count of known or suspected lead service lines.

The districts are being included in the identification and verification efforts for the lead service line inventory. These efforts include records review, site surveys, potholing, and water quality sampling. Prior to the execution of Phase II of the Lead Reduction Program Plan, an agreement will be reached with the Integrated Service Agreement districts to comply with the program elements and schedule as outlined in the plan.

READ AND BILL

Read and Bill districts are also integrated systems where the distributor owns and is responsible for construction, operation, maintenance, and replacement of its water system into which Denver Water delivers water. Denver Water reads the meter of each individual customer and bills each individual customer at the established "Read and Bill" rate.

Read & Bill District	***Total***	***< 1951***	***> 1950***
North Lincoln	***248***	40	205
Phillips Petroleum	***4***	0	4
Country Homes Metro	***39***	0	37
South Sheridan	***1111***	0	1109
Alameda	***503***	0	501
Southgate	***11943***	22	11778
Southwest Metro	***14355***	6	14112
Bear Creek	***3201***	0	3161
Platte Canyon	***6095***	11	6031
Suncor	***3***	0	3
Lockheed Martin	***1***	0	1
Colorado DNR	***9***	0	8
Willows	***1131***	0	1127
Totals	***38643***	79	38077
Percentage		***0.20%***	***98.50%***

Based upon available tap date data

Based upon available tap date data

TOTAL SERVICE

In Total Service areas, Denver Water owns the water system and is responsible for its operation, maintenance and replacement. Denver Water reads each individual customer's meter and bills each individual customer at the established "Total Service" rate. In Total Service areas, the water service provided to the customers is identical to that provided to customers inside the City and County of Denver.

Total Service District	*Total*	*< 1951*	*> 1950*
Southeast Englewood	***12200***	5	12039
Holly Hills	***803***	1	802
HI-LIN	***259***	4	254
Bennett Bear Creek Farm	***220***	1	213
Fehlmann	***19***	0	19
Sheridan	***1606***	115	1470
Cherry Hills North	***146***	0	146
Mansfield Heights	***181***	1	175
Littleton	***11387***	49	11199
Lloyd King	***10***	0	10
Loretto Heights	***83***	23	58
Columbine	***748***	0	733
Lochmoor	***58***	0	58
Cherry Hills Heights	***52***	4	48
Southwest Plaza Metro	***37***	1	32
Havana	***2442***	0	2394
Southwest Suburban	***2234***	0	2232
Grant	***776***	0	775
Hillcrest	***262***	0	262
Devonshire	***68***	3	65
Panarama Park	***71***	0	61
Galleria Metro	***55***	0	55
Greenwood Village	***269***	14	254
South University Place	***36***	12	24
Cherry Hills Village	***1287***	19	1230
Arapahoe Estates	***282***	0	282
Holly Mutual	***48***	0	47
Colorado Academy	***39***	0	39
Berkeley	***1361***	361	986
Castlewood	***2957***	3	2902
East Cherry Hills Village	***58***	0	57
Totals	***40054***	616	38921
Percentage		***1.50%***	***97.20%***

Based upon available tap date data

Based upon available tap date data

MASTER METER

Master Meter districts are integrated systems that are solely supplied by our water through one or several meters, but they set their own rates and maintain their own infrastructure. These systems can reside in municipalities that have several water sources.

Master Meter District	***Total***	***< 1951***	***> 1950***
Con Mutual	***16,249***	213	15902
Wheat Ridge	***6,160***	2065	4053
Edgewater	***1,522***	42	1467
Bow-Mar	***290***	68	222
Alameda	***352***	2	346
Bonvue	***172***	0	172
Cherry Creek Valley	***2,422***	13	2333
Northgate	***11***	6	5
High View	***975***	2	950
Valley	***1,896***	39	1825
South Adams County	***183***	2	179
Lakehurst	***5,756***	4	5713
North Washington	***3,787***	5	3750
Cherry Creek Village	***472***	9	458
Meadowbrook	***1,365***	1	1356
Willowbrook	***3,875***	0	3825
North Pecos	***708***	3	676
Ken-Caryl Ranch	***4,388***	3	4326
Bancroft-Clover	***9,380***	57	9296
Lakewood	***835***	364	459
Green Mountain	***10,375***	17	10319
Crestview	***5,156***	2420	2706
Glendale	***285***	6	271
Willows	***4,746***	0	4746
Totals	***81,360***	5341	75355
Percentage		***6.60%***	***92.60%***

Based upon available tap date data

Based upon available tap date data

APPENDIX III.B.2 - PRELIMINARY IDENTIFICATION OF LEAD SERVICE LINES

September 2019

DENVER WATER

MOTT MACDONALD

Technical Memorandum

To Denver Water
From Mott MacDonald
Cc Denver Water, Corona Environmental, and AECOM
Date August 8, 2019
Project No. 507100139
Page Page 1 of 15
Subject Denver Water Lead Reduction Program
Appendix III.B.2 – Refinement of the Lead Service Line Inventory

I. EXECUTIVE SUMMARY

Based upon additional information and further analysis of the data presented in the Preliminary Identification of Lead Service Lines and other data, a refinement to the service line inventory for the Denver Water service area was completed. The refinement resulted in service lines being removed from inventory and adjustments to the probability of a service line being lead pipe. Results of the refinement to the inventory are:

- 319,700 service lines used for drinking water in the Denver Water service area
- 84,546 service lines identified as known, suspected and possible lead service lines – these premises are candidates for the filter program
    - 63,955 service lines are estimated to be lead services lines – this is the lead service line inventory and the basis for the annual 7.0% ALSLR
    - 20,591 service lines are estimated to be non-lead services lines – these will be investigated and confirmed non-lead

This technical memorandum documents the background, analysis and results of the refinement to the inventory.

II. BACKGROUND

As Denver Water does not own its customers' service lines, an inventory of lead service lines was compiled based upon available data. It should be noted that compiling and analyzing available data sets to develop a service line inventory is an extensive and challenging process. For Denver Water this is compounded by the fact that service line materials were not historically recorded until this past decade and the analysis of available data (dates service lines were tapped to the water main, building dates, parcel dates, water main installation dates, and other data) collected in multiple databases over the past century results in numerous scenarios to determine the probability of lead. Incomplete or missing data and changes to service line replacement policies and procedures over time further complicate these efforts.

The starting point for our analysis is the *Preliminary Identification of Lead Service Lines* prepared by Corona Environmental Consulting dated August 7, 2019 (included as

ATTACHMENT 1). The *Preliminary Identification of Lead Service Lines* includes details on lead service line background, data sources, data preparation and clean-up, results, and next steps. An earlier version of this initial inventory technical memorandum was included in the July 11, 2019 draft submittal. The estimated inventory of service lines in the Denver Water service area developed in the *Preliminary Identification of Lead Service Lines* is shown in Table 1.

Table 1. Preliminary Inventory

	Preliminary Identification of Lead Service Lines	
Service Type	July 11, 2019	August 7, 2019
Known LSL	1,118	926
Suspected LSL	63,597	62,816
Possible LSL	36,533	36,388
Unlikely LSL	83,543	83,312
Not LSL	150,666	152,015
Total Services	335,457	335,457
Lead Service Lines	75,036	72,158

III. METHODOLOGY

Additional detailed records analysis of the *Preliminary Identification of Lead Service Lines* inventory was completed, which resulted in an update to the estimated lead service line inventory. The purpose of this Technical Memorandum is to document the analysis and refinements to the inventory. The framework for the analysis is as follows:

Category A: Service Lines Removed from Inventory

- Re-evaluation of source information
- Resolution of data discrepancies from different record systems

Category B: Adjustment to the Probability of Lead

- Adjustment based on evaluation of baseline data and new data
- Modification of rules due geographic applicability of the logic
- Resolution due to data discrepancies

Category C: Service Lines Excluded from Filter Program

- Inactive accounts
- Vacancies
- Service lines not associated with a parcel
- Water use types

This update documented is through defined accounting procedures and replaces the numbers estimated in the lead service line inventory dated July 11, 2019.

IV. VERSION CONTROL

The starting point for our analysis is the results from the Technical Memorandum titled *Preliminary Identification of Lead Service Lines* prepared by Corona Environmental Consulting dated August 7, 2019 (included as ATTACHMENT 1).

The new analytics applied to the lead service line inventory allotted the necessity to manage tracking of changes for version control and tracking for changes in the inventory. In order to manage changes between version, new rules were added as follows:

Rules for Removing or Updating Records

Two additional fields were added to the lead service line inventory to prevent double-counting of a service line which may be included in multiple categories. The two additional fields include:

1. **lsli_remove_20190802** is a flag if a record is removed (Category A)
   - 1 if removed, 0 if not
2. **lsli_update_20190802** is a flag if a record is updated (Category B)
   - 1 if updated, 0 if not

Updates to the inventory were applied using the two flags in the order as presented herein. The two flags were applied to ensure that a record is only counted for removal or update the first time it is encountered during the sequence of data processing.

V. CATEGORY A: ANALYSIS AND FINDINGS

A review of the source data to develop the lead service line inventory compared to the output identified locations that needed further refinement based on the outcome of the probabilities of lead.

A.1 – Distributor Contracts

In May 2019, a list of Distributor Contracts was annotated by Denver Water (MS Excel file ISA_LSL_Clarification_Final20190507.xlsx) to identify service lines that should be

included in the inventory. Denver Water provided data for the initial inventory that included Distributor Contracts noted as "Include in LSL Inventory".

A further analysis was completed to confirm service lines associated with Distribution Contract are captured in the inventory, which is highlighted below.

- *A.1.1 – Raw Water (4,489 removed)*

  A geographic review of the inventory with Denver Water staff identified the inclusion of service lines from North Table Mountain Water and Sanitation District (NTMWSD). Although NTMWSD contract (M169) was listed as "Include in LSL Inventory", it was determined that the NTMWSD contract (M169) is for Raw Water only.

  Denver Water provides the Raw Water distributors with untreated raw water only and Denver Water is not responsible for distribution water quality. The distributor is responsible for treating and delivering the water. Service lines associated with "Raw Water" distributors are not included in the lead service line inventory.

  As such, 4,489 service lines associated with NTMWSD contract (M169) were removed from the inventory.

- *A.1.2 – Emergency Connections (3 removed)*

  A search of records that have Distributor Contracts listed as "Include in LSL Inventory" was completed. The initial inventory included three (3) service lines identified with E000 - Emergency Interconnect.

  In some cases, water is provided to distributors or neighboring cities during emergency scenarios (main break, major fire, etc.) through an emergency connection. Under normal operations, the distributor is responsible for treating and delivering the water. Service lines associated with "Emergency Connection" distributors are not be included in the inventory.

  Three service lines (X34069(6"), 335073 (16"), X25117B (6")) with Distributor Contract E000 were removed from the inventory.

Based upon the above, Denver Water reviewed and confirmed the updated Distributor Contracts noted as "Include in LSL Inventory" (ISA_LSL_Clarification_Update20190723.xlsx).

A.2 – Service Point Types, Irrigation (3,166 removed)

Denver Water uses the service point type field to identify the use of water associated with a customer's service line. In some cases, water use defined by service point type is not for drinking. In May 2019, Denver Water identified service point types that should be included in the inventory, which are listed in Table 2.

Table 2. Service Point Types as Selected by Denver Water May 2019

Service Point (SP) Type	SP Type Description	Selected for LSLI
TAP-BHMM	TAP Behind Master Meter	X
TAP-BBYF	TAP Behind Master Meter Bypass Meter Fire Line	
TAP-BCOM	TAP Behind Master Meter Commercial	X
TAP-BFIR	TAP Behind Master Meter Fire Line (non-metered)	
TAP-BIRR	TAP Behind Master Meter Irrigation	X
TAP-BMFM	TAP Behind Master Meter Multi-Family	X
TAP-BRES	TAP Behind Master Meter Residential	X
TAP-BYFL	TAP Bypass Meter Fire Line	
TAP-COM	TAP Commercial	X
TAP-EMCY	TAP Emergency Interconnect	X
TAP-FIRE	TAP Fire Line (non-metered)	
TAP-IRR	TAP Irrigation	X
TAP-MAST	TAP Master Meter	X
TAP-MFM	TAP Multi-Family	X
TAP-RAW	TAP Non-Potable/Raw Water	
TAP-PLAN	TAP Planning	
TAP-QUAL	TAP Quality Control	
TAP-RECY	TAP Recycled Water	
TAP-RES	TAP Residential	X
TAP-TEMP	TAP Temporary	

Further evaluation of service point type records was completed. Multiple service point types may be associated with a single service line.

It was concluded by Denver Water that irrigation services should be excluded from the inventory, as follows:

- service point type = “TAP-IRR” and no other service point types listed; or
- service point type = “TAP-IRR” and all other service point types are also excluded from the inventory, as noted in Table 2.

Irrigation services do not fall into the guidelines of the LRP – their service point type is not for drinking and they should be removed from the inventory.

Denver Water will implement a policy that prevents the reclassification of existing “TAP-IRR” services to a service point type for drinking unless there is confirmation of non-lead service or replacement of the lead service. In addition, COE efforts will be completed to educate on why not to use irrigation for water consumption.

The results of this analysis identified 3,444 service lines as "TAP-IRR". However, 278 had another service point type that fit the criteria in Table 2 and these service lines should remain in the inventory. The remaining 3,166 service lines were removed from the inventory.

A.3 – Data Reconciliation (8,099 removed)

Denver Water provided data for the initial inventory from multiple sources. The initial inventory did not include data from Denver Water's internal tap lifecycle status fields. Denver Water uses tap lifecycle status fields to record information on service line tap work completed. However, other departments such as Water Sales routinely use other internal fields, such as additional address fields to add notes about lifecycle status. Based upon a review by Denver Water of these additional tap lifecycle status fields, it was concluded that services lines with a tap lifecycle status indicating "Cancelled Stub-in"; "Cancelled Tap"; "Customer Cancelled"; "Tap Cut"; and "License Change – See New Tap" indicate cut, cancelled, replaced, or non-drinking use water service lines which should be removed from the inventory. Some of these services may have been active once but per Denver Water these service lines currently are not in service. These premises will be flagged by Denver Water to not become active service lines in the future until the service line is confirmed non-lead or a new service is installed. Since tap lifecycle status fields are from different sources, Denver Water developed a list of suspect service lines, falling into the following four broad data fields from the records:

1. *A.3.1 – Resident ID (3,463 removed)* - The field indicated cut, cancelled, or replaced service line.
2. *A.3.2 – Address Line 4 (41 removed)* - The field indicated service line cut, abolished, or fire line.
3. *A.3.3 – Tap Remarks (3,610 removed)* - The field indicated service line cancelled or cut.
4. *A.3.4 – Data Source Combination (3,015 removed)* - The tap lifecycle status and other fields indicated abolished or disconnected.

The Water Sales group within Denver Water will continue to investigate these service lines. This is a manual desktop review of various data sets and it is expected for this to be completed by October 2019. An initial review by Denver Water indicates that approximately 80-90% of the manual reviews confirmed that the service line should be removed from the inventory. At most 10-20% of the service lines identified for removal could be re-added to the inventory. Accordingly, a 20% contingency was applied to account for this possibility, resulting in the inclusion of 2,030 service lines as item A.3.5. However, the best information available at present indicates these service lines should be removed from the inventory.

- *A.3.5 – 20% Readjustment (2,030 added)* – Contingency for re-added service lines.

VI. CATEGORY B: ANALYSIS AND FINDINGS

B.1 – Service Line Replacements (189 adjusted)

Denver Water confirmed that service line replacement work completed after July 2016 was a full replacement (water main to house). As such, service lines with a "Replaced Date" after July 2016 were changed to have a p-value of "0".

B.2 – Manifolds (1,191 adjusted)

A geographic review of the initial inventory identified some recently developed areas having a high probability of lead. Based upon further review of the data in those areas, a "." entry for the "Tap Date" was identified. Denver Water confirmed that service lines with a "." entry for the "Tap Date" indicates that the service line is tracked as part of a manifold. Denver Water provided a list of parent and child service lines. The parent manifold tap date is provided as the "Tap Date" for the child and the p-value has been updated using the logic rules 31-37 as noted in the *Preliminary Identification of Lead Service Lines*.

- *B.2.1 – Manifolds with Tap Date (1,143 adjusted)*
  1,144 service line p-values were updated due to having a "." entry for the "Tap Date".
- *B.2.2 – Manifolds without Tap Date (48 adjusted)*
  48 service lines were updated based on the parcel date alone.

B.3 – Geographic Considerations (Littleton) (3,846 adjusted)

A geographic review of the initial inventory identified some recently developed areas with results having a high probability of lead. Upon further review, the initial inventory of service lines in the Littleton service area were identified as having the same "Tap Date" of 1971. Denver Water's evaluation of this record determined that 1971 was the year Littleton entered into a service agreement with Denver Water and is not reflective of the actual "Tap Year". For this reason, the processing performed for the initial inventory removed this tap year. In lieu of using "Tap Year", the "Parcel Year Built" will be used for Littleton as an indicator of the likelihood of a lead service line using the logic rules 31-37 as noted in the *Preliminary Identification of Lead Service Lines*. In addition, to ensure that re-developed properties that were originally built prior to 1952 were not included in the adjustment, only those service lines with a "GIS Main Install Year" and "GIS Abandoned Main Year" greater than 1951 (if present) were adjusted. Based upon the above, resulting analysis included 3,846 adjustments to p-values.

B.4 – Scrape-Offs (783 adjusted)

A geographic review of the initial inventory identified services in areas under development with high probability of lead, which are known as scrape-offs. Recent aerial photography was utilized to confirm development. Denver Water maintains a database tracking "scrape-offs" in the City and County of Denver as far back as 2013. Starting in July 2016, Denver Water required full-service line replacement (water main to house) for all scrape-offs.

- *B.4.1 – Completed Scrape-Offs (779 adjusted)*
  Service lines located at a post July 2016 scrape-off are considered "non-lead" (p value = 0), resulting in 783 p-value adjustments (779 are completed, 4 are pending). The inclusion in the post-July 2016 scrape-off list takes precedence over the tap date to assign the p-value.
- *B.4.2 – Pending Scrape-Offs (4 adjusted)*
  Pending scrape-offs were only included if there was a one-to-one relationship between the premise ID and the tap number, since the provided list of pending scrape-offs included only a premise ID and not the tap number.

B.5 – Tap and Parcel Year Mismatched (5,045 adjusted)

The initial inventory applied a conservative set of logic rules to analyze the lead service line inventory for conflicting date ranges for "Parcel Built Year" and the "Tap Year". When both the "Parcel Built Year" and the "Tap Year" are after 1951 but one or the other is before 1958, a year mismatch resulted and a p-value of 0.5 was applied according to rule 38 in the *Preliminary Identification of Lead Service Lines*. However, if both the tap year and parcel year are after 1951, the likelihood of lead is very low and should have a similar probability of lead as those service lines subject to rule 34 (where both the parcel year and tap year are between 1952 and 1958) in the *Preliminary Identification of Lead Service Lines*. Like the B.3 adjustment, p-value adjustments were only made to service lines where the "GIS Main Install Year" and "GIS Abandoned Main Year" were both after 1951 to ensure that older redeveloped properties that could have a lead service line are not included in the adjustment. Accordingly, the p-values for the 5,045 service lines with a mismatched tap and parcel year have been updated to "0.03" to reflect the low likelihood of a lead service line.

B.6 – Geographic Considerations (District 11) (59 adjusted)

A geographic review of the initial inventory identified some recently developed areas having a high probability of lead. Development in Denver Council District 11 primarily occurred after 1971, with the construction of Denver International Airport and the redevelopment of the Stapleton area. Based upon further review of the data, several service lines in District 11 were missing a tap year and were therefore categorized with p-value showing possibility of lead. Evaluation of the records with a missing tap year indicates lead is highly unlikely. Due to the inconsistency of this record (tap year) in

District 11, the "Parcel Year Built" field was the primary field used to evaluate the probability of lead resulting in an update to the p-value using the logic rules 31-37 as noted in the *Preliminary Identification of Lead Service Lines*. This analysis caused 59 service lines to have their p-values adjusted (after the previous adjustments). A remaining eight service lines with no parcel year or tap year remain in the dataset due to insufficient records to determine their likelihood of lead. Further record review and investigation will be needed to identify their status in the lead service line inventory.

B.7 – Systems Data Exchange Integration (Default: 01/01/1901 Tap Date) (225 adjusted)

Data processing between systems may have resulted in a date conversion error based on the manner that different systems interpreted field types and null values. During data migration, the date field defaulted to populate cells with no data with 01/01/1901. In conjunction with a Denver Water geographic review of areas that should not have a high probability of lead, fields with 01/01/1901 taps dates were reviewed to verify this date. It was established that the 01/01/1901 date is an error in data transfer. It was concluded that service lines with a "Tap Date" of 01/01/1901 will prioritize the "Parcel Year Built" and "GIS Main Install Year" as the primary fields to determine the probability of lead (p-value) instead of the "Tap Date" field. Based on the evaluation of these records, adjustments to the inventory are as follows:

- *B.7.1 – Parcel and GIS Main After 1972 (62 adjusted)*
- *B.7.2 – Parcel and GIS Main After 1952 (163 adjusted)*

B.8 Distributor Evidence (207 adjusted)

Additional information from the City of Edgewater indicated that some service line replacements were in fact only partial replacements. Information from the provided Excel file "edgewater_Lead_Line_Replacements_2014.xlsx" was used to assign a p-value of "1" to service lines known to have lead material between the meter and the premise while others were assigned p-value "0.5" indicating uncertainty with further investigation required. This analysis resulted in adjustments of the p-value to 207 service lines.

B.9 Potholing Data (20 adjusted)

In 2019, Denver Water began performing field investigations by "potholing" service lines to determine the service material type. The standardization of potholing efforts is evolving, and past work completed may not identify when a service line transitions from one material to another. As a result, pothole information was used to confirm lead and assign a p-value of "1" to 20 service lines. However, determination of a different material resulted in no change to the p-value. In other words, potholing information can confirm a lead service line but is not applied to confirm a non-lead service line. Future investigation

will use other available information such as water quality results to better estimate locations with a non-lead service line.

B.10 Water Quality (37 adjusted)

Denver Water has two primary sources of water quality data showing lead levels in the customer's plumbing / service line: Lead and Copper Rule (LCR) compliance testing, and Customer Service (CS) requested testing. The LCR tests involves first draw single liter test results, while CS tests involve a series of three one-liter tests to determine lead levels through the customer's plumbing and service line. Review of the available LCR data from 1997 to the present proved inconclusive as elevated lead levels in the first liter can indicate an issue with customer plumbing (e.g. brass fixtures or lead solder) independent of the presence of a lead service line. Alternatively, the CS data were well-suited to estimating the presence of a lead service line. Using the most recent test at each testing site, a p-value of "0.8" was assigned to all tests where the second or third bottle had a result of 5 µg/L or higher. P-values were only adjusted when the pre-existing p-value was less than 0.8. Like B.9 potholing data, water quality information is not currently being applied to confirm a non-lead service line. This analysis resulted in p-value changes to 37 service lines. Further investigation will be performed to incorporate LCR water quality data, including investigation to determine if water quality testing can be used to identify premises with copper with lead solder.

B.11 Universal Metering (none adjusted)

A universal metering project was completed in 1989-90 and the meter installation worksheets included observations of service line material type. A database from the scanned meter installation worksheets from the universal metering project was completed by Denver Water. Review of these records indicated the following:

- Eight (8) service lines identified as lead, however these lines were already listed in the inventory with a p-value ≥ 0.8.
- 1,127 lines identified as galvanized
    - 183 services have a current p-value <0.5.
- 783 service lines were identified as copper
    - 458 have a p-value >= 0.5.

Since many records have information contradicting other information sources, data from the universal metering program was not used to confirm a non-lead service line at this time. No adjustments were made.

VII. CATEGORY C: ANALYSIS AND FINDINGS

This category consists of identifying service lines that do not directly affect activities related to the Filter Program and/or are a low priority for Accelerated Lead Service Line Replacement (ALSLR). These service lines include those associated with inactive customer accounts, vacant properties, and others that are not used for drinking water.

Service lines identified in Category C will be fully developed by October 2019, prior to the implementation of the Filter Program. These service lines will remain a part of the lead service line inventory and Denver Water will track for future administrative action when the status changes.

C.1 – Inactive Customer Accounts

If there is no water use at a property for an extended period, the service is shut-off at the meter / curb stop and the customer account is considered inactive. A review of the Denver Water customer account status (active/inactive) shows that 3,918 service lines in the lead service line inventory are inactive. On August 7, 2019, the number of inactive service lines is 2,718. Identifying and tracking active/inactive customer service accounts will be integrated into the program. Filters will not be distributed to inactive customer accounts and they will not be prioritized for ALSLR.

C.2 – Vacant Property

Vacant properties were considered for removal when determining the lead service line inventory, as their service lines are not in use. Because service lines may not remain vacant, they are preserved in the lead service line inventory, though filter distribution is not required at vacant properties. Identifying and tracking vacant properties will be integrated into the program. Filters will not be distributed to vacant properties and they will not be prioritized for ALSLR.

C.3 – Service Lines Not Associated with a Parcel

Geographic inspection of some service lines indicates that some service lines do not seem to be associated with a parcel. Denver Water has begun a review of geolocation results and may recommend action based on the results of this analysis. However, no action is taken at present. Reconciling these service lines is expected to be completed by October 2019. Filter distribution may not be required for these service lines if there is no identifiable entity to receive a filter.

C.4 – Fire Lines and Hydrants

Service lines associated with fire lines and hydrants have been flagged for further review. Service lines identified in these categories have not been removed as the evaluation of these service lines has not ruled out splices to properties services or association with other

service types on the same service line that are to be included in the inventory. These service lines will be reviewed on a case by case basis for inclusion in the lead service line inventory.

VIII. RESULTS

The *Preliminary Identification of Lead Service Lines* inventory included 335,457 service lines and an estimated 72,158 lead service lines. As part of this analysis,

- Removals documented in category A resulted in an inventory reduction of 15,757 service lines, resulting in a service line total of 319,700.
- The adjustments in category B resulted in revised p-values for 11,602 service lines.
- Based upon the above, the inventory estimate of lead service lines is 63,955.

Table 3 below highlights the service line inventory breakdown from July 11, 2019 to date.

Table 3. Refinement to Inventory - Summary

	Preliminary Identification of Lead Service Lines		Refinement of Inventory
Service Type	July 11, 2019	August 7, 2019	August 8, 2019
Known LSL	1,118	926	1,066
Suspected LSL	63,597	62,816	61,374
Possible LSL	36,533	36,388	22,106
Unlikely LSL	83,543	83,312	89,388
Not LSL	150,666	152,015	145,766
Total Services	335,457	335,457	319,700
Lead Service Lines	75,036	72,158	63,955

Tables 4, 5, 6 & 7 on the following pages provides a detailed breakdown of removals and adjustments to the lead service line inventory.

Service lines identified in Category C will be fully developed by October 2019, prior to the implementation of the Filter Program. These service lines will remain a part of the lead service line inventory and Denver Water will track for future administrative action when the status changes.

Table 4. Refinement to Inventory – Service Lines Removed

	Refinement to Inventory	
Update Description	Service Lines Removed	Change in LSLI
A.1) Distributor Contracts - Removed Raw Water / Emergency Connections	-4,492	-391
A.2) Removed Irrigation Only Services	-3,166	-199
A.3) Removed Service Lines with Tap Lifecycle Status = Service Line Cut, Cancelled, Abolished, Replaced, etc.	-8,099	-2,024
	-15,757	-2,614

Table 5. Refinement to Inventory – p-value Adjustments

	Refinement to Inventory	
Update Description	p-value Adjustments	Change in LSLI
B.1) Recent Service Line Replacements	189	-106
B.2) Newer Service Lines Have Manifolds: Use Parent Tap Year or Parcel Year Built	1,191	-595
B.3) Littleton Tap Year was 1971: Use Parcel Year Built & Main Install Date	3,846	-1,923
B.4) Scrape-offs	783	-500
B.5) Tap Year and Parcel Year > 1951 Adjusted to p-value <0.5	5,045	-2,523
B.6) District 11 (newer development)	59	-29
B.7) Data Exchange Had 01/01/1901 Tap Date: Use Parcel Year Built & Main Install Date	225	-112
B.8) New Data - City of Edgewater	207	180
B.9) Potholing Data	20	4
B.10) Water Quality Data	37	15
		-5,589

Table 6. Refinement to Inventory – Details Removals and p-value Adjustments

Key
A: removed from LSI, Filters and ALSLR
B: p-value adjustment - remain in LSI, Filters and ALSLR

			p-value											
			1	0.9	0.8	0.7	0.5	0.05	0.04	0.03	0.02	0.01	0	
			Known	Suspected			Possible	Unlikely					Not lead	Total
		July 31, 2019 Inventory	926	28,417	33,837	562	36,388	766	637	31,383	46,869	3,657	152,015	335,457
				62,816				83,312						
Distributor Contracts	A.1.1	Raw Water	-	-	-	(1)	(782)	(1)	(83)	(190)	(753)	-	(2,679)	(4,489)
				(1)				(1,027)						
	A.1.2	Emergency Connections	-	-	-	-	-	-	-	-	-	-	(3)	(3)
				-				-						
Service Point Types	A.2	Irrigation	-	(17)	(25)	(8)	(319)	(55)	(15)	(452)	(35)	(1,391)	(849)	(3,166)
				(50)				(1,948)						
Data Reconciliation	A.3.1	Resident ID	(4)	(137)	(114)	(70)	(1,132)	(54)	(88)	(394)	(134)	(79)	(1,257)	(3,463)
				(321)				(749)						
	A.3.2	Address Line 4	-	(1)	(7)	-	(6)	-	-	-	(1)	(4)	(22)	(41)
				(8)				(5)						
	A.3.3	Tap Remarks	(4)	(65)	(86)	(46)	(1,419)	(23)	(22)	(108)	(160)	(46)	(1,631)	(3,610)
				(197)				(359)						
	A.3.4	Data Source Combination	(7)	(252)	(279)	(21)	(691)	(22)	(8)	(98)	(91)	(110)	(1,436)	(3,015)
				(552)				(329)						
	A.3.5	20% Readjustment	3	91	98	28	650	20	24	120	78	48	870	2,030
				217				290						
Service Line Replacements	B.1	Service Line Replacements	(18)	(51)	(44)	(1)	(14)	(3)	-	(24)	(33)	(1)	189	-
				(96)				(61)						
Manifolds	B.2.1	Manifolds with Tap Date	-	-	-	-	(1,143)	-	-	635	508	-	-	-
				-				1,143						
	B.2.2	Manifolds w/o Tap Date	-	-	-	-	(48)	3	-	45	-	-	-	-
				-				48						
Geographic Considerations	B.3	Littleton	-	-	-	-	(3,846)	1,568	2,131	147	-	-	-	-
				-				3,846						
Scrape-Offs	B.4.1	Completed Scrape-Offs	(2)	(226)	(218)	(11)	(224)	(9)	(2)	(36)	(43)	(8)	779	-
				(455)				(98)						
	B.4.2	Pending Scrape-Offs	-	-	-	-	(2)	-	-	(1)	(1)	-	4	-
				-				(2)						
Tap and Parcel Year	B.5	Tap and Parcel Year Mismatched	-	-	-	-	(5,045)	-	-	5,045	-	-	-	-
				-				5,045						
Geographic Considerations	B.6	District 11	-	-	-	-	(59)	-	-	-	59	-	-	-
				-				59						
Systems Data Exchange Integration	B.7.1	Parcel and GIS Main >= 1972	-	-	-	-	(62)	-	-	-	-	62	-	-
				-				62						
	B.7.2	Parcel and GIS Main >= 1952	-	-	-	-	(163)	-	-	163	-	-	-	-
				-				163						
Distributor Evidence	B.8	Distributor Evidence	152	-	-	-	55	-	-	-	-	-	(207)	-
				-				-						
Potholing Data	B.9	Potholing Data	20	(5)	(10)	-	(5)	-	-	-	-	-	-	-
				(15)				-						
Water Quality	B.10	Water Quality	-	-	37	(1)	(27)	-	-	(1)	(1)	-	(7)	-
				36				(2)						
Universal Metering	B.11	Universal Metering Records	-	-	-	-	-	-	-	-	-	-	-	-
				-				-						

Table 7. Refinement to Inventory – Lead Service Line Inventory Details

	p-value											Total
	1	0.9	0.8	0.7	0.5	0.05	0.04	0.03	0.02	0.01	0	
Total Service Line Inventory	1,066	27,754	33,189	431	22,106	2,190	2,574	36,234	46,262	2,128	145,766	319,700
	Known	Suspected			Possible	Unlikely					Not lead	Total
	1,066	61,374			22,106	89,388					145,766	319,700
Change from Preliminary Inventory	140	(663)	(648)	(131)	(14,282)	1,424	1,937	4,851	(607)	(1,529)	(6,249)	(15,757)
Updated LSLI*	1,066	24,979	26,553	303	11,054						-	63,955
	Known	Suspected			Possible						Not lead	Total
	1,066	51,835			11,054						-	63,955

* = Total Service Line Inventory X p-value when p-value >= 0.5

ATTACHMENT 1 TO APPENDIX III.B.2:

Preliminary Identification of Lead Service Lines

Date:	Revised August 16, 2019 March 21, 2019
To:	Denver Water
From:	Corona Environmental Consulting, LLC

Background

The purpose of this Technical Memorandum is to present how the estimate of lead service lines (LSLs) was generated. An inventory of LSLs is needed to determine how many and where to deploy point-of-use filters as well as determine how many LSLs must be replaced each year. The inventory is also used in the Lead Exposure Model to compare the effectiveness of the variance versus OCCT of orthophosphate for public health protection.

This estimate of LSLs in Denver Water's integrated system is based on data available from several sources available at each tap. No fieldwork has been performed to verify this effort to date. While the logic has been substantiated, and the mapping results appear to match our expectations, the estimate is only as good as the underlying data. No warranty is expressed or implied that these data are correct. These data represent the best available information.

Data Sources

Data used in this effort were aggregated from multiple sources. Data used are summarized in the following table:

Data	Use	Source
OM Current	Data from the field recorded in CCB, reported to O&M. Includes >=2018. Current service line material	CCB
OM Previous	Data from the field recorded in CCB, reported to O&M. Includes >=2018. Previous service line material	CCB
PBCU SERVICE	Service line material from LCR Sample Sites materials survey	Water Quality
ARG Full/Partial	ARG historical data. Goes up to 2018. Records of full and partial service line replacements.	ARG
Year Built	The year the parcel was developed.	Counties
Year Tapped	Year the tap was made to the main.	CCB
Main Install Date	Year the main was constructed.	ARG
Tap Size	Tap size.	CCB
Service Line Size	Service line size. Lead was rarely used for large diameters.	CCB
Distributor Name	Distributor name.	CCB
Service Area	Service area.	CCB
WQ Count	Number of lead samples at the tap.	Water Quality
WQ Max	Highest concentration of lead at the tap.	Water Quality
WQ Avg	Average concentration of lead at the tap.	Water Quality
Tap Cut Date	Full date of the tap cut.	CCB
Aban Install Date	Date the first time a water main was available to tap.	ARG

Data Preparation and Clean-up

1. File contains 335,457 records of taps that are for active, treated water. Provided by Denver Water GIS on 6/17/2019.
   Read in additional file of service line replacement dates, provided by Denver Water on 7/12/2019. Keep only Tap.Number and Date.Replaced and remove duplicates.
   Files merged into one dataframe by Tap.Number.
2. Created three new fields:
   - "p-value" the probability that the service has some lead materials. For example, a p-value of 0 indicates that tap does not contain lead, and a p-value of 1 indicates that a tap does contain lead. A for the p-values of 0.5, half of them would be expected to contain lead. The p-value will be used to produce a numeric estimate of the total number of LSLs in the Denver Water service area.
   - "Category" the categorical classification of the likelihood of an LSL. This should be used for communicating the results.

- "Basis" which reports what data was used in the p-value and categorical determination. This is used to supplement our knowledge of the estimate.

3. Populate new "CCB.Service.Line.Type" column with "OM_Current" information. Service line material reflected in this field did not always reflect the material from the main to the house, depending on the main install year and service line replacement date.
    a. Populate column with abbreviated service line material. For example: "Copper meter to main, Lead meter to house" becomes "COPPLEAD"
    b. For records with Main Install Date before 2010, change to UNKUNK unless they are lead or galvanized. Complete service line replacement during main installs and replacements was not standard practice at this time.
    c. For records from 2010 to 2016, change to COPPUNK unless they are lead or galvanized. Lines were typically replaced only to the property line during this time period.
    d. For records 2016 and later, change any COPPUNK, UNKUNK, and UNKCOPP to COPPCOPP. Service lines were replaced entirely beginning in 2016.
    e. Repeat steps b-d using Date Replaced. This overrides all previous assignments; the replacement date is considered more accurate.
4. Prioritize distributor provided tap dates when possible. These records are presumed to be more accurate than Denver Water records.
    a. Rename "TappedYear" column "DW_TappedYear"
    b. Create new "TappedYear" column that populates first with "D_ISA_Tapped_Date" then with "DW_TappedYear"
5. Clean up City of Littleton data. 1971 was the year Littleton became part of the integrated system and some data reflects that rather than the actual tap or main install dates. The dates being removed were selected based on large peaks in the number of records on a specific date close to 1971.
    a. Filtered by "DistributorName" for "City of Littleton". Deleted all "TappedYear" and "TappedDate" with "TappedDate" = 01-01-1971. 4,727 records.
    b. Filtered by "DistributorName" for "City of Littleton". Deleted all "GISMainInstallYear" and "GISMainInstallDate" with "GISMainInstallDate" = 05-12-1970. 1,821 records.
    c. Filtered by "DistributorName" for "City of Littleton". Deleted all "GISAbanMainInstallYear" and "GISAbanMainInstallDate" with "GISAbanMainInstallDate" = 05-12-1970. 48 records.

Estimation Procedure

The estimation procedure can be outlined as follows:

- Identify service lines where there is a record of observation (direct evidence) of the service line material
- Service lines installed before 1950 were required to be lead. However, a portion of those LSLs will have been replaced with non-lead materials.
- In 1971, lead was prohibited as a service line material. Services after this date are considered to not contain any lead.
- Services installed between 1950 and 1971 will have a low rate of lead occurrence. Lead had already fallen out of favor for service lines by the time Denver Water allowed use of other materials in mid-1949.
- Denver Water has some records on full and partial replacements that they have made.

- The model is further refined with data from retail areas in the integrated system and other evidence that is available (e.g. water quality tests).

The detailed procedure follows.

Use CCB OM records first because these records are considered the most accurate by Denver Water. These are completed by field workers on leak repairs and line replacements.

1. Filtered by "CCB.Service.Line.Type" for "COPPLEAD", "LEADLEAD", "LEADCOPP", or "LEADUNK".

p-value	Category	Basis	No. Records
1	Known LSL	Direct Evidence	29

   These records were not considered further in the analysis based on other data. This data field is considered to be known when complete and contains the most reliable records.

2. Filtered by "CCB.Service.Line.Type" for "COPPGALV" and "OM_Previous" to "Lead meter to main, galvanized meter to house". These are considered to behave as LSL.

p-value	Category	Basis	No. Records
1	Known LSL	Direct Evidence	5

   These records were not considered further in the analysis based on other data. This data field is considered to be known when complete.

3. Filtered by "CCB.Service.Line.Type" for "COPPCOPP".

p-value	Category	Basis	No. Records
0	Not lead	Direct Evidence	10,189

   These records were not considered further in the analysis based on other data. This data field is considered to be known when complete.

Incorporate the pool of LCR monitoring sites which have had a materials survey.

4. Filtered by "PBCU_SERVICE" for "PB".

p-value	Category	Basis	No. Records
1	Known LSL	Direct Evidence	142

   These records were not considered further in the analysis based on other data. This data field is considered to be known when complete.

5. Filtered by "PBCU_SERVICE" for "CU".

p-value	Category	Basis	No. Records
0	Not Lead	Direct Evidence	117

   These records were not considered further in the analysis based on other data. This data field is considered to be known when complete.

Use ARG records next because they are direct evidence, but tend to be not as accurate as CCB records because the recordkeeping shifted from ARG to CCB a few years ago and may be dated.

6. Filtered by “ARG_FullPartial” for “Partial”.

p-value	Category	Basis	No. Records
1	Known LSL	Direct Evidence	146

These records were not considered further in the analysis based on other data. This data field is considered to be known when complete, but “CCB.Service.Line.Type” takes precedence. “Full” was not used because the definition of a “full replacement” has changed over time. At times in the past, “full replacement” may have referred to meter to main only.

Incorporate records from retail customers.

7. Filtered by “D_Confirmed_Copper” for “Y”. This column was added to the database to reflect results of the ISA survey conducted by Denver Water. Records were assigned “Y” when distributors verified the line was copper based on visual inspection, detailed records, or distributor policies.

p-value	Category	Basis	No. Records
0	Not Lead	Distributor Evidence	447

8. Filtered by “DistributorContractDesc” for North Washington, City of Edgewater, and Crestview. These distributors have verified that there are no LSLs in their service areas. North Washington and Crestview first installed water service lines in 1954; the lines were required to be copper. In addition, both areas have completed extensive main replacements recently and did not discover lead services. Edgewater completed potholing of all lines and replaced lead lines in 2014.

p-value	Category	Basis	No. Records
0	Not Lead	Distributor Evidence	9,898

9. Filtered by “DistributorContractDesc” for City of Glendale and “TappedYear”>1952. Glendale was incorporated in 1952 and has never allowed LSLs.

p-value	Category	Basis	No. Records
0	Not Lead	Distributor Evidence	260

10. Filtered by “DistributorContractDesc” for Cherry Creek Valley and “TappedYear”>1961. Cherry Creek Valley was formed in 1961 and has never allowed LSLs.

p-value	Category	Basis	No. Records
0	Not Lead	Distributor Evidence	2,486

11. Filtered by “DistributorContractDesc” for North Pecos and “TappedYear”>=1967. North Pecos was formed in the mid-1960s and has used only copper lines.

p-value	Category	Basis	No. Records
0	Not Lead	Distributor Evidence	463

12. Filtered by “DistributorContractDesc” for Valley Water District and “TappedYear”>1957. The District was connected in 1957 and has no known lead.

p-value	Category	Basis	No. Records
0	Not Lead	Distributor Evidence	1,842

13. Filtered by “DistributorContractDesc” for Southgate Water District and “TappedYear”>1961. Southgate formed in 1961 and all records indicate that lines are copper or poly.

p-value	Category	Basis	No. Records
0	Not Lead	Distributor Evidence	11,356

14. Filtered by “DistributorContractDesc” for Meadowbrook and Willowbrook and “TappedYear”>=1964. Neither district allowed lead from 1964 forward. DW tap dates on older homes in the area were checked against tap permit records by the Districts and found to be matching.

p-value	Category	Basis	No. Records
0	Not Lead	Distributor Evidence	5,242

Identify service lines first installed after lead was prohibited. Records in this category with a water quality sample result indicative of an LSL is considered to be a positive identification.

15. Filtered by “ParcelYearBuilt” for years 1972 to present and “TappedYear” for years 1972 to present.

p-value	Category	Basis	No. Records
0	Not Lead	Post No Lead	108,676

16. Filtered by “ParcelYearBuilt” & “TappedYear” for years 1951 and earlier. Filtered by for those with 3 or more lead samples. Considered an average lead concentration >=5 ppb conclusive evidence of an LSL.

p-value	Category	Basis	No. Records
1	Known LSL	pre 1952, WQ results	604

To this point, the information used is considered as an inventory. 151,902of the 335,457 services under consideration have been assigned (45%). 926 LSLs, 150,976non-LSLs.

The following steps have two recorded dates <=1951 and 1/2” or 5/8” service line sizes. Services lines in these sizes during this time period are indicative of lead; however, evidence shows that size records are less likely to be updated when lines are replaced.

17. Sort for records with “ParcelYearBuilt” and “TappedYear” <=1951 and “ServiceLineSize” of 1/2 or 5/8.

p-value	Category	Basis	No. Records
0.9	Suspected Lead	5/8 or 1/2 Service, pre 1952	28,329

18. Sort for records with no “ParcelYearBuilt” and “TappedYear” <=1951, “GISAbanMainInstallYear”<=1951 and “ServiceLineSize” of 1/2 or 5/8.

p-value	Category	Basis	No. Records
0.9	Suspected Lead	5/8 or 1/2 Service, pre 1952	13

19. Sort for records with no “ParcelYearBuilt” and “TappedYear” <=1951 , “GISMainInstallYear”<=1951, no “GISAbanMainInstallYear” and “ServiceLineSize” of 1/2 or 5/8.

p-value	Category	Basis	No. Records

0.9	Suspected Lead	5/8 or 1/2 Service, pre 1952	163

20. Sort for records with no “TappedYear” and “ParcelYearBuilt” <=1951 , “GISAbanMainInstallYear”<=1951 and “ServiceLineSize” of 1/2 or 5/8.

p-value	Category	Basis	No. Records
0.9	Suspected Lead	5/8 or 1/2 Service, pre 1952	0

21. Sort for records with no “TappedYear” and “ParcelYearBuilt”<=1951 , “GISMainInstallYear” <=1951, no “GISAbanMainInstallYear” and “ServiceLineSize” of 1/2 or 5/8.

p-value	Category	Basis	No. Records
0.9	Suspected Lead	5/8 or 1/2 Service, pre 1952	4

The following steps have two recorded dates <=1951. Denver Water required lead service lines until 1951 but does not have records of all service line replacements.

22. Filtered by “ParcelYearBuilt” for <=1951, and “TappedYear” for <=1951.

p-value	Category	Basis	No. Records
0.8	Suspected Lead	Build & Tap Date	33,750

23. Filtered by no “ParcelYearBuilt”, “TappedYear” for <=1951, and “GISAbanMainInstallYear” <=1951. The abandoned main install likely reflects the year the service line was installed, given that it is the date of the original main install.

p-value	Category	Basis	No. Records
0.8	Suspected Lead	Build & Tap Date	12

24. Filtered by no “ParcelYearBuilt”, “TappedYear” for <=1951, “GISMainInstallYear” <=1951, and no “GISAbanMainInstallYear”. For records that do not have an abandoned main install date, the main install year is the original install date.

p-value	Category	Basis	No. Records
0.8	Suspected Lead	Build & Tap Date	137

25. Filtered by no “TappedYear”, “ParcelYearBuilt” for <=1951, and “GISAbanMainInstallYear” <=1951.

p-value	Category	Basis	No. Records
0.8	Suspected Lead	Build & Tap Date	4

26. Filtered by no “TappedYear”, “ParcelYearBuilt” for <=1951, “GISMainInstallYear”<=1951, and no “GISAbanMainInstallYear”.

p-value	Category	Basis	No. Records
0.8	Suspected Lead	Build & Tap Date	22

The following steps have two recorded dates >=1972. Unlike the subset included in the inventory, the following records are missing either “ParcelYearBuilt” or “TappedYear” data and are therefore considered to be less certain.

27. Sort for records with no “ParcelYearBuilt” and “TappedYear” >=1972 and “GISAbanMainInstallYear” >= 1972

p-value	Category	Basis	No. Records
0.01	Unlikely Lead	Tap & Main Install Date	72

28. Sort for records with no “ParcelYearBuilt” and “TappedYear” >=1972 and “GISMainInstallYear”>= 1972 with no “GISAbanMainInstallYear”

p-value	Category	Basis	No. Records
0.01	Unlikely Lead	Tap & Main Install Date	3,317

29. Sort for records with no “TappedYear” and “ParcelYearBuilt”>=1972 and “GISAbanMainInstallYear” >= 1972

p-value	Category	Basis	No. Records
0.01	Unlikely Lead	Build & Main Install Date	20

30. Sort for records with no “TappedYear” and “ParcelYearBuilt”>=1972 and “GISMainInstallYear”>= 1972 with no “GISAbanMainInstallYear”

p-value	Category	Basis	No. Records
0.01	Unlikely Lead	Build & Main Install Date	434

The following steps have either “TappedYear” or “ParcelYearBuilt” information. Since fewer data are available, less certainty is applied than in previous steps.

31. Filtered by “TappedYear”<=1951 and no other dates. Later dates in other date categories indicate uncertainty as to when the current service line was installed.

p-value	Category	Basis	No. Records
0.7	Suspected Lead	Tap Date	277

32. Sort for records with “TappedYear”>=1972 and no “ParcelYearBuilt”. An early parcel build date could indicate that a new tap was installed without completely replacing the service line material.

p-value	Category	Basis	No. Records
0.03	Unlikely Lead	Date and Distributor	2,734

33. Filtered by ParcelYearBuilt<=1951 and no other dates. Later dates in other date categories indicate uncertainty as to when the current service line was installed.

p-value	Category	Basis	No. Records
0.7	Suspected Lead	Date and Distributor	323

The following steps work with the records that are between the last required lead year, 1951, and the first no lead year, 1972. During this time, lead was not commonly used. For this analysis, it is divided into two bins, surrounding the year 1958. 1958 was chosen based on the latest build date associated with a known LSL of 1956.

34. Filtered by “ParcelYearBuilt” for >1951 and <=1958, and “TappedYear” for >1951 and <=1958.

p-value	Category	Basis	No. Records
0.03	Unlikely Lead	Build & Tap Date	28,872

35. Filtered by “ParcelYearBuilt” for >1958, and “TappedYear” for >1958.

p-value	Category	Basis	No. Records
0.02	Unlikely Lead	Build & Tap Date	47,286

36. Filtered by “TappedYear” >1951 and <=1958 and no other dates

p-value	Category	Basis	No. Records
0.05	Unlikely Lead	Date and Distributor	237

37. Filtered by “TappedYear” >1958 and no other dates

p-value	Category	Basis	No. Records
0.04	Unlikely Lead	Date and Distributor	680

38. Unassigned records at this point consist of conflicting date ranges between threshold dates.

p-value	Category	Basis	No. Records
0.5	Possible Lead	Build & Tap Date	36,869

Adjust assigned values by removing the large diameters and main replacements.

39. Filter for “ServiceLineSize” & “TapSize” = 3 or 4 inches with an existing p-value > 0.05. Large diameters are rarely lead; however, LSLs up to 4 inches have been found.

p-value	Category	Basis	No. Records
0.05	Unlikely Lead	Build & Tap Date + Size	419

40. Filter for “ServiceLineSize” & “TapSize” >= 3 inches excluding records above.

p-value	Category	Basis	No. Records
0	Not Lead	Size	1,039

41. Filter for “GISMainInstallYear” after 1/1/2016 with p-value >0.5. Denver Water policy requires any LSL found during a main replacement after 1/1/2016 should be replaced to the first fitting in the building. However, Denver Water records and interviews indicate that the policy was not fully employed.
https://www.denverwater.org/project-updates/pipe-replacement

p-value	Category	Basis	No. Records
0.05	Unlikely Lead	Presumed replacement at scrape	133

Results

The results have been mapped by Denver Water GIS and the results are consistent with our expectations based on areas where LSLs are known to occur. The following table summarizes the number of taps in each category:

Service Type	Services
Known LSL	926
Suspected LSL	62,816
Possible LSL	36,388
Unlikely LSL	83,312
Not LSL	152,015

An estimate of the total number of lead service lines can be made by summing of the p-values greater than 0.5. This would indicate 72,158 LSLs in the Denver Water service area. However, it should be noted that the p-values assigned were based on consensus and judgment and not actual data. As the data becomes available, this estimate may be refined.

	Basis	LSLs	Non-LSLs	Total
Census	Direct Evidence	322	10,306	10,628
	Distributor Evidence	0	31,994	31,994
	Post No Lead	0	108,676	108,676
	Pre 1952 + WQ	604	0	604
Estimate	Build & Tap Dates	71,232	110,732	181,964
	Service Size	0	1,458	1,458
	Presumed Replacement	0	133	133
	Totals	**72,158**	**263,299**	**335,457**

Most of the probable LSLs are located in the core Denver Water service area. The Table below summarizes the occurrence of LSLs by service area.

Service Area	LSLs	Total	% LSL
Inside City	61,596	172,499	36%
Littleton	2,413	10,622	23%
SE Englewood	378	11,797	3%
Berkeley	369	1,336	28%
Sheridan	235	1,566	15%
Wheat Ridge	2,409	6,310	38%
South Sheridan	76	1,084	7%
Southgate	26	11,644	0.2%
Holly Hills	51	853	0.6%

Next Steps

Denver Water is currently undertaking a field verification effort of potholing as many service lines as possible. These will be used to verify the logic used in the development. This will also supplement existing data to be able to base p-values on actual occurrence data. The estimate will continue to improve as data begins to come in when the ALSLR program begins. Denver Water also continues to refine methods in being able to identify service lines from water quality sampling.

The full-scale lead service line replacement program will include an identification component consisting of a combination of replacement, water quality testing, potholing, and potentially other technologies. Also, customers will be asked to help in identifying lead services lines by providing proof of replacement, pictures of the first fitting in the house, and requesting a lead sample kit.

APPENDIX III.B.3 - PREDICTIVE MODEL AND PRIORITIZATION

September 2019

DENVER WATER

Memo

AECOM
1600 S Quebec Street
Greenwood Village, CO 80111
aecom.com

Project name: Accelerated Lead Service Line Replacement Plan

To: Denver Water

Project ref: Denver Water Lead Reduction Plan

From: AECOM

CC:

Date:
August 20, 2019

Appendix III.B.3 Predictive Model and Prioritization

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Acronyms

p-value	Predictive Model Probability of Lead Score
ACR	American Census Record
ALSLR	Accelerated Lead Service Line Replacement
CDPHE	Colorado Department of Public Health and Environment
COE Program	Communications, Outreach, and Education Program
EPA	Environmental Protection Agency
LRP	Lead Reduction Plan
LRP Plan	Lead Reduction Program Plan
O&M	Operation and Maintenance
PPB	Parts Per Billion
RF	Random Forest
WM	Water main

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Background and Purpose

The Lead Reduction Program Plan (LRP Plan) is supported by an Accelerated Lead Service Line Replacement (ALSLR) Program (see Appendix III.D). Properties with known and suspected lead service lines are enrolled in the ALSLR Program and Denver Water will replace the service lines within its service area (including distributor areas) within 15 years of the approved variance.

The ALSLR Plan details the process and resource estimates to replace the estimated 63,955 lead service lines at a minimum cumulative program year average replacement rate of 7.0%. Of interest is the number of total lead services estimated in the Denver Water service area: not only will this serve as the basis for the target for annual replacements, but it also serves as the basis for developing the ALSLR Plan. To efficiently identify the number of lead services that exist in the Denver Water service area, a predictive model will be used with the lead service line inventory to strategically perform explorations.

This technical memorandum (TM) describes the development of the predictive model. The predictive model will be used to generalize the results of explorations completed to date and to guide subsequent explorations in the future, without having to undertake an excavation at every property. Once developed, the predictive model will be applied to the Denver Water Lead Service Line Inventory to prioritize enrollment in the Filter Program and prioritize the replacement of lead service lines. The TM defines data sources used to populate the predictive model and its application toward prioritization regarding those efforts.

Predictive Model Implementation

Introduction

Denver Water's lead service line Inventory was developed to identify lead service line within Denver Water's service area and surrounding communities (see Appendix III.B.2, Preliminary Identification of Lead Service Lines). A set of logic rules was applied to the data to sort service lines into groups based on the estimated probability that a lead service line is present. The probability represents the uncertainty in our knowledge of the service line material and is captured as a "p-value" that is assigned based on known construction practices, historical records, expert judgement, and data interpretation. The inventory assigns a p-value score to each property to guide Filter Program enrollment, service line material exploration, and lead service line replacement. The p-value score ranges from 0 to 1, with 0 being a known non-lead service and 1 being a known lead service line in the service line. The service connections are grouped into classes of likelihood based on p-value. Table 1 (Estimate of Service Materials Based on Probabilities of Lead) shows the estimated number of services in each class. The inventory currently contains a preliminary estimate of approximately 319,700 records and will be updated to incorporate additional information periodically.

Table III.B.3-1. Estimate of Services Based on Probabilities of Lead

Probability of Finding a Lead Service	p-Value	Estimated Number of Services
Known lead service line	p = 1	1,066
Suspected lead service line	0.8 ≤ p < 1	61,374
Possible lead service line	0.5 ≤ p < 0.8	22,106
Unlikely lead service line	0.01 ≤ p ≤ 0.05	89,388
Non-lead service line	p = 0	145,766
Numbers in the table are provisional, subject **to change will be updated by the August submission**		

The existing inventory (see Appendix III.B.2, Preliminary Identification of Lead Service Lines) was constructed based on data available from several sources. It includes apartments, schools and businesses. To date, some fieldwork has been performed to gain a better understanding of the estimated number of lead service lines. As additional data become available for a property, the p-value score for properties with similar characteristics will be adjusted accordingly to reflect the inventory updates. Enhancements to the inventory and predictive model are underway to support enrollment in the Filter Program and implementation of the ALSLR.

Using the Lead Service Inventory to Build the Predictive Model

A predictive model will be used throughout the ALSLR Program to take advantage of results from field investigation of service line type or service line material and service line replacements to better estimate the materials expected. This data-driven approach will permit the estimation of the possible presence of an lead service line based on observed property and other common characteristics. The recommended approach involves the use of a machine learning model known as a random forest (RF) (Breiman, 2001).

The RF can be set to include existing rules and has the capacity to generate new rules based on the discovery of relationships between input and output variables. In addition, this approach offers the means to audit and explain the decision-making process. Finally, the model can be used to address data inconsistencies, handling data measurements on a variety of scales, and categorical data.

The model will be used to build on the current lead service line inventory based on learning from the results of completed work. The model will make use of the results of field lead service line data collection indicating service line composition found, as well as potholing data collected to verify presence/absence of lead service lines in areas not participating in the ALSLRP. This data driven approach will permit the estimation of “p-value” scores based on observed direct evidence findings and other common characteristics incorporated into the model. These will include tap data as derived for the initial lead service line inventory (year installed, etc.) as well as possible additional variables (sewer age, median income levels, etc.). The model calibration and investigation of service line type or service line material process will identify variables that contribute significantly to the accurate identification of lead service line.

The RF model uses an ensemble of individual decision trees to assign a decision and a probability to observations. A simple decision tree is shown in **Figure III**.B.1 **Decision Tree Example**.

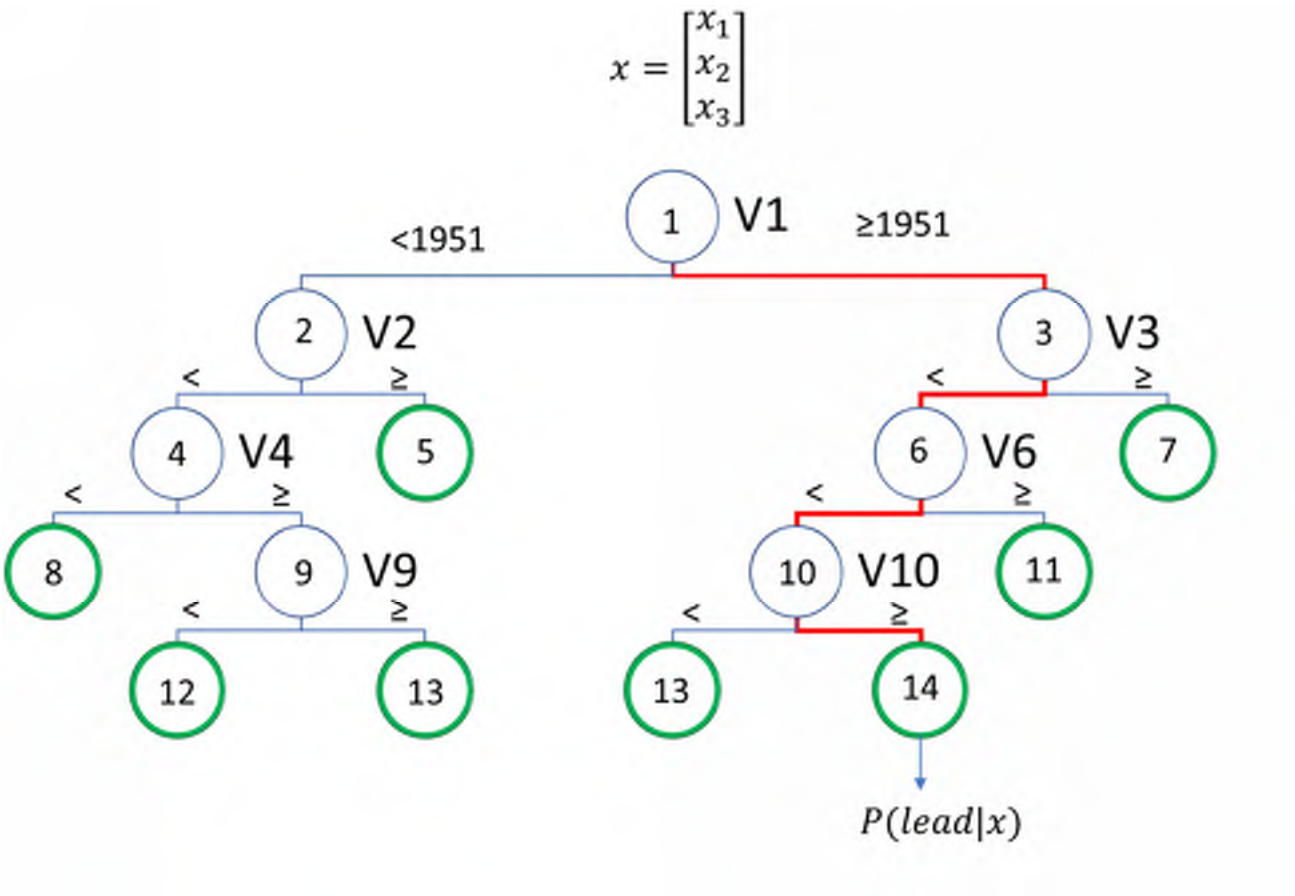


Figure III.B.1 Decision Tree Example

Figure III.B.1 **Decision Tree Example** has four layers of decision processing. The branching node labeled as 1 is where all properties enter the tree and are split according to a characteristic variable (V1). This variable could represent the tap year with the threshold of 1951 representing the year prior to which service lines are most likely lead (the algorithm uses statistical methods to decide on the variables and thresholds to be used). In this example, properties will be split to node 2 or 3 based on the year and a probability of lead being present assigned based on this variable alone. If this split perfectly distinguished lead services from non-lead services in the data, we could stop there, but this will not be the case. The next layer of decisions at nodes 2 and 3 will use two additional variables (V2 and V3) to further split the property services, such as tap size, and assign probabilities for the presence of lead at the child nodes. This process continues using different thresholds of different variables until the algorithm decides to terminate the branching process. These terminal nodes (known as leaf nodes, in green) contain all the property services. Each leaf node classifies the services that fall into it based on the suite of variables expressed in the rules necessary to reach it. A prediction for a property service based on this tree simply considers all relevant variables starting at node 1 and splits through each node until it lands in a leaf node.

The RF algorithm uses many individual trees (as described above) that are randomized both in terms of the data sampled for training (known as “Bagging” (Breiman 1996) and the variables used at each split in the decision tree. Each tree provides a prediction that are on average close to the true mean (low bias), but inherently noisy and sensitive to changes in the data (high variance). When the “forest” of many low bias and high variance trees are averaged for the final model, each tree contributes a vote, thereby reducing the variance and retaining a low bias (Hastie et al. 2009:588). Figure III.B.2 shows a schematic representation of how the ensemble method works. This example shows individual trees (1

through b), which can number as computer resources allow, although there is a point of dimensioning returns.

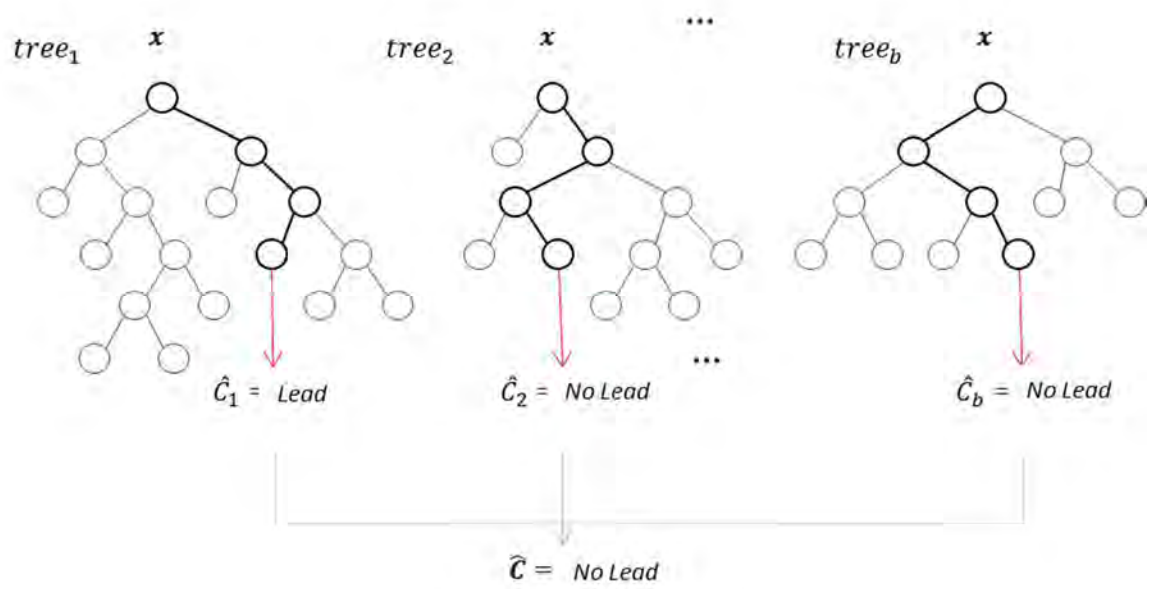


Figure III.B.2 Schematic of Prediction Based on a Decision Tree Ensemble

As a new property observation (x) is sent though each tree, it is split at each node according to the splitting criterion established when the tree was fit to field inspection data that is essential for project delivery. This follows the track of the bolded branches and nodes depicted in **Figure III**.B.2 **Schematic of Prediction Based on a Decision Tree Ensemble**. Even though the property data x are the same, each tree sends it along a different path because each tree was built with a randomized sample and randomly selected variables at each node. For each tree, the property is split until it reaches a leaf node and its service is then assigned a classification and probability. This can be represented as $\hat{C}_b(x)$ where C-hat is the predicted class of x for the bth tree.

The final prediction, represented as $\hat{C}_{rf}^{B}(x)$, is simply the class that the majority of trees agree on, in this case two out of three trees predicted that x is not lead. The algorithm also provides a final probability that property x service line is lead, expressed as $P\left(\hat{C}_{rf}^{B} \mid x\right)$.

An algorithm incorporating the RF model based on decision trees was selected because it is a natural extension of the decision logic developed for the initial lead service line inventory. Further, there is a precedent for incorporating RF as part of lead service line models as discussed by Abernethy et al. (2018), Chojnacki et al. (2017), and Goovaerts (2019) for Flint, Michigan; Gurewitsch (2019) for Pittsburgh, Pennsylvania; and Ardila et al. (2016) for Chicago, Illinois. The approach has the capacity to give priority to existing classification rules, to generate new rules based on the discovery of relationships between input and output variables, and weight specific observations. Furthermore, this approach offers the means to audit and explain the decision-making process through machine learning explanation tools (Biecek and Burzykowski 2019). Finally, is robust to data on different scales of measurements as well as categorical data.

The RF algorithm is a non-parametric tree-based estimator focused on reducing prediction variance through the use of randomization (bagging) and the majority-votes principle of an ensemble (Breiman 1996).; as discussed in the text above. The assumptions of this approach are like other parametric and

non-parametric classification models. Namely that the input data consist of a set of observed outcomes in specific classes and a series of variables that lend to the discrimination of the observed classes. It is assumed that the observed classes are *exchangeable*, meaning that the reordering of each observation does not change the outcome (i.e. the data do not represent a time series or possess some other inherent ordering). It is also assumed the explanatory variables are not highly correlated, however RF is less affected by this property compared to other models. Finally, for the purposes of model diagnostics and scoring, it is assumed that the model residuals are normally distributed (violations of this assumptions can be verified, and appropriate action taken to control for this). It is acknowledged that spatial correlation will lead to bias in the assumptions of exchangeability and residual distribution. For these reasons' additional steps for spatially valid cross-validation and neighborhood random effects are being explored.

Model Updates

The model enhancements will change the approach from inventory to prediction, based on field validated results. The predictive model will support decisions regarding the location of future construction activities, will provide support for long-term strategies to maintain the 7.0% target for lead service line replacements, and will be referenced by the Communications, Outreach, and Education Program (COE Program). This will be completed by transforming estimates of the presence of lead service lines into actionable items and developing a better understanding of the likelihood (or not) of finding a lead service line.

The predictive model will support Denver Water's annual ALSLR Plan by allowing Denver Water to focus efforts on the areas with a higher likelihood of lead. It will also be used by Denver Water to determine where additional investigation of service line type or service line material activities are needed, particularly at properties enrolled in the Filter Program (i.e., possible lead service). It is anticipated that this model will be updated when field results are available from the previous year's activities. Both the model data inputs, the model itself, and the output property lead service line probabilities will be assessed after each update to support the development and prioritization of construction work areas. It is currently projected that the model will be run twice a year to include probability and consequence updates to support enrollment in the Filter Program and construction sequencing of the ALSLR Program.

Model Performance Analysis

Model performance assessment involves several approaches and metrics. The area under the receiver operator characteristic (ROC) curve is computed. The area under the curve (AUC) is a measure of the probability that the model will assign a higher probability to a randomly selected lead tap versus a randomly selected non-lead tap. A value of 50% means the model is no better than random guessing. Residuals (errors between predictions and outcomes) also can be examined for patterns. Additionally, several metrics capturing different aspects of classification accuracy can be computed for different threshold p-values. These include: sensitivity (true positive rate, i.e. the fraction of lead taps correctly identified); specificity (fraction of non-lead taps correctly identified); accuracy (fraction of positives and negatives together correctly identified over all taps); precision (the fraction of predicted positive taps that turn out to be positive); F1 score (the harmonic mean between precision and sensitivity); and the false negative rate (fraction of lead taps predicted to be non-lead) among others.

In addition to model performance metric, structural aspects of the model and data will be considered. Independent variables will be examined for the strength of their contribution to the p-value. This can include an assessment of the loss in predictive capability when a variable of interest is resampled randomly (i.e. its value is selected randomly from existing values), and plots of p-values as a function of the value of a particular variable (all others held constant). These methods allow one to simplify the model or otherwise take into account information in the data. For example, identification of correlations between independent variables can be useful to model development.

Prioritization

Properties with a known, suspected or possible lead service will be prioritized for i) Filter Program enrollment and ii) ALSLR implementation. The results of the prioritization analysis will be used to identify areas having the greater potential to benefit from the ALSLR Plan while considering logistical needs.

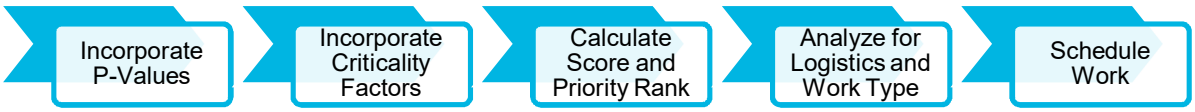
Prioritization involves developing a risk-based approach for long-term construction activity planning that accounts for impacts to public health, equity and environmental justice as well as logistical issues related to other planned capital improvements. The prioritization evaluation will be completed by integrating the p-value from the lead service line Inventory with a measure of consequence.

There are three primary factors that are used to develop a prioritization. These include i) a probability of having a lead service, ii) considerations that affect the consequence of lead exposure, and iii) logistical constraints that need evaluation to turn planning into work activities. Each of these individual components are incorporated into an analytical process for evaluation.

The analytical process consists of gathering the datasets from the respective sources and compiling them into a Geographic Information Systems (GIS) centric environment. Once all the datasets are obtained, they are combined with the lead service line inventory data to create one source of information. The information is then used to calculate the resulting likelihood and criticality scores which are computed from each individual service line location represented in the lead service line inventory. Upon completion of the individual risk calculations, the scores are totalized to the census tract area for normalization analysis

the results of this analysis are incorporated into a multistep process that incorporates logistical constraints and then be administered for construction activities as shown in Figure III.B.3-3 (Prioritization Process).

Figure III.B.3-3. Prioritization Process



Prioritization and Confirming a Lead Service

Under the current Lead Service Line Inventory, properties with known, suspected or possible Lead Service Lines will be included in the Filter Program and be placed in the ALSLR Program. In order to implement the ALSLR Program prioritized sets of actionable properties must be extracted from the Lead Service Line Inventory based on risk and placed into contracting groups (see below and in Appendix III.D.1). Actions taken on properties within these groups will be based on the group type and their lead service lines status. These are presented in Table III.B.3-2 (Lead Service Line Status Cohorts and Actions).

Table III.B.3-2 Service Line Category and Actions

Group	Service Line Category	ACTION AND RESPONSES		
		Filter Program	Lead Inventory	ALSLR Program
A	Known lead service line	Provide Filter	Add to lead inventory as confirmed lead	1. Add to list for replacement 2. Remove from inventory / Filter Program through replacement
B**	Suspected and possible lead service line	Provide Filter	Confirm materials (per Table III.D-6)	1. Add to list for replacement 2. Remove from inventory / Filter Program through replacement
C	Unlikely lead service line	Desk-top review / COE as necessary. Review predictive model output regularly for change in service line material assumption		
D	Confirmed to be lead-free	COE Program		
E***	Other (fire lines, recycled water taps, consecutive system)	No Action / COE Program		

*Table was developed using information in Appendix III.B.2 (Preliminary Identification of Lead Service Lines).

**Water Quality sampling will be limited to clusters or groups of properties in Group B.

*** Inclusion in Group E is based on application process, not likelihood of lead. Service lines will be maintained in the inventory, should the application change in the future. Provide COE that indicates the water supply is not a suitable source of drinking water.

The preliminary set of service line category and actions shown in Table III.B.3-2 (Service Line Category and Actions) are based on the current lead service line inventory predictions. This approach is conservative in the sense that properties with a possible lead service line status are included in the Filter Program. The predictive model that is under development will reduce this uncertainty and refine the inventory lead service line status and allow for refinement of the target properties over time.

Revisions to the inventory lead service line status based on future updates and learning by doing will allow action levels to be refined as needed to assess the estimated number of lead services and how this is reported.

Properties classed as having a known or suspected lead service will be visited and subject to an investigation with the lead service replacement performed as necessary. Properties identified as possible lead service lines will be investigated by either water quality sampling, and/or potholing as necessary (in that order) to confirm service line material. Those properties found to have a lead service will have it replaced. Properties confirmed to have no lead will be taken off the Filter Program. Properties unlikely to have a lead service will be given a record review, customer outreach and or visual inspections,

water quality as necessary (in that order) to confirm service line material. The results of these investigations will provide data to verify the results of the model and improve its predictive power.

Probability Factors

The probability of the presence of a lead service is determined primarily through the lead service line inventory p-values (see Appendix III.B.2, Preliminary Identification of Lead Service Lines), and through the predictive model p-values in future updates. Subsequent actions can be taken to revise these numbers. These include:

- Digging or potholing
- Water quality sampling
- Visual inspections (by field crews)
- Customer outreach
- Additional and/or more detailed records review

Digging and potholing is considered definitive confirmation of service line material. The validity of the remaining methods in assigning service line status will be evaluated as part of the ALSLR, and where appropriate such information integrated into the predictive model.

Criticality Factors

The criticality factors are used to describe the potential impact of lead exposure, based on features unique to a property such as water quality sampling results or the demographics of the occupants. These factors are selected to consider the health consequences of lead exposure in the larger context of health equity and environmental justice (HE&EJ).

The consequence of lead exposure provides a priority categorization separate from the likelihood of lead. It provides additional justification for selecting work locations on a yearly basis. Each property of the Lead Service Line Inventory will be evaluated based on health impacts of lead exposure, equity and environmental justice. Criticality factors associated with each property will be identified and weighted. The criticality factors and weights can be defined by analysis tools and/or stakeholder consensus agreement. The process to develop the criticality score is presented in Figure III.B.3- 4 (Criticality Weighting Process).

Figure III.B.3-4 Criticality Weighting Process

Table III.B.3-3 A list of proposed criticality factors and their weights developed in consultation with EPA and CDPHE presented in Table III.B.3-3 (Proposed Criticality Factors and Weighting). Each factor's

values are expressed as a score on a scale of zero (0) to one (1) and a weighted combination computed as shown below. Values for factors will be determined based on the best available data. In some cases, estimates will need to be substituted for missing values (e.g. using an average age for a missing age attribute).

Table III.B.3-3 Proposed Criticality Factors and Weightings

Criticality Factor* (Cf)	Description	Criticality Co-efficient*	Criticality Weight*(%) (Cw)
Public Health Consideration	Odds Ratio (OR) Contours from the Spatial Confounder-Adjusted Spatial Risk Model (Berg, et al, 2017)	Spatial risk odds ratio for elevated childhood blood lead level	0.2
Filter Adoption Rate**	Areas where filter adoption is low.	Non-successful filter adoption X 1) / total number of customers per area	0
Critical Customers	Day care centers child care providers, schools, dialysis centers, formula fed infants	Count of critical customers	0.3
Age (Census Data)	Children	Population estimates of children under 5 years of age	0.4
	Expecting Families	Population estimates of existing families within XX-XX years of age***	
Socio-Economic Factors	Probability of being below the Federal Poverty Level	Population estimates of Residences that fall under the defined federal poverty level	0.1
	Median Income Level	Weighted Income Distribution	
		Criticality Weight Total:	1

* List of criticality weightings currently in use changes shall be based on learn by doing or coordination with CDPHE and EPA.

** To be incorporated in future model iterations

*** Based on available data from the 2010, 2013-2017 ACS data that encompasses medically derived age bearing years. Considerations from CDPHE and EPA are recommended.

The Odds Ratio from the Spatial Confounder data was converted to a score of zero (0) to one (1), with a ratio of 1 set to 0.5 (see Equation 1, where OR is the odds ratio). In addition, a default value of 0.5 was set for locations that were within the extent of the odds ratio data.

Equation 1 Odds Ratio Score Rescaling

$$\begin{cases} OR < 1 & \sqrt{\frac{OR}{\max(OR)}} + mult1 * \left(\frac{\sqrt{\frac{OR}{\max(OR)}}}{\sqrt{\frac{1}{\max(OR)}}} \right) \\ OR \geq 1 & \sqrt{\frac{OR}{\max(OR)}} + \frac{mult1}{mult2} * \left(1 - \sqrt{\frac{OR}{\max(OR)}} \right) \end{cases}$$

$$mult1 = 0.5 - \sqrt{\frac{1}{\max(OR)}}, \qquad mult2 = 1 - \sqrt{\frac{1}{\max(OR)}}$$

Other factors' values were split into five (5) groups using Jenks natural breaks, and a score assigned to each group (0, 0.2, 0.5, 0.8 and 1). With all criticality factors scored on a scale of zero (0) to one (1), the weighted criticality score (between 0 and 1) is calculated as follows:

Equation 2 Consequence of Lead

$$F_{LSL_C} = Tap\ Prioritization\ Ranking\ Value$$

$$F_{LSL_C} = (Cw1 * Cf1) + (Cw2 * Cf2) + (Cw3 * Cf3) \ldots$$

The list of criticality factors has gone through an analysis to evaluate the data usage and their alignment with HE&EJ and program goals. Each one of the criticality factors was given different weights and run through the prioritization model to better understand the sensitivity of the criticality factor as it relates to output and the performance to meet the objectives of the LRP Program. This sensitivity analysis showed how adjustments to weights affected the outcome to guide the factors considered and their preferred weightings. For example, the dataset that included an older population category was removed to focus on customers more vulnerable to lead exposure. In coordination with CDPHE, review of the criticality model indicated that additional information, such as data from women, infant, and children (WIC), is most beneficial for inclusion as critical customers. The current weights as shown in Table III.B.3-3 (Proposed Criticality Factors and Weighting) were chosen to ensure the risk score is in alignment with HE&EJ and program goals and will continue to evolve in coordination with CDPHE and EPA.

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Risk Factors

Once the individual likelihood (probability of lead, p-value) and criticality scores are generated for each property, a risk score is then calculated for the property to establish the individual risk score (Equation 3 Individual Risk Score).

Equation 3 Individual Risk Score

$$Risk = Probability\ of\ lead\ x\ Criticality\ of\ lead$$

Individual risk scores are totalized to a common spatial boundary (i.e., the 2010, 2013-2017 Census Neighborhood Blocks / American Census Survey records (ACS)) to establish an overall risk score. The result of this is the aggregate risk over an area that is normalized to take into account density by summing over parcels with taps and dividing by the area of parcels with taps in each census area. (Equation 4 Normalized Risk Score).

Equation 4 Normalized Risk Score

$$Normalized\ Risk = \frac{\sum(Probability\ of\ lead\ x\ Criticality\ of\ lead)\ for\ parcels\ with\ tap}{\sum Area\ of\ Parcels\ with\ Tap}$$

This process allows for the control of differences in area/size between spatial units (larger areas tend to have more taps, while at the same time some areas have significant open spaces with no taps). The result of this analysis is that individual and accumulated risk scores can be assigned to a spatial feature based on occupied area rather than total area. Additional issues can then be considered in the prioritization process, including logistics and ALSLR contracting work development.

Using Risk Scores to Prioritize Construction and Filter Distribution

The process used for establishing priority ranked activities is based on the results of the probability and consequence evaluations. The goal is to take the risk scores from all the (census) areas and look at replacing lead services in a way that addresses both the (high) risk of lead exposure at a property and the efficiency of working through an area of properties to consider the risk to a broader portion of the community. This is considered a geographical construction area. Additionally, locations that are high risk that are not incorporated in a census area for production are also evaluated for sequence of constructions as part of individual construction activities. As a result, lead service replacements may be completed on an individual basis or as part of a larger grouping of properties.

Both the prioritization risk scores that are established for individual locations and grouped together in the Census survey areas are used to produce lists where both the greatest probability and the greatest consequence is considered. An example of how the individual and combined scores (from Equations 2 and 3) will be applied is described in Table III.B.3-4 (Applying Risk Scores for Prioritization).

Table III.B.3-4 Applying Risk Scores for Prioritization

Risk Score Types	Description
Individual	Individual scores are considered for properties defined as high consequence but are geographically isolated.
Geographic Area	Combined scores are considered for properties where the categories of known and possible lead scores define an area.

Evaluation of the two types of risk scores is the basis to prioritize i) enrollment in the Filter Program, ii) sequencing the ALSLR Program contracting needs, and iii) communication efforts. Additionally, the output from this analysis shows where additional investigative efforts are needed to drive the LRP and

sustain the year-over-year annual targets for the number of lead service line replacements. As described above, all properties in a high-risk contractor group derived using census areas will be investigated.

The Predictive Model and Coordination with Other Capital Programs

The results from the predictive model in terms of prioritizing lead service line replacements will be evaluated with other activities within the Denver Water service area for scheduling and coordination of construction. Other considerations (mobilization, street repair, scheduled water main replacement, etc.) are necessary scheduling components to minimize repeat visits to the same street or block and to efficiently complete the necessary lead service line replacements. The logistical considerations (see Table III.B.3-5, Predictive Model and Coordination with Other Capital Programs) will influence the development of construction activities. Additionally, information related to current customers will be identified to ensure that work is performed at connected services.

Table III.B.3-5 Predictive Model and Coordination with Other Capital Programs

Coordination Item*	Description
Previously Completed Partial Replacements (where some portion of the service line is still lead)	Public to curb box previously completed; follow-up work outside of the full replacements
Water Main Replacement Program Schedule	ALSLR based on scheduled water main replacements
Long-term Roadway Full Depth Resurfacing Plan	Full depth or resurfacing roadway projects in areas susceptible to lead services
Leak Repairs and Operation and Maintenance Activities	ALSLR based on a response to reported leaks or necessary maintenance
Redevelopment Properties	City of Denver Development in areas susceptible to lead services
Archeological / Cultural / Historic Areas / Locations	Identification of areas requiring more sensitive construction coordination and approval
Property Type (Single Family Commercial / Industrial / Multi-dwelling units)	Building inventory of data regarding residential, commercial, and industrial units
Active Water Account	Identifies taps that have service agreements
Property Status	Identification of property status (occupied, abandoned, etc.)

Implementing the Predictive Model Outcomes

Upon completion of the analysis phase, information for i) individual and grouped risk scores and ii) logistical considerations that exist within the Denver Water service area will be available to support the annual planning cycle for the LRP. The next step is to apply the results to the Filter Program and ALSLR Program.

Filter Distribution Prioritization

Filter distribution will target the properties with a known, suspected, or possible lead service line under the current lead service line inventory. The predictive model will be used to identify the risk category for each census area to allow a sequence of distribution of the Filter Program based on starting at the highest risk areas and working down in priority.

ALSLR Prioritization

The process used to develop the ALSLR Program construction sequence is presented in Figure III.B.3-5 (The Role of the Prioritization Analysis for Annual Updates to the ALSLR Plan). This is based on taking the results from the predictive model and prioritization analysis to establish the annual ALSLR work activities.

Figure III.B.3-5 The Role of the Prioritization Analysis for Annual Updates to the ALSLR Plan

The predicative model and consequence data will be used to identify candidate properties for the different ALSLR contracting groups presented in Appendix III.D.1 (see Table III.D.8 Contracting Groups Summary). The contracting groups include:

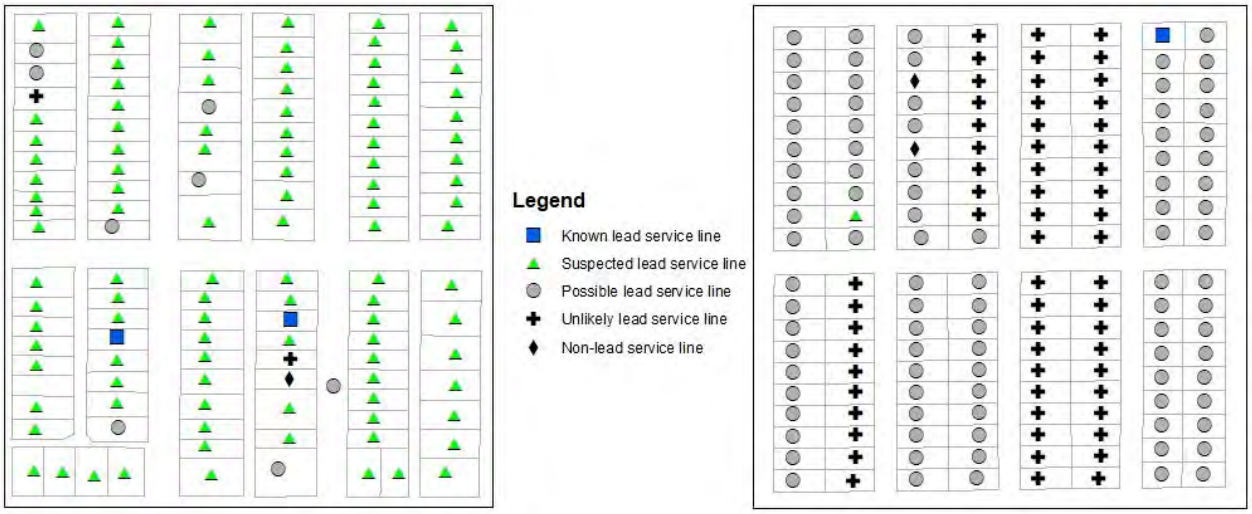
- Group A – Geographic Area ALSLR Type
- Group A – Individual ALSLR Type
- Group B – Investigation

The risk scores developed from the prioritization analysis will be used to further define the groups and sub-group categories that will comprise the yearly work plan.

Group A - Geographic Area ALSLR Work Type

The list of properties with a known lead service included in Group A – Geographic Area ALSLR will be generated from the output of the prioritization risk analysis. Grouped risk score areas will be reviewed to identify the highest priority areas for inclusion in the annual ALSR Program's scope of work. The properties associated with the identified areas will be collectively issued to contractors for replacement of lead service lines on blocks or streets as needed. Figure III.B.3- 4 (Geographic and Individual Area Visual Representation) shows an example of an area selected for the ALSLR Program. In this example, the results of normalized risk (Equation 3) were used to identify the work area. This geographical area shown below would hypothetically receive a high priority ranking and would incorporate all the properties within the boundary for the contract in accordance with the yearly construction goals. As described above, all properties in this group will be investigated using progressively more invasive methods based on p-values.

Figure III.B.3- 4 Geographic Area (left) and Individual Map (right) Visual Representation



Group A – Individual ALSLR Work Type

The properties with a known lead service included in Group A – Individual ALSLR are properties that were individually prioritized as “high” but are not in close enough proximity (geographically) for inclusion in the geographic lead service line replacement areas. This ASLR contracting strategy takes into consideration where critical properties would not typically rise to the top of the list from a grouped risk-based analysis. Figure III.B.3- 4 Geographic and Individual Area Visual Representation defines an area where the density of properties is low, but a select group of properties were defined to be critical for prioritized construction activities. In this situation the individual risk score (equation 3) was evaluated and the top ranked properties were identified in accordance with the yearly construction goals.

Group B – Investigation Work Type

The goal of investigation work areas is to gather more information where necessary to produce better predictive model results in areas where available information is limited and to provide a more representative sampling of data. Investigation type activities include detailed records review, non-intrusive inspections, water quality sampling and potholing to support the ALSLR construction and planning. In areas where there are groupings of similar properties with similar p-values, then a sample of the total group population will be investigated to evaluate the composition of taps at these properties.

Another example for where investigation is needed occurs at properties for which risk is high due to a high consequence of having a lead service, but the likelihood of lead is relatively low. In this case, investigations as described above will be performed to determine service line material and support better model prediction outcomes as new iterations of the predictive model are run.

APPENDIX III.C.1 - FILTER ADOPTION

September 2019

DENVER WATER

Appendix III.C.1

Lead Filter Program Sample Size Required for Determining Rate

Date:	Revised August 16, 2019 March 14, 2019
To:	Denver Water
From:	Corona Environmental Consulting, LLC

Executive Summary

The objective of this memorandum is to develop a statistical method to estimate the number of Denver Water customers that adopt a lead filter and therefore reduce their exposure to lead in their drinking water. To meet this objective, the memorandum answers the following question: "How many Denver Water customers must respond to the lead filter program survey to sufficiently estimate filter adoption rate for all customers provided a lead filter?" Survey responses from 1,059 or more randomly selected Denver Water customers that received lead filters are needed to estimate the filter adoption rate (p) with at least 95% confidence and no more than 5% error, based on an adoption rate greater than 60%. Distributing the survey to a group of 1,250 Denver Water customers that received a lead filter is recommended to achieve the requisite survey response from 1,059 random surveyed customers while limiting the self-selection bias.

Introduction

Corona prepared a statistical approach to support Denver Water's efforts in understanding the required number of customers to be surveyed to sufficiently estimate point of use filter device adoption rates. Denver Water is investigating a program to provide filter devices to customers to protect them from lead exposure. When used properly, filter devices are effective at removing dissolved and particulate lead from drinking water. Therefore, the effectiveness of the filter devices in protecting Denver Water customers from lead exposure relies on customers' adoption of the devices. Filter device adoption assumes customers are installing, using and maintaining the device properly, as well as replacing the filters at the appropriate time. Customers not using the filter device but relying on bottled water for drinking and cooking will also be considered an adoption. Corona's statistical approach described in this memorandum details the number of customers that received a filter device that need to be surveyed based on the acceptable confidence level and the error in the estimated filter device adoption rate.

Statistical Analysis

The objective of the statistical analysis is to estimate the number of Denver Water customers that adopt their lead filter and therefore reduce their exposure to lead in their drinking water. The total number of Denver Water customers that adopt their lead filter can be estimated using the total number of Denver Water customers that receive a lead filter and the filter adoption rate for this entire population. To avoid having to survey the entire population of customers receiving a lead filter, a statistical analysis can be used to estimate the filter adoption rate utilizing a subset of the population. To determine the

subset sample size required, the adoption rate distribution, confidence level, and acceptable error must be considered.

Lead filter adoption takes on a binomial distribution of "adoption" or "lack of adoption" (e.g. 1 or 0), which gives a discrete probability distribution of Bernoulli trials. A Bernoulli trial is an event that has two possible outcomes, such as flipping a coin. Each filter adoption, or lack of adoption, can be described as a Bernoulli trial because there are only two possible outcomes: adoption ("success") or no adoption ("failure"). We assume each customer's lead filter adoption, or lack of adoption, is independent of other customers' filter device adoption, and therefore, each "trial" constitutes a random, independent experiment. This assumption that each customer's filter adoption is not dependent on any other's customer's filter adoption emphasizes the need for Denver Water to ensure that surveyed customers are randomly selected. More information on the recommended survey procedure to prevent sampling bias is provided in the following section. We also assume that the probability, p, of a success in each trial remains constant. This means that we assume the probability that each customer will adopt the lead filter is constant and equal to some value p. Because actual adoption may not be constant, we recommend Denver Water repeat the survey annually.

The binomial distribution has a mean np and variance $np(1-p)$ where n is number of Bernoulli trials. In the context of this memorandum, n is equal to the number of surveyed Denver Water customers offered lead filters. The number of surveyed customers who have adopted their filter are defined as X, where $X \leq n$. The quantity X/n is the point estimator ($\hat{P}$) of the filter adoption rate (p) for all customers receiving a lead filter. The binomial distribution is described in further detail in the Appendix. The descriptions were developed utilizing Montgomery & Runger (2007)[1].

The size of the confidence interval, which can also be defined as the difference between the true proportion of all Denver Water customers' filter adoption rate, p, and the proportion of surveyed customers' lead filter adoption rate, $\hat{p}$, is dependent on both α, which defines the confidence level, and n, the sample size of surveyed customers[2]. By defining the error $E = \left|p - \hat{P}\right|$ and selecting an acceptable error (i.e. 0.05) and an acceptable statistical power (i.e. 95%) that *E* is less than our acceptable error, we can determine the required sample size utilizing the statistical computing software R package Binomial Confidence Intervals For Several Parameterizations ("binom")[3]. The power of a statistical test is the probability of rejecting the null hypothesis H_0 when the alternative hypothesis is true, which can be interpreted as the probability of correctly rejecting the false null hypothesis. In this application, the alternative hypothesis is true if the true proportion of all Denver Water customers' adoption rate p is greater than the proportion of surveyed customers' adoption rate $\hat{p}$ minus the error E.

$$H_0: p = \hat{p} - E$$

$$H_0: p > \hat{p} - E$$

Figure 1 illustrates the relationship between the survey sample size of Denver Water customers needed to estimate the filter acceptance rate and the acceptable error and confidence level. Table 1 summarizes

[1] Montgomery, D.C. & Runger, G.C. 2007. Applied Statistics and Probability for Engineers: Fourth Edition. John Wiley & Sons, Inc. USA.

[2] Note that $\hat{P}$is a random variable point estimator for the filter device adoption rate (p) and $\hat{p}$ is the filter device adoption rate for surveyed Denver Water customers.

[3] Dorai-Raj, S. 2015. Package 'binom'. "Binomial Confidence Intervals For Several Parameterizations. Accessed 5/8/2019. https://cran.r-project.org/web/packages/binom/binom.pdf

the required sample sizes for acceptable errors of 10%, 5%, and 1% and for filter adoption rates of 50%, 60%, 70%, 80%, 90%, and 95% assuming 95% statistical power. To ensure, with 95% statistical power, that the sample size filter device acceptance rate, of at least 60%, is within 5% of the entire customer population filter acceptance rate, responses would be required from 1,059 random surveyed customers. If the adoption rate falls to 60% with the sample size of 1,059 random surveyed customers, the error of the estimate increases by less than 1%. Therefore, we recommend a sample size of random surveyed customers of 1,059 to be both achievable and representative.

Figure 1 Survey sample size based on acceptable error and filter adoption rate using a binomial distribution assumption with 95% statistical power

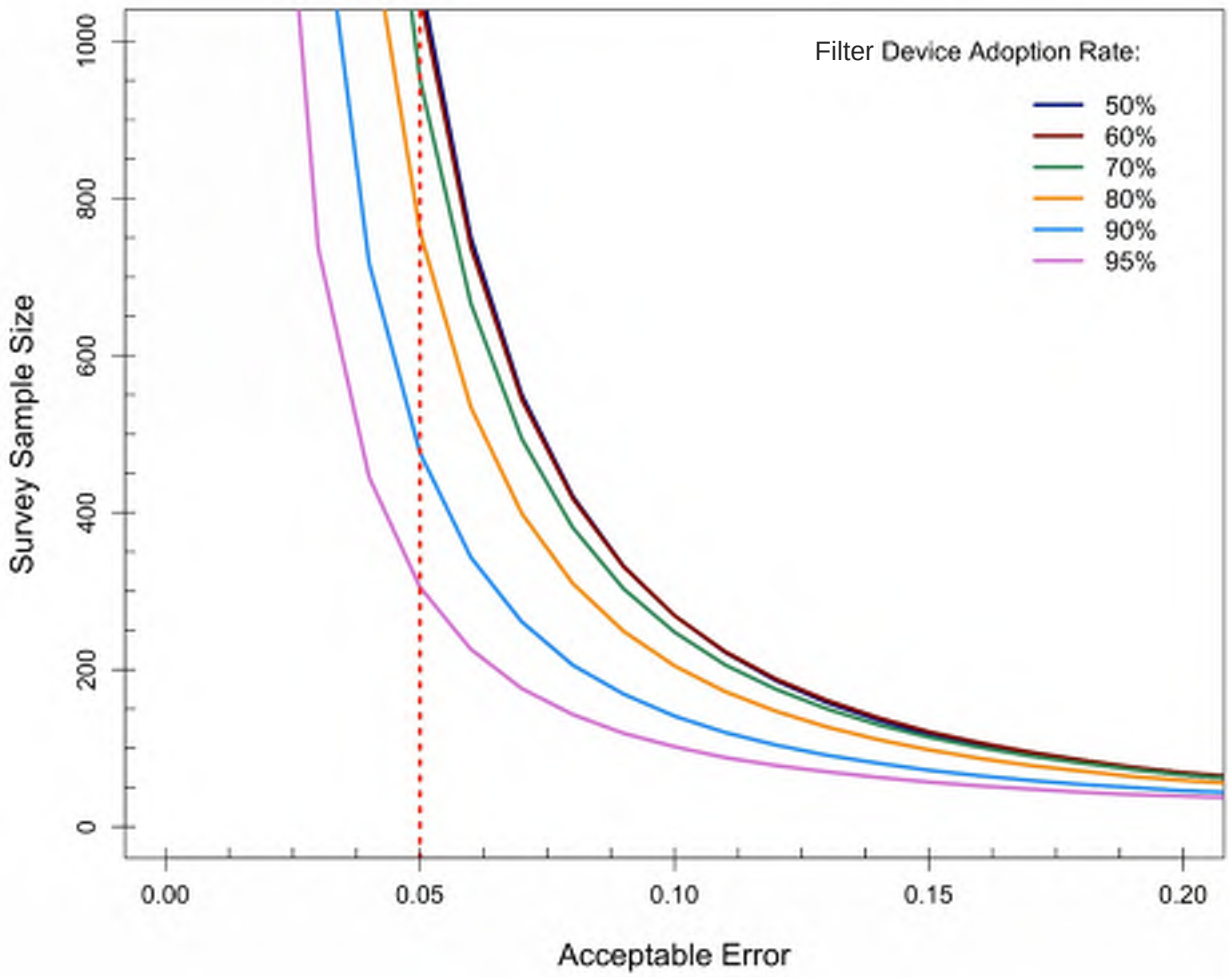


Table 1 Required sample size of surveyed customers based on acceptable error and filter adoption rate and 95% statistical power

Acceptable Error	50% Adoption	60% Adoption	70% Adoption	80% Adoption	90% Adoption	95% Adoption
10%	n=269	n=269	n=248	n=205	n =141	n=102
5%	n=1,081	n=1,059	n=951	n=757	n=476	n=305
1%	n=27,054	n=26,080	n=22,942	n=17,640	n=10,173	n=5,630

Alternatively, a normal approximation can be assumed for the point estimator $\hat{P}$ of the filter adoption rate (p) for all customers receiving a lead filter if the sample size (n) is sufficiently large and p is not too close to 0 or 1. To apply this approximation, we require that np and $n(1-p)$ are greater than or equal to 5. The normal distribution, standard normal distribution and the normal approximation and confidence interval for the probability p that each customer will adopt the filter are described in detail in the Appendix.

Using the normal approximation, the size of the confidence interval, which can also be defined as the difference between the true proportion of all Denver Water customers' filter adoption rate, p, and the proportion of surveyed customers' filter adoption rate, $\hat{p}$, is dependent on both α, which defines the confidence level, and n, the sample size of surveyed customers[4]. If we define the error $E = \left|p - \hat{P}\right|$, and we select an acceptable error (i.e. 0.05) and an acceptable confidence (95%) that *E* is less than our acceptable error, we can determine the required sample size as:

$$n = \left(\frac{z_{\alpha/2}}{E}\right)^2 p(1-p) \qquad \textit{Equation 1}$$

Using the exact binomial distribution results in a more conservative sample size requirement as compared with the normal approximation assumption. Therefore, if the surveyed customers' filter adoption rate is greater than 60% a sample size of 1,059 for survey responses from Denver Water customers is a sufficiently conservative requirement to determine that the filter adoption rate for all Denver Water customers receiving a lead filter is within 5% of the surveyed customers' filter adoption rate.

Sample Selection and Verification

A random selection of 1,250 customers from the group of all of the customers provided a filter should be performed each year. The customers selected and the corresponding surveys received should be randomized based on geography and demographics. Efforts to achieve the requisite response rates (e.g. at least 1,059 of 1,250) must be undertaken to prevent self-selection bias in the reporting group. These efforts may include mailings, phone calls, and site visits to the randomly selected customers. Community groups present an opportunity to leverage independent parties that might obtain higher response rates and a higher level of truthfulness in the responses.

Even though the number of respondents may approach a level of confidence and error that are acceptable, efforts should be continued to complete responses from all the customers selected for

[4] Note that $\hat{P}$is a random variable point estimator for the filter device adoption rate (p) and $\hat{p}$ is the filter adoption rate for surveyed Denver Water customers.

verification. A high response rate from the random selection ensures a full representation of the diversity of Denver Water's customer base.

Recommendation

For the lead filter program to be considered successful, the adoption rate needs to be greater than or equal to 60% for equivalence. However, Denver Water should continue efforts to maximize the adoption rate. Corona recommends obtaining responses from a minimum of 1,059 customers out of a randomly selected group of 1,250. The survey should be repeated on an annual basis to detect changes in adoption rate over time. Responses from 1,059 randomly selected customers would achieve 95% confidence that the true sample adoption is within 5% of the subsample adoption if the subsample adoption is above 60%. If the subsample adoption is greater than 60%, then the confidence is increased and/or the error is decreased. If the subsample adoption is lower, then Denver Water should take measures to increase the adoption rate.

Appendix

Binomial Distribution

A random experiment consists of n Bernoulli trials such that

(1) The trials are independent
(2) Each trial results in only two possible outcomes, labeled as "success" and "failure"
(3) The probability of a success in each trial, denoted as p, remains constant

The random variable X that equals the number of trials that result in a success has a binomial random variable with parameters $0 < p < 1$ and n = 1,2,…. The probability mass function X is:

$$f(x) = \binom{n}{x} p^x (1-p)^{n-x} \qquad \textit{Equation 2}$$

$\binom{n}{x}$ equals the total number of different sequences of trials that contain x successes and $n - x$ failures. The total number of different sequences that contain x successes and $n - x$ failures times the probability of each sequence equals $P(X = x)$.

If X is a binomial random variable with parameters p and n, the mean $\mu = E(X) = np$ and the variance $\sigma^2 = V(X) = np(1-p)$.

Normal and Standard Normal Distributions

A normal random variable X from a normal distribution with mean μ and variance σ^2 can be standardized by the following:

$$Z = \frac{\bar{X} - \mu}{\sigma} \qquad \textit{Equation 3}$$

Z is then a standard normal random variable with a standard normal distribution. A standard normal distribution is a normal distribution with mean μ=0 and variance σ^2=1. The standard normal distribution probability density function is described below by $P(x)$:

$$P(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2)/(2\sigma^2)} = \frac{1}{\sqrt{2\pi}} e^{\left(-x^2/2\right)} \qquad \textit{Equation 4}$$

To determine the probability that the standard normal random variable Z is less than or equal to some value z, written as $P(Z \leq z)$, we can use the cumulative distribution function of a standard normal random variable, denoted as $\Phi(z)$, which is found by integrating the probability density function:

$$\Phi(z) = P(Z \leq z) = \int_{-\infty}^{z} \frac{1}{\sqrt{2\pi}} e^{\left(-z^2/2\right)} dz \qquad \textit{Equation 5}$$

To determine the probability that Z is greater than some value z, $P(Z > z)$, we can utilize the fact that the integral of the probability density function taken from -∞ to ∞ is equal to 1:

$$P(Z > z) = 1 - P(Z \leq z) \qquad \textit{Equation 6}$$

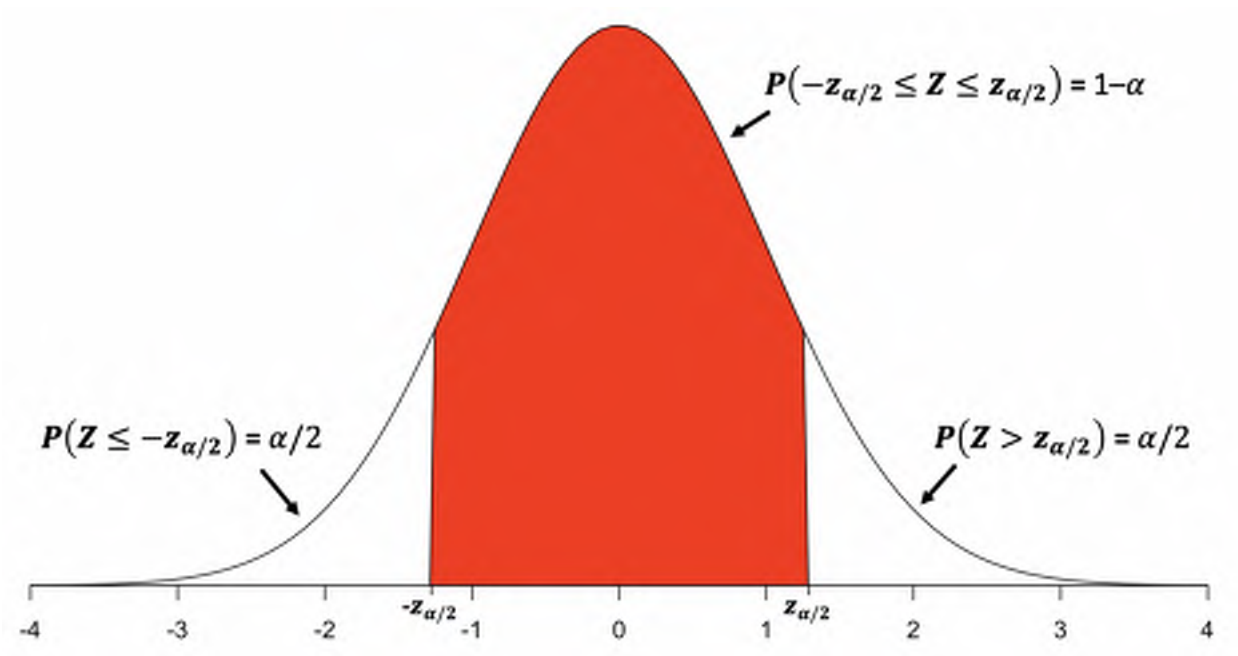
For a standard normal distribution, we can define the probability that Z is within a defined confidence interval with a confidence level of 100(1-α)% by:

$$P\left(-z_{\alpha/2} \leq Z \leq z_{\alpha/2}\right) \cong 1 - \alpha \qquad \textit{Equation 7}$$

where $z_{\alpha/2}$ is defined as the z value that corresponds with the upper $\alpha/2$ percentage point of the standard normal distribution (see Figure 2). Alternatively, we can say with 100(1-α)% confidence that:

$$-z_{\alpha/2} \leq Z \leq z_{\alpha/2} \qquad \textit{Equation 8}$$

Figure 2 Standard normal distribution showing confidence intervals for Z



Large Sample Confidence Intervals for the Mean of a Normal Distribution

In the case of sampling from a normally distributed population with an unknown mean and a known standard deviation σ with the objective to estimate the population mean, a large sample confidence interval for the mean μ can be determined if the sample size is sufficiently large. Given the assumption that the sample size is large, the central limit theorem can be applied such that the sample mean $\bar{X}$ has an approximate normal distribution with mean μ and variance ${\sigma^2}/{n}$. Therefore, for a normal distribution with a large sample size:

$$Z = \frac{\bar{X} - \mu}{S/\sqrt{n}} \qquad \textit{Equation 9}$$

where: $\bar{X}$ is the sample mean,

μ is the distribution mean,

S is the sample standard deviation, and

n is the sample size.

The large sample confidence interval for μ for a confidence level of approximately 100(1-α)% can then be described as:

$$\bar{x} - z_{\alpha/2}\frac{s}{\sqrt{n}} \leq x \leq \bar{x} + z_{\alpha/2}\frac{s}{\sqrt{n}} \qquad \textit{Equation 10}$$

Normal Approximation to the Binomial Proportion

Using the normal approximation, the sampling distribution of $\hat{P}$ is approximately normal with mean *p* and variance *p*(1-*p*)/n. If Denver Water uses a sufficiently large sample size n and *p* is not too close to 0 or 1, the normal approximation for *p*, the probability that each Denver Water customer who receives a lead filter will adopt the filter, is equal to the following:

$$Z = \frac{\hat{P} - p}{\sqrt{\frac{p(1-p)}{n}}} \qquad \textit{Equation 11}$$

where Z has an approximate standard normal distribution. Using the normal approximation of the binomial proportion, we can use the standard normal confidence intervals to determine the following approximate confidence interval for our binomial proportion, p:

$$\hat{p} - z_{\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \leq p \leq \hat{p} + z_{\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \qquad \textit{Equation 12}$$

The error E between the true filter adoption rate among all Denver Water filter recipients p and the filter adoption rate among all surveyed Denver Water customers $\hat{p}$ can be defined as $E = \left|p - \hat{P}\right|$ where $\hat{P}$ is a random variable from a binomial distribution with mean *p* and variance *p*(1-*p*)/n. Thus, there is 100(1-α)% confidence that $E < z_{\alpha/2}\sqrt{p(1-p)/n}$. If we set $E = z_{\alpha/2}\sqrt{p(1-p)/n}$, we can solve for the sample size n.

LEAD REDUCTION PROGRAM PLAN

APPENDICES

VOLUME 2 OF 2

DENVER WATER

APPENDIX III.C.2 - FILTER PILOT

September 2019

DENVER WATER

TECHNICAL MEMORANDUM

To Denver Water
From Mott MacDonald
Date August 13, 2019
Project No. 507100139
Page Page 1 of 19
Subject Denver Water Lead Reduction Program (LRP)
Appendix III.C.2 Filter Pilot Plan

I. PURPOSE

The purpose of this Technical Memorandum (TM) is to summarize the framework for Denver Water's Filter Lead Out of Water (FLOW) Pilot program. The FLOW Pilot targets a subset of premises that will be included in the full-scale FLOW Program. The basis for the FLOW Pilot is twofold:

1. Demonstrate processes and workflows that can be used for the full-scale FLOW Program implementation.
2. Survey customers to obtain feedback on filter use adoption for at least 200 premises.

Presented herein is a summary of the background, processes and workflows, filter distribution methods, customer notifications, filter kit materials, follow-up/survey information, filter use adoption validation basis, schedule, and filter survey summary.

II. BACKGROUND

General

Denver Water serves high-quality drinking water to approximately 1.4 million people and continuously monitors water quality. Drinking water entering the distribution system prior to the connection to the customer's service line is free of lead. However, lead may leach into the drinking water as it stagnates in the customer-owned lead service line and/or premise plumbing.

Denver Water believes there is no safe level of lead in drinking water and is committed to taking steps to optimize its water system for control of lead by implementing a Lead Reduction Program (LRP). One element of Denver Water's LRP is FLOW, which includes the distribution of filters certified to NSF/ANSI Standards 53 to Denver Water households according to Denver Water's service line inventory, as follows:

Denver Water's service line inventory dated August 8, 2019 includes:

- 319,700 service lines used for drinking water in the Denver Water service area.
- 84,546 service lines identified as known, suspected and possible lead service lines – these premises are candidates for FLOW.

Multi-family properties are included in the 84,546 service lines that are part of the filter program. A multi-family property has multiple household units. A household unit is an individual residence that receives a filter. Using available data, it is estimated that Filter

Program participants consist of 119,250 Denver Water household units, with each household unit receiving a filter.

FLOW is used as the interim treatment barrier to remove lead from customers' drinking water until the lead service line is replaced or confirmed as non-lead. Denver Water is considering providing filters through the end of 15 years as Denver Water progresses through the inventory of lead service line properties and replaces lead service lines. Denver Water households using an NSF certified filter to reduce lead will experience a >97% reduction in lead levels.

Upon LRP approval, it is expected that the full-scale implementation of FLOW will commence immediately following the multi-media public information campaign and customer notification model in accordance with the Communication, Outreach and Education (COE) Plan. The success of the COE and FLOW is paramount to provide Denver Water with information and, also to share information with Denver Water households that does as much as possible to encourage filter use and education.

The goal of the FLOW Pilot is to distribute filters and collect follow-up surveys from at least 200 Denver Water households. The schedule for the FLOW Pilot is:

- General LRP press release by Denver Water on July 1, 2019.
- Distribute approximately 300 filters starting July 9, 2019.
- Collect and analyze follow-up surveys on filter usage from at least 200 Denver Water households by early August 2019.

Filter Type

As part of Denver Water's current practice, a pitcher filter is distributed by Denver Water to a Denver Water household:

- after the replacement of their lead service line, with five (5) months of replacement cartridges; or
- after potholing reveals a lead service line, with five (5) months of replacement cartridges.

Denver Water currently distributes a ZeroWater pitcher filter with the following features:

1. 10-cup capacity
2. NSF/ANSI Standards 42 and 53 certified
3. 5-stage filter with ion exchange that removes 99.6% of detectable dissolved solids, including lead and fluoride
4. filter cartridges replaced based upon average use (approximately 30-days for a Denver Water household)

In addition to pitcher filters, other filters certified to remove lead by NSF include: filters attached to the kitchen faucet and refrigerators filters. Denver Water will be able to purchase filters from multiple vendors that are NSF certified to remove lead and do not remove fluoride. A summary of available pitcher filters and available alternative filter

types and replacement cartridges for consideration by Denver Water is included in Appendix A.

Although Denver Water's available inventory of ZeroWater 10-cup pitcher filters remove fluoride, the ZeroWater pitcher filters were distributed for the FLOW Pilot due to the pilot schedule and use of Denver Water's stock of pitcher filters.

Filter Kit

Each participant of the FLOW Pilot received a kit with the pitcher (including a filter), three replacement filter cartridges (four total filter cartridges), and education/outreach material. Details on the pilot filter kit (education / outreach documents, pitcher filter and cartridge manufacturer instructions, packaging, and other contents) are included in Appendix B.

Filter Distribution Method

Filter kits were distributed to Denver Water households using various methods:

- Direct mail by Denver Water with tracking and delivery confirmation through USPS shipping software, Pirate Ship
  - USPS - Priority Mail (1 to 3 day delivery)
- Hand delivery by Denver Water or contractor
  - Door-to-door canvassing
    - In-person transaction
    - Drop-off

For the FLOW Pilot, Denver Water distributed approximately 300 filter kits as outlined in Table III.C.2-1.

Table III.C.2-1 Kit Distribution Breakdown

Distribution Method	Number of Denver Water households
Direct mail USPS	200
Door-to-door	100

Notification Methods

Notification methods that were employed in the FLOW Pilot are intended to be similar to those proposed for the full-scale implementation of the FLOW Program. Methods include:

- Direct mail and door-to-door delivery of filter kits (Appendix B) with a letter to the customer (Appendix C), detailed instructions regarding the FLOW Pilot, water filter cartridge use and replacement, an informational frequently asked questions (FAQ) explainer, a survey/response form (bilingual), a quick response (QR) code

for access to Denver Water's digital registration page (in lieu of mail-in survey/response), a reminder magnet for maintenance of the pitcher, and other related details. For the full-scale FLOW Program, the material will be available on Denver Water's website.

- Door-to-door canvassing of neighborhoods campaigns, neighborhood meetings, and additional strategic community outreach.
- Robo calls to impacted Denver Water households.
- Follow-up communication using mail, email, phone, and door-to-door survey.
- Offer water quality sampling to quantify the magnitude of lead release, if not previously sampled.
- Interview Denver Water households to determine whether or not an alternative means to reduce lead exposure is employed, such as an existing filter system (confirmed NSF certified to remove lead), or if the Denver Water households rely on bottled drinking water for infant formula, drinking, and cooking.
- Make one additional attempt to encourage the customer to use a filter, based on site specific information for materials of construction and the water quality sampling results.

In addition, water quality sampling and community outreach and education materials will continue to be provided to customers not in the FLOW Pilot, as requested.

Survey

The four categories of surveys for gathering information from FLOW Pilot participants about how filters are used for infant formula, drinking, and cooking activities include:

- **Initial Survey:** The intent of this survey is to obtain initial feedback from the Denver Water household. This survey is included in the hand-delivered and mailed filter kits. The questions in the initial survey are included in Appendix D. If the Denver Water household receives a kit and does not complete the initial survey, follow-up emails and phone calls were performed. A $15 Amazon gift card incentive was offered to the Denver Water household, upon completion of this survey, to encourage them to complete the survey. The Initial Survey is located at: denverwater.org/Lead-survey. Further details on follow-up are included in Table III.C.2-2.
- **Use Survey:** The use survey was sent to FLOW Pilot participants a week or two after they have received their filter kit. The primary intent of this survey is to confirm if a Denver Water household is using the pitcher filter for infant formula, drinking, and cooking. The survey includes an option if the Denver Water household prefers an alternative filter other than a pitcher filter, such as filters attached to the kitchen faucet or refrigerator filters. The questions in the survey are included in Appendix D. To remind the Denver Water household to complete the survey, Denver Water sent emails and made follow-up phone calls. A $15 Amazon gift card incentive was offered to the Denver Water household, upon completion

of this survey, to encourage them to complete the survey. The Use Survey is located at: denverwater.org/FLOW-survey.

- **Alternative Survey:** If a Denver Water household has an alternative filter installed, the alternative survey would be sent to confirm if the Denver Water household is using the alternative filter for infant formula, drinking, and cooking. The questions in the survey are included in Appendix D. If the Denver Water household receives an alternative filter and does not complete the survey, Denver Water sent emails and make follow-up phone calls to remind the Denver Water household to complete the survey. A $15 Amazon gift card incentive was offered to the Denver Water household, upon completion of this survey, to encourage them to complete the survey. The Alt Survey is located at: http://bit.do/LSL-AlternativeFilter. Alternative filter cartridge replacement schedules range from 3 to 8 months.
- **Ongoing Surveys:** The intent of this survey is to confirm if the Denver Water household is continuing to use the filter for infant formula, drinking, and cooking. Surveys will be conducted, monthly, in coordination with a reminder for the Denver Water household to change their pitcher filter cartridge. The survey will obtain feedback of the COE and the FLOW Pilot. The questions in the survey are included in Appendix D. Denver Water will send emails and make follow-up phone calls to remind the Denver Water household to complete the survey. A $15 Amazon gift card incentive will be offered to the Denver Water household, upon completion of this survey, to encourage them to complete the survey. The Ongoing Surveys are located at: http://bit.do/LSL-Ongoing. The schedule for the ongoing surveys is as follows:
    - August 26th - Follow-up phone calls/emails to remind participants to complete Use Survey, obtain feedback, and inform customer that pitcher filter cartridge should be replaced per manufacturer's recommendations*.
    - September 23rd - Survey - follow-up phone calls/emails to complete survey and inform customer that pitcher filter cartridge should be replaced per manufacturer's recommendations*.

    ** To evaluate the potential filter adoption rate, a survey of all participants of the FLOW Pilot was undertaken to measure filter use and understand reasons for non-adoption.*

For all surveys, Denver Water provides an online survey option that is mobile friendly (Snap Survey). Surveys included a unique website/Uniform Resource Locator (URL) and a Quick Response (QR) code and may be accessed by mobile phones. Each participant has a unique survey access code assigned, so that responses can be tracked to the Denver Water household.

Denver Water will follow-up to provide education on methods to reduce lead exposure; determine whether or not an alternative lead reduction strategy is used; and ultimately encourage the use of the filter for customers that either do not respond to the survey or communicate that the filter was not used.

Vulnerable Populations

Vulnerable populations, such as expecting families, children, and those of low socioeconomic standing, will be identified, contacted, and tracked using the following methods:

- COE – Outreach to specific groups will be completed using community outreach, meetings, and individual interaction with Denver Water households using the tactics noted in Appendix III.A Communications, Outreach and Education Plan.
- Survey Questions - The survey questions will help identify expecting families and families with infants.

Information will be incorporated into the Lead Service Inventory (LSI) for use with the predictive modelling effort described in Appendix III.B.3 Prediction Model and Prioritization.

Lessons Learned

Other entities have distributed filters to customers for lead and non-lead programs. The lessons learned from distribution of filters for other entities are shown in Table III.C.3-3.

Table III.C.2-2 Lessons Learned in Other Jurisdictions

Item No.	Description
1	Directions for filter use must be clear to ensure proper use of filters.
2	Reach out to Denver Water households through various methods: phone calls, emails, door-to-door, website videos, tables at community events, local TV stations, etc.
3	Impersonators may be an issue. Make sure all staff have ID badges and outreach material spells out what Denver Water households can expect from Denver Water staff.
4	Many man hours are needed for door-to-door delivery of pitchers.
5	Be prepared to field questions of why certain citizens are included in the filter program, and others are not. Make sure the criteria are clear and there is consensus on who is in the filter program and who may be added, as more information is gathered.

General Water Quality - Flushing

To reduce your exposure to lead in drinking water, we recommend flushing following the steps highlighted on www.denverwater.org (https://www.denverwater.org/your-water/water-quality/lead/reduce-your-risk).

When using water for drinking, cooking and making ice, beverages and infant formula:

- *Use cold water. Hot water dissolves lead faster and is likely to contain higher levels of lead.*
- *If water has not been used for a few hours, run the kitchen or any bathroom faucet for a few minutes. You also can run the dishwasher or take a shower.*

III. DENVER WATER HOUSEHOLD IDENTIFICATION/SELECTION OF CANDIDATES

Candidates for the FLOW Pilot are representative of the general Denver Water customer population, including:

- varied income levels, and
- mix of English-speaking and Spanish-speaking.

For the FLOW Pilot, the neighborhoods selected are:

- West Colfax
- Villa Park
- Barnum West
- Barnum
- Westwood
- Valverde, and
- Athmar Park

These neighborhoods are generally considered to have mixed income and include English-speaking and Spanish-speaking Denver Water households.

Candidates for the FLOW Pilot were identified by Denver Water using available GIS data per the following criteria:

- Suspected lead service line
- Premise address is the mailing address
- Owner occupied
- One phone number. Denver Water households with multiple phone numbers on the "Person" table were deleted. Due to the compressed pilot schedule, the use of one phone number will eliminate potential confusion where one tap has many different phone numbers.

Based upon the data query above, Denver Water GIS generated a file of 992 candidates with suspected lead service lines, living in the seven selected neighborhoods. A subset of 300 customers were identified from the 992 candidates. As the 992 customers were not evenly distributed over the seven neighborhoods, customers were proportionally selected based on roughly 3 in 10 customers, while ensuring the proportion of customers in each neighborhood remained close to the original dataset. The records were sorted by

neighborhood, then every third record was selected until the number of selected records was 30% of the original number of records in that neighborhood. Every third record was selected because it was noted that there was some geographic correlation between the natural order of the records which would have otherwise resulted in geographic bias within each neighborhood. The final selection of 300 customers was reviewed by Denver Water staff to ensure they are suitable for inclusion in the FLOW Pilot program (i.e., have a suspected lead service line).

Maps showing the location of the 300 selected premises are provided in Appendix E.

IV. FILTER PILOT - 5100 SERIES

The framework for the FLOW Pilot consists of the following four (4) stages of processes and workflows:

- 5110 – Initial Distribution
- 5120 – Use Survey & Alternative Filters
- 5130 – Filter Adoption
- 5140 – Filter Cartridge Replacements

The FLOW Pilot – 5100 Series: Workflow/Flowchart that illustrates the sequence of the steps for each stage is included in Appendix F. Below are the details of the key steps for each of the stages.

A. Initial Distribution (5110)

Initial Distribution (5110) is the first stage of the FLOW Pilot with the following steps:

- **5111 - Notify Stakeholders:** In addition to the July 1, 2019 press release, Denver Water notified / informed city, community and neighborhood leaders and stakeholders of the FLOW Pilot.
    - Identify key leaders and stakeholders
    - Contact the leaders and stakeholders via telephone call or email
        - Review details in the press release.
        - Notify / inform leaders and stakeholders of the FLOW Pilot.
- **5112 – Training:** Office and field staff supporting the FLOW Pilot were trained.
    - Finalize filter kit education/outreach material, surveys, phone / in-person scripts, FAQs, and other key references, as included in Appendix G.
    - Conduct in-person training.
- **5113 – Kit Assembly:** The filter kit contents (see Appendix B) were procured, assembled into kits, and stored in Denver Water Building H – Warehouse.
    - 200 kits boxed for mailing
    - 100 kits bagged for hand delivery
- **5114 – Mail Kits:** Two-hundred (200) boxed filter kits with letters were mailed to Denver Water households via USPS Priority Mail. The letter is provided in

Appendix C. Denver Water households that are enrolled in the Denver Water email subscription were also emailed the letter highlighting that the filter kit package has been mailed, encourage participation, and request for the Denver Water household to contact Denver Water if the Denver Water household does not receive the kit within 5 days. Further details on the filter kit distribution and follow-up are included in Table III.C.2-2. For the mailed kits, the intent is to split into four groups with varying levels of follow-up. Field staff carried a Denver Water photo identification and were dressed in safety t-shirts, adorned with the approved Denver Water logo, for ease of identification.

- **5115 – Hand-Deliver Kits:** Bagged filter kits with letters were hand delivered to Denver Water households. The letter is provided in Appendix C. Denver Water households that are enrolled in the Denver Water email subscription were also emailed the letter highlighting that the filter kit package will be delivered, and encourage participation. Further details on the filter kit distribution and follow-up are included in Table III.C.2-2. For the hand-delivered kits, the intent is to split into two groups with varying levels of follow-up. Field staff carried a Denver Water photo identification and were dressed in safety t-shirts, adorned with the approved Denver Water logo, for ease of identification.
- **5116 – Initial Survey**

Table III.C.2-3 FLOW Pilot Distribution Plan

Distribution Method	Number of Denver Water households	Details / follow-up
Direct mail USPS (5114)	50	One (1) phone call follow-up reminder to use filter and request Denver Water household to complete the Initial Survey (5116)
	50	Up to three (3) phone call follow-up reminders to use filter and request Denver Water household to complete the Initial Survey (5116)
	50	Up to three (3) phone calls and one (1) follow-up visit / door hanger to remind the Denver Water household to use filter and request Denver Water household to complete the Initial Survey (5116)
	50	Up to three (3) phone calls and up to two (2) follow-up visits / door hangers to remind the Denver Water household to use filter and request Denver Water household to complete the Initial Survey (5116)
Door-to-door canvassing of	50	Visit 1 - in-person transaction (explain the program and encourage use of the filter, hand-deliver a filter kit, and ask Denver Water household to complete Initial Survey

Table III.C.2-3 FLOW Pilot Distribution Plan

Distribution Method	Number of Denver Water households	Details / follow-up
neighborhood (5115)		One (1) phone call follow-up reminder to use filter and request Denver Water household to complete the Initial Survey (5116)
	50	Visit 1 - in-person transaction (same as above) or leave kit on door Up to three (3) phone calls follow-up reminders to use filter and request Denver Water household to complete the Initial Survey (5116)

B. Use Survey & Alternative Filters (5120)

Use Survey & Alternative Filters (5120) is the second stage of the FLOW Pilot with the following steps:

- **5121 - Analysis/Tracking:** Data gathered from the filter kit distribution, door-to-door visits, surveys, and other feedback received were captured in a centralized database. For this step, data was further analyzed related to the participant's pitcher filter use and requests for alternative filters.
- **5122 – Use Survey**
- **5123 – Mail Alt Filter**: If an alternative filter has been requested by the Denver Water household and they have opted for a home-owner-installed alternative filter, the alternative filters will be directly mailed to the Denver Water household. The Alt filter option is predicted to be used for alternative filters that are easily installed.
- **5124 – Install Alt Filter:** If an alternative filter has been requested by the Denver Water household and they have opted for Denver Water to install, an appointment will be made and the alternative filter will be installed. Before installing the filter, Denver Water will conduct a visual inspection of the service line as it enters the house. With the aid of the homeowner, the entry point for the service line will be identified. Field staff will carry a Denver Water photo identification and will be easily identifiable.
- **5125 – Alternative Survey**

C. Filter Adoption (5130)

Starting approximately one week following Initial Distribution (5110), the Filter Adoption (5130) stage commenced with the following steps:

- **5131 - Analysis/Tracking:** Data gathered from the filter kit distribution, door-to-door visits, surveys, and other feedback received were captured in a centralized database. For this step, data was further analyzed related to the Denver Water household's filter use and COE.
- **5132 – Ongoing Surveys**

D. 5140 – Filter Cartridge Replacements

- **5141 – Transition:** When the LRP Variance is approved, the full-scale FLOW Program will be implemented. At this point, the Denver Water household will be transitioned to the Filter Cartridge Replacement: 5200 Series, as part of the full-scale FLOW Program. Filter Cartridge Replacement: 5200 Series will include distribution of replacement cartridges until six (6) months after the replacement of the lead service line. The 5200 Series will continue to have monthly reminders to replace filter cartridges and requests to complete surveys. The tentative transition schedule is as follows:
    - November 8th
        - Distribute next batch of replacement cartridges.
        - Follow-up phone calls/emails to inform customer that pitcher filter cartridges require replacement per the manufacturer's recommendation and the next batch of replacement cartridges was mailed.
        - Finalize transfer of Denver Water household into the Filter Cartridge Replacement: 5200 Series workflow.
- **5142 – Discontinue FLOW Pilot:** If the LRP Variance is not approved, the FLOW Pilot will be discontinued. A letter will be sent to the Denver Water household notifying them.

V. DATA MANAGEMENT

Microsoft SharePoint, Microsoft Excel, and GIS was used to manage data related to the FLOW Pilot. The use of SharePoint and Excel is based primarily on the limited sample size (approximately 300 residences) and the accelerated schedule of the FLOW Pilot, which favors ease of access and customizability compared to more structured data management platforms, like databases, which may have limited access or require advanced knowledge to manipulate. Use of Excel in the SharePoint environment avoids many of the versioning issues resulting from stand-alone Excel files while also taking advantage of distributed access and concurrent editing capabilities. Standards were set for editing information to ensure consistency and facilitate data analysis and reporting, such as applying data validation and locking columns which should not be edited. Quality Assurance/Quality Control (QA/QC) techniques were used to check the accuracy of the data.

Filter recipients were asked to respond to several online surveys related to filter use. The surveys have been administered using the survey tool, Snap Survey, to seamlessly collect data directly from FLOW Pilot participants. The collected survey data was then exported to Microsoft Excel on SharePoint for further analysis/aggregation of results. Excel or PowerBI may be used to produce a dashboard tracking metrics or interest for the FLOW Pilot. The Mott MacDonald Field Inspection Tools (MMFIT) application will not be available during the FLOW Pilot; however, consideration will be given to how data collection efforts may be performed using MMFIT for the full filter program.

VI. FILTER USE ADOPTION SUMMARY

Multiple surveys will continue to be completed by the Denver Water households that are participating in the FLOW Pilot, which include the Initial Survey (5116); Use Survey (5122); Alternative Survey (5125); and Ongoing Surveys (5132). The survey questions and a copy of the surveys are included in Appendix D. Survey results included are supported by a hard copy or an electronic output from the online platform, as shown in Appendix H. Filter use adoption was completed primarily based upon the responses to the following two survey questions:

1. Do you use your filter for drinking water? Yes/No
2. Do you use your filter for water used in cooking? Yes/No

Filter adoption rates and primary sources for drinking water and cooking was tracked during the FLOW Pilot and data collected is included in Appendix H. Filter adoption assumes customers are using the pitcher filter for drinking water and cooking. Denver Water will continue to follow-up with the Denver Water households to complete additional Use Surveys.

A summary of the FLOW Pilot survey responses as of August 13, 2019 is as follows:

1. 247 kits were mailed (187 to original FLOW candidates, 34 to additional FLOW participants who requested kits; 25 re-sent to pilot participants that did not initially receive them; 1 kit sent to resident who requested a second filter for cooking).
2. Kits were mailed on Wednesday, July 10 and hand-delivered on Thursday, July 11, additional kits were mailed July 13, July 23, July 30, and August 2 and hand-delivered on July 27, 30, and 31, 2019.
3. Two kits were refused and mailed back.
4. 93 kits were hand-delivered on Thursday, July 11.
5. 8 kits were hand-delivered during follow-up visits to pilot participants who did not receive their initial kit.
6. 4 kits were hand-delivered during a community resource fair on Saturday, August 10, 2019.
7. All 280 pilot participant houses had at least one follow-up visit.
8. **Initial Survey Responses Received:** 25% - 69 total (out of 280 pilot participants): 52 hard copy surveys and 17 online surveys. Of the 69 surveys received, 5 were completed in Spanish - 7%.

- Use unfiltered tap water for drinking and cooking: 31/69 – 45%
- Use bottled water for drinking: 16/69 – 23%
- Use filtered water for drinking: 22/69 – 32%
- Use filtered or bottled water for cooking: 13/69 – 19%
- Participants who reported that they had a lead service line:
    - Yes: 13/69 – 19%
    - No: 3/69 – 4%
    - Did not know: 53/69 - 77%

9. **Use Survey Responses Received:** 28% – 79 total (out of 280 pilot participants): 54 hard copy surveys and 25 online surveys. Of the 78 surveys received, 10 were completed in Spanish - 13%.
    - Use for drinking water: 72/79 – 91%
    - Use for drinking and cooking: 48/79 – 61%
    - Use for infant formula*:
        - Yes: 19/79 – 24%
        - No: 11/79 – 14%
        - Not Applicable: 49/79 – 62%

    **Survey responses indicated that there may have been confusion regarding the response of "no" or "not applicable" for the infant formula question.*

    - Pilot participants who would prefer an alternative filter:
        - Faucet-mounted filter: 36/79 – 46%
        - Larger pitcher filter: 12/79 – 15%
        - Refrigerator filter: 6/79 – 8%

A summary of the resources required and associated cost to implement the FLOW Pilot as of August 13, 2019 is summarized in Table III.C.2-4.

Table III.C.2-4 Flow Pilot Resource Summary

Task Description	No. of Staff	No. of Hours per Staff	Total Hours / Units	Hourly Rate / Unit Cost	Total Cost	Kits / Customers	Cost per Kit
Labor Costs							
Develop COE Materials and Surveys (Kits)	2	100	200	$175	$35,000	300	$120
Develop Maps and Data Tracking Forms (Kits)	1	40	40	200	$8,000	300	$30
Assemble for Mailing (Kits)	12	12	144	$75	$10,800	200	$50
Assemble for Hand Delivery (Kits)	12	6	72	$75	$5,400	100	$50
Door to Door Hand Delivery (Kits)	12	8	96	$75	$7,200	93	$70
Door to Door Follow-up (Customers)	9	24	216	$75	$16,200	300	$50
Telephone Calls (Customers)	2	15	30	$100	$3,000	300	$10
Logging Data, Survey Results, and Tracking (Kits)	2	40	80	$110	$8,800	300	$30
Gift Card Distribution and Responses (Customers)	2	4	8	$110	$880	142	$7
Oversight (Kits)	1	80	80	$110	$8,800	300	$30
				Total Labor	**$104,080**	300	$450
Direct Costs							
Filter Kits, Replacement Cartridges, Magnets, Bags, Door Hangers, Flyers, Miscellaneous	--	--	300	$50	$13,000	300	$50
Mail Kits (Outside Vendor)	--	--	247	$12	$3,000	247	$12
Gift Cards for Completed Surveys	--	--	142	$15	$2,150	142	$15
				Total Direct Costs	**$18,150**	300	$80
				Total Pilot Cost	**$122,230**	300	$530

VII. PILOT DEMOGRAPHIC SUMMARY

As part of the use survey, it is important to determine the adoption rate amongst the diverse populations in the Denver Water service area. The American Community Survey (ACS) is part of the U.S. Census Bureau's Decennial Census Program and is designed to provide current social, economic, housing, and demographic estimates throughout the decade. Combining American Census Survey (ACS) data with FLOW Pilot data allowed for the estimation of trends between levels of diversity in a neighborhood and filter adoption rates within the FLOW Pilot neighborhoods. ACS information at the Block Group Level will be taken from the 2013 to 2017 American Community Survey estimates. The information was adjusted for the Hispanic representation included as a category to reflect additional available diversity information. The information was linked to the Survey Census Block Groups to develop a geographic component to the data. The survey data was then evaluated by Diversity Categories By Block Group (ACS Data for B02001) as follows:

- Hispanic alone
- White (Non-Hispanic) alone
- Black or African American alone
- American Indian and Alaska Native alone
- Asian alone
- Native Hawaiian and Other Pacific Islander alone
- Some other race alone

The FLOW Pilot survey results were geolocated based on the address, tap number, or other available spatial information. The geolocation allows the data collected from the FLOW Pilot to be associated to a location and a block group for further analysis of the adoption rates and other survey results compared to the available diverse population statistics for each area. The following evaluations were completed for the Filter Pilot premises:

1. The comparison of the adoption rate noted on completed surveys to the diverse population for each surveyed area.
2. The comparison of areas where surveys where sent but not returned or the adoption rate is low.
3. The identification of specific diverse populations where surveys were sent but not returned or the adoption rate is low.
4. The comparison of the survey results between different areas and diverse groups to establish trends by ethnic population.
5. The populations where filters were sent but surveys not returned.
6. The comparison of adoption rate to the baseline approved adoption metric.

The survey results were then compared to the neighborhood demographics. The COE program can be adjusted if there is a lack of survey results or negative feedback from a certain area are identified. If an area is systemically not participating in FLOW, then the areas' criticality (and thus risk) will be ranked as higher priority in the ALSLR Program.

A summary of the FLOW Pilot demographics evaluation, for three of the seven neighborhoods, is shown in Table III.C.2-5.

Table III.C.2-5 Survey Results by Diversity Analysis (sample results)*

Neighborhood	1	2	3
White Hispanic (%)	62	64	61
White Non-Hispanic (%)	29	16	18.6
Black or African American (%)	3	1	0.1
American Indian and Alaska Native (%)	2	1	0
Asian (%)	0	9	19
Native Hawaiian and Other Pacific Islander (%)	0	0	1
Other (%)	4	9	0.3
Number Using Filter for Drinking	8	4	2
Number Using Filter for Cooking	6	4	2
Initial Survey Completed	7	8	0
Filter Use Survey Completed	9	6	2
Using for Drinking (%)	89	67	100
Using for Cooking (%)	67	67	100
Initial Survey Completed (%)	64	73	0
Filter Use Survey Completed (%)	82	55	9

**The demographic data was developed using limited survey data from August 2, 2019 and available census data. The demographic data is provided as an example and will be further developed for the full-scale filter plan.*

The data indicate that at least 67% of the population surveyed use the filter for drinking and cooking in three (3) of the seven neighborhoods where White Hispanics make up the majority of the population. Other considerations may be affecting neighborhood 3, which shows a markedly lower survey response rate. A geographic strategy analysis will be conducted to determine how the COE plan should be adjusted in neighborhood 3 as opposed to modifying the overall COE efforts specified for the White Hispanic population. Neighborhood 3 has a larger Asian pvopulation and this information will be used to provide guidance for increased COE for filter adoption in this neighborhood.

VIII. PILOT LESSONS LEARNED SUMMARY

The intent was to proceed with the FLOW Pilot Distribution Plan described in Table III.C.2-3 but, as a result of the compressed schedule for completion of the pilot, the decision was made to make follow-up home visits to all 280 FLOW Pilot participants. Field staff provided information regarding the program, encouraged program participants to use their filters for infant formula, drinking water, and cooking, and complete the surveys. Door hangers, with educational information, and reminders to use the filters for infant formula, drinking water, and cooking were left on doors of homes with no answer during the door-to-door follow-up field visits. Telephone calls were made to all

participants that were not home during the follow-up field visits. Outreach via telephone calls and the receipt of survey responses continue, on a daily basis, as of August 7, 2019.

Lessons learned from the FLOW Pilot that will be implemented into the full-scale FLOW Program are shown in Table III.C.2-6.

Table III.C.2-6 Lessons Learned From the Filter Pilot Program

Item No.	Description
1	Provide advance targeted communications, outreach and education prior to filter distribution to introduce the program and explain the importance of filter use.
2	Reinforce the importance of using the filter for cooking and infant formula preparation (in addition to drinking water).
3	Inform participants the filters and replacement cartridges are provided at no cost to the customer for the duration of the program.
4	Provide alternative filters such as refrigerator, larger pitchers, and faucet mount.
5	Provide additional Spanish-speaking staff for field crews for initial distribution and follow-up visits.
6	Have one adoption survey after the participants have been contacted, are aware of the program, and have been using the filter for period of time.
7	Send filters addressed to tenants, not owners of the homes, if renters reside in the household.
8	Print individual participant's survey access codes directly on their survey in order to easily track the participant's responses.
9	Make survey questions clear, so that each answer doesn't have more than one meaning.
10	Have more outreach materials educating customers about how the service line is owned by the homeowner and how they can request a lead test kit.
11	Simplify outreach materials.
12	Update phone numbers in the database as project progresses.
13	Provide alternative filters and additional filters as filling the pitcher is cumbersome and slow.
14	Younger generation prefer online survey responses and electronic communications.
15	Not all residents have email addresses and internet access and hard copy surveys should continue to be provided.
16	Follow-up calls should be made from a Denver Water phone number.
17	Outreach staff should fill out and request a water quality sampling kit for concerned residents.
18	Include lead service line replacement information and talking points with filter program.
19	Follow-up visits and door-to-door outreach is not preferred for all participants. Some have requested communication via email only.
20	Simplify survey questions to prevent confusion.

In addition to the FLOW Pilot, Denver Water is distributing and will continue to distribute water pitcher filters to customers:

- post lead service line replacement, with five (5) months of replacement cartridges
- potholing program participants when a lead service line is detected, with five (5) months of replacement cartridges

The non-pilot customers will be surveyed and provided additional education/instruction material that is distributed with the FLOW Pilot.

IX. FLOW PILOT TIMELINE

Date	Activity	Milestone
	5110 – Initial Distribution	
June 2019	Develop FLOW Pilot Plan	Review FLOW Pilot plan
Week of June 3, 2019	Prepare pitcher filter supply	Confirm pitcher filter supplies
June 13, 2019	COE	Launch Denver Water internal COE plan
June 20, 2019	Kick-off meeting with DW, GWD, and MHYC	Contracts completed Project plan implementation begins
June 24, 2019	Order Filter Kit Supplies (door hangers, instructions, bags)	Filter kit supplies ready for kit assembly
Week of July 1, 2019	Go/No Go	Authorization to proceed with FLOW Pilot program
July 8, 2019	Notify Stakeholders	Stakeholders prepared for roll-out of the FLOW Pilot
July 8 & July 9, 2019	Training/Kit Assembly	GWD and MHYC are given training materials and filter kits are ready for distribution
July 10, 2019	Kit Pick-Up	Filter Kits picked up by USPS Priority Mail (1-3 day shipping)
July 10 to July 14, 2019	Hand-Deliver Kits	• Filter Kits hand-delivered • Determination of in-house filter services
July 10 to July 14, 2019	Initial Survey (5116)	Initial Survey (5116) distributed in filter kits (via mail and hand-delivered)
July 11, 2019	Mail & Deliver Kits	Earliest delivery of mailed filter kits to Denver Water households
July 15 to July 17, 2019	External COE	Follow-up phone calls and emails to FLOW Pilot participants

Date	Activity	Milestone
5120 – Use Survey & Alternative Filters		
Starting July 22, 2019	• Analysis/Tracking • Use Survey (5122)	• GWD/MHYC feedback and collection of data • Filter Adoption: Use Survey (5122) • Determine alternative filter type requested
August 19 to September 30, 2019	• Mail Alternative Filters • Install Alternative Filters • Alt Survey (5125)	• Order, delivery, and installation of alternative filter equipment • Filter Adoption: Alt Survey (5125)
August 1 to August 2, 2019	Progress Meeting	• GWD/MHYC feedback and collection of data
5130 – Filter Adoption		
August 1, 2019 to October 31, 2019	• Analysis/Tracking • Ongoing Surveys (5132)	• GWD/MHC feedback and collection of data • Filter Adoption: Ongoing Surveys (5132) • Follow-up phone calls
5140 – Filter Cartridge Replacements		
October 31, 2019	Variance Approved, Yes/No	• Variance Approved - Transition to Cartridge Replacement: 5600 Series • Variance Not Approved - Discontinue FLOW Pilot

APPENDIX A – FILTER TYPES

DENVER WATER

Filter Types

Federal regulations do not exist for residential water treatment filters. Voluntary national standards and National Sanitation Foundation (NSF) / American National Standards Institute (ANSI) protocols have been developed to establish minimum requirements for the safety and performance of residential water treatment filters. NSF/ANSI Standards 42 and 53 are applicable for water quality and lead removal, as described, below.

- **NSF/ANSI 42**

  Filters are certified to reduce aesthetic impurities such as chlorine, taste, and odor. Filters can be point-of-use (POU) (faucet filter, water pitcher, etc.) or point-of-entry (POE) (whole house) treatment systems.

- **NSF/ANSI 53**

  Filters are certified to reduce a contaminant with a health effect, such as lead. The standard establishes health effects as regulated by the U.S. Environmental Protection Agency (EPA). Both standards 42 and 53 include adsorption and filtration treatment.

NSF established laboratories that may test and certify filters that meet the NSF protocols for lead removal. The certified laboratories include: NSF International, CSA International, Water Quality Association (WQA), International Association of Plumbing and Mechanical Officials, Underwriters Laboratory, Truesdail, and Intertek.

A summary of different types of filters, certification laboratory to NSF/ANSI Standards 42 and 53, and associated filter life is shown in Table A1. The general range of filter life for pitcher filters is 1-6 months and the general range of filter life for alternative filters is 1-10 months. Product detail sheets are attached.

DENVER WATER

Table A1: Point-of-Use Filter Types

Filter Type	Brand/Model	Certification Laboratory	Filter Life	Percent Lead Reduction at pH 8.5
Pitcher	Brita Monterey (#OB50) 10-cup pitcher with Longlast filter (#OB06)[1]	WQA	6 months	99.6%
	DuPont 8-cup pitcher (WFPT100) with WFPTC100N filter[2]	WQA	3 months	97.4%
	DuPont WFTP200 10-cup pitcher with WFPTC100N filter[3]	WQA	3 months	97.4%
	ZeroWater 10-cup filter pitcher (ZP-010)[4]	NSF	1 month	99.0%
	Pur Classic 11-cup pitcher (PPT111WV1) with lead reduction filter (PPF951K)[5]	WQA	2 months	97.9%
Water Dispenser	ZeroWater 20-cup water filter jug (ZD-20RP)[6]	NSF	1 month	99.0%
	ZeroWater 30-cup water filter jug (ZD-30RP)[7]	NSF	1 month	99.0%
	ZeroWater 40-cup water filter jug (ZBD-040)[8]	NSF	1 month	99.0%

Table A1: Point-of-Use Filter Types

Filter Type	Brand/Model	Certification Laboratory	Filter Life	Percent Lead Reduction at pH 8.5
Water Dispenser	Brita Ultramax 18-cup Dispenser (#OB24) with Brita Longlast filter (#OB06)[9]	WQA	6 months	99.6%
Faucet-Mount	DuPont WFFM100 Faucet Mount Filter with WFFMC100 or WFFMC300 filter[10]	WQA	5 months	99%
	DuPont WFFM350 with Ultra Protection Filter (WFFMC300)[11]	WQA	10 months	99%
	Brita Faucet Filtration System FF-100 with FR-200 filter[12]	NSF & WQA	5 months	99.3%
	Brita Basic Faucet Filtration System SAFF-100 with FR-200 filter[13]	NSF & WQA	5 months	99.3%
	Pur PFM400H Faucet with MineralClear Filter (RF9999)[14]	WQA	3 months	99.9%

DENVER WATER

Table A1: Point-of-Use Filter Types

Filter Type	Brand/Model	Certification Laboratory	Filter Life	Percent Lead Reduction at pH 8.5
Refrigerator Filters	Frigidaire PureSource 3 (WF3CB)[15]	NSF	6 months	99.1%
	Maytag Refrigerator Water Filter (UKF8001)[16]	NSF	6 months	99.3%

Notes:

1. *https://www.brita.com/water-pitchers/monterey-longlast/?ds_rl=1238837&gclid=Cj0KCQjw9JzoBRDjARIsAGcdIDUi8xyyMENARguLCz_NAqDULgUppLOhn01Pd3XbXRcXZGGWDHWOyLgaAslGEALw_wcB&gclsrc=aw.dshttp://www.protectplus.com/PD-Water-Filtration-82/DuPont-Traditional-Water-Filter-Pitcher-WFPT100-653*
2. *http://www.protectplus.com/PD-Water-Filtration-82/DuPont-Mirage-Water-Filter-Pitcher-WFPT200-652*
3. *http://www.protectplus.com/PD-Water-Filtration-82/DuPont-Mirage-Water-Filter-Pitcher-WFPT200-652*
4. *https://ww.zerowater.com/products-10-Cup-Pitcher?gclid=Cj0KCQjw9JzoBRDjARIsAGcdIDWhrdUxnskz0UuAp4CIuQcDKJ27qwbOVoqxdOPq9XYFa3QJlVwIK2YaAhvzEALw_wcB*
5. *https://www.pur.com/water-filter-pitchers-and-dispensers/pur-ultimate-pitcher-filtration-system-with-lead-reduction*
6. *https://ww.zerowater.com/products-20-Cup-Ready-Pour*
7. *https://ww.zerowater.com/products-30-Cup-Ready-Pour*
8. *https://ww.zerowater.com/products-40-Cup-Ready-Pour*
9. *https://www.brita.com/water-dispensers/ultramax-longlast/*
10. *http://www.protectplus.com/PD-Water-Filtration-82/DuPont-Premier-Faucet-Mount-Drinking-Water-Filter-WFFM100-647*
11. *http://www.protectplus.com/PD-Water-Filtration-82/DuPont-Deluxe-Faucet-Mount-WFFM350-646*
12. *https://www.brita.com/faucet-systems/complete/*
13. *https://www.brita.com/faucet-systems/basic/*
14. *https://www.pur.com/faucet-filtration-systems/pur-advanced-faucet-filtration-system-with-mineralclear-filter*
15. *https://www.frigidaire.com/Filters--Accessories/Filters/water-filters/WF3CB/?gclid=CjwKCAjwuqfoBRAEEiwAZErCsqQkifIHCX2HhuFjxt_hL213qbrqvzOJ96upk87nk6SIa4b2_4hT2BoCuXYQAvD_BwE&gclsrc=aw.ds*
16. *https://www.homedepot.com/p/Maytag-UKF8001-Refrigerator-Water-Filter-UKF8001/100671093*

APPENDIX B – FILTER KIT CONTENTS

DENVER WATER

Filter Kit Contents

Each participant of the Filter Lead Out of Water (FLOW) Pilot will receive a filter kit via direct mail or door-to-door hand delivery. Each filter kit includes the following:

Kit Items:

- FLOW Pilot Letter
- Frequently Asked Question (FAQ) summary for lead service lines and FLOW Pilot program questions
- One (1) ZeroWater 10-cup water pitcher - NSF certified for lead removal with one (1) filter cartridge
- Three (3) pitcher replacement cartridges
- Pitcher filter instructions and maintenance guidelines in English, Spanish, and French
- Initial Survey (5116)
- Reusable bag
- Magnet with reminders to use filtered water for infant formula, drinking, and cooking, cartridge date change information, program contact information, website, and telephone number
- Door hanger

The ZeroWater 10-cup pitcher should be used for all infant formula, drinking water, and cooking. The manufacturer's instructions for use and maintenance should be followed and the filter should be replaced in accordance with the manufacturer's guidelines.

ZEROWATER
GET MORE OUT OF YOUR WATER™

10 CUP PITCHER

WITH FREE WATER QUALITY METER

PRODUCT HIGHLIGHTS:

- ZeroWater's premium 5-stage filtration vs. competitors 2-stage filtration
- Certified by NSF to reduce Lead and other heavy metals
- Removes 99.6% of all dissolved solids, 2X more than leading brand filters
- FREE Water Quality Meter included to test your water
- Contoured handle for and non-slip ergonomic grip
- One-hand push to dispense spigot
- 80 oz capacity
- BPA Free

DIMENSIONS: 11.63” x 5.93” x 11" MSRP: $34.99

REMOVES TDS | NSF CERTIFIED | REMOVES LEAD | BPA-FREE | 5 STAGE FILTRATION

5-STAGE FILTRATION

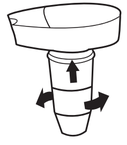
1. Removes suspended solids such as dust and rust that make your water appear cloudy
2. Removes additional suspended solids
3. Removes organic contaminants; pesticides, herbicides, Mercury, Chlorine, Chloramine, and stops bacteria from growing
4. Removes inorganic compounds i.e. metals, nonmetals and radiological contaminants.
5. Removes remaining suspended solids, holds the resin in place

#SS-ZP010-01

ASSEMBLY INSTRUCTIONS
INSTRUCCIONES DE MONTAJE

1 **REMOVE** lid and water reservoir from top of the pitcher and remove filter from packaging. Unscrew the blue protective cap (if applicable).

QUITE la tapa y el depósito de agua de arriba de la jarra y retire el filtro del empaque. Desenrosque la tapa protectora azul (cuando proceda).

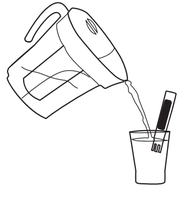


2 **TWIST** filter into the bottom of reservoir (from below) and tighten filter to obtain a complete seal with the reservoir. ***Do not drop the filter in from above.*** Tighten until there is a complete seal between the filter, o-ring and reservoir.

GIRE el filtro en el fondo del depósito (desde abajo) y apriételo hasta que haya un sellado perfecto con el depósito. No deje caer el filtro desde arriba. Apriete hasta que haya un sello completo entre el filtro, el aro en O y el depósito.

3 **FILL** reservoir by pouring/filling with cold tap water (directly into the filter) and place lid on top. Allow all the water to pass through the filter before filling again.

LLENE el depósito con agua fría de la llave (directamente en el filtro) y coloque la tapa. Permita que el agua pase por el filtro antes de volver a llenar.



4 **POUR OR DISPENSE** using spigot (if applicable) to fill your cup or glass once the reservoir has emptied into the body.

VIERTA EL AGUA para llenar su taza o vaso utilizando una boquilla (si procede) una vez que el depósito se haya vaciado en el cuerpo de la jarra.

CLEANING INSTRUCTIONS // INSTRUCCIONES DE LIMPIEZA

Clean your device in warm water using mild soap. Rinse and dry thoroughly.

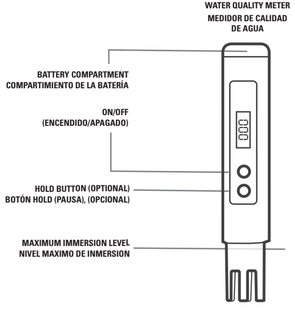
Limpie su dispositivo en agua tibia con un jabón suave. Enjuáguelo y séquelo perfectamente.

ZEROWATER
7 Neshaminy Interplex, Suite 116
Trevose, PA 19053

TDS WATER QUALITY METER
MEDIDOR DE TDS PARA CALIDAD DEL AGUA

The TDS meter supplied is intended to detect and measure TDS (total dissolved solids) in PPM. ***Test your water regularly.***

El medidor de TDS suministrado está diseñado para detectar y medir TDS (sólidos disueltos totales) en PPM (partes por millón). ***Haga pruebas a su agua de manera regular.***



FOR WATER QUALITY METER: Remove cap, turn on, submerge in water, change filter when it reads ***006 or higher***.

PARA EL MEDIDOR DE CALIDAD DE AGUA: Quite la tapa, encienda, sumerja en agua, y cambie el filtro cuando la lectura sea de ***006 o mayor***.

REPLACEMENT BATTERY INSTRUCTIONS: Meter includes (2) alkaline batteries. Do not mix old and new batteries. Do not mix alkaline, standard or rechargeable batteries.

INSTRUCCIONES DE REEMPLAZO DE LA BATERIA: El medidor incluye dos (2) pilas alcalinas. No mezcle baterías viejas y nuevas. No mezcle baterías alcalinas, estándar o recargables.

TDS meters included with select ZeroWater pitchers/dispensers
Los medidores de TDS vienen incluidos con ciertas jarras/despachadores ZeroWater

TROUBLESHOOTING TRY THESE TIPS...
DETECCIÓN DE PROBLEMAS PRUEBE ESTOS CONSEJOS...

1. Not getting a "000" reading? Ensure that the filter is threaded correctly and fully seated in the water reservoir. Watch for cross-threading and ensure that the rubber gasket is seated properly and has not gotten stuck in one of the threads.

   ¿No está obteniendo una lectura de "000"? Asegúrese de que el filtro esté roscado correctamente y asentado completamente en el depósito de agua. Observe si está roscado de manera incorrecta yasegúrese de que el empaque de hule esté bien asentado y no se haya atascado en la rosca.

2. Rinse and dry your pitcher/dispenser, TDS meter, and parts completely. Left over tap water, soap residue or a dirty TDS meter may give false meter readings.

   Enjuague y seque perfectamente la jarra/despachador, el medidor de TDS y todas las piezas. Si se deja agua de la llave, residuos de jabón o un TDS sucio, el medidor podría dar lecturas falsas.

3. Check the O-ring on your filter. If there is no O-ring present on your filter, unfiltered tap water will flow around the filter and into the dispenser.

   Revise el aro en O del filtro. Si no está presente el aro en O en su filtro, el agua de la llave no filtrada podría fluir alrededor del filtro y hacia el despachador.

4. Make sure you are pouring your filtered water into a clean glass. The indicator may pick up trace residue from previous use or soap.

   Asegúrese de verter el agua filtrada en un vaso limpio. El indicador podría detectar residuos de jabón o de usos anteriores.

5. Check for cracks in the reservoir or filter. If you have a crack, please contact customer service for additional instructions.

   Revise si el depósito o el filtro tienen grietas. Si tienen alguna grieta, comuníquese con el servicio al cliente para que le den más instrucciones.

For all other issues, please contact our customer service center at **1-800-503-2939** or email **customerservice@zerowater.com**.

Para otros tipos de problemas, comuníquese con nuestro centro de servicio al cliente al **1-800-503-2939** o envíe un correo electrónico a **customerervice@zerowater.com**.

#2-810INSERTSP-01

FILTRACIÓN PREMIUM EN CINCO ETAPAS

SOLO ZEROWATER DEJA 000 SÓLIDOS DISUELTOS[3]

PARA EL AGUA CON EL SABOR MÁS PURO[2]

PREMIUM 5-STAGE FILTRATION

ONLY ZEROWATER LEAVES

000

DISSOLVED SOLIDS[3]

FOR THE PUREST TASTING WATER[2]

MEDIDOR INCLUIDO:
MIDE LOS SÓLIDOS PERMANENTES DISUELTOS[5]

CERTIFICADO PARA REDUCIR EL PLOMO Y OTROS METALES PESADOS[4]

LIMITED WARRANTY FOR ZEROWATER DISPENSER, PITCHER, BOTTLE FILTRATION SYSTEM, TRAVEL BOTTLE & TDS METER Zero Technologies, LLC warrants the ZeroWater Dispenser, Pitcher, Bottle Filtration System, Travel Bottle and TDS Meter to be free from manufacturing defects for 90 days from the date of purchase, when used in compliance with the Owner's Manual. During this 90-day period, if you discover a manufacturing defect in your ZeroWater Dispenser, Pitcher, Bottle Filtration System, Travel Bottle or TDS Meter (excluding the filter), we will replace the parts free of charge. To file a warranty claim, call 1-800-503-2939 or visit www.zerowater.com/contactsus.aspx. Dated proof of purchase required.

FILTER CARTRIDGE LIMITED WARRANTY Zero Technologies, LLC warrants its filters to be free from manufacturing defects for 30 days from the date of purchase, when used in compliance with the Owner's Manual. During this 30-day period, if you discover a manufacturing defect in your filter, we will replace it free of charge (minus shipping costs). Dated proof of purchase required. To place a claim for a defective filter, you must first call 1-800-503-2939 and speak to customer service to trouble shoot the problem. If a potential manufacturing defect is identified, we will provide instructions on how to return the filter for laboratory testing. If the lab determines that the filter is defective, we will replace it free of charge. If no defect is found, your filter will be returned to you. *NOTE: This warranty does not guarantee the life of the filter for any specific period or volume of use. For more information about expected filter life, see www.zerowater.com/filtration-filter-life.aspx.*

For information about warranty, service or how to use your ZeroWater product, please call Customer Service toll free 8am-8pm CT, Mon-Fri, at 1-800-503-2939, or visit our website at www.zerowater.com.

GARANTÍA LIMITADA EN EL DISPENSADOR DE AGUA ZEROWATER, LA JARRA, EL SISTEMA DE FILTRACIÓN DE BOTELLAS, LA BOTELLA DE VIAJE Y MEDIDOR DE TDS Zero Technologies, LLC garantiza durante 90 días a partir de la fecha de compra, que el dispensador, la jarra, el sistema de filtración de botellas, la botella de viaje y el medidor de TDS de ZeroWater no tienen defectos de fabricación, cuando se utilicen de conformidad con el Manual del Propietario. Si descubre un defecto de fabricación en su dispensador, jarra, sistema de filtración de botellas, botella de viaje o medidor de TDS de ZeroWater (excluyendo el filtro), durante este período de 90 días, reemplazaremos las piezas sin cargo. Para presentar una reclamación de garantía, llame al 1-800-503-2939 o visite www.zerowater.com/contactsus.aspx. Se requiere comprobante de compra con fecha.

GARANTÍA LIMITADA DEL CARTUCHO DE FILTRO Zero Technologies, LLC garantiza durante 30 días a partir de la fecha de compra, que el filtro no tiene defectos de fabricación, cuando se utilice de conformidad con el Manual del Propietario. Si descubre un defecto de fabricación en su filtro, durante este período de 30 días, lo reemplazaremos de forma gratuita (menos los costos de envío). Se requiere comprobante de compra con fecha. Para presentar una reclamación por un filtro defectuoso, debe llamar primero al 1-800-503-2939 y hablar a servicio al cliente para resolver el problema. Si se identifica un posible defecto de fabricación, le proporcionaremos instrucciones sobre cómo devolver el filtro para las pruebas de laboratorio. Si el laboratorio determina que el filtro está defectuoso, lo reemplazaremos sin cargo. Si no se encuentra ningún defecto, su filtro le será devuelto. NOTA: Esta garantía no cubre la vida útil del filtro por algún período o volumen específico de uso. Para obtener más información sobre la vida útil del filtro, visite www.zerowater.com/filtration-filter-life.aspx.

Para obtener información acerca de la garantía, el servicio, o cómo utilizar su producto ZeroWater, llame sin costo a servicio al cliente al 1-800-503-2939 de lunes a viernes de 8 am a 8 pm Hora del Centro, o visite nuestro sitio web en www.zerowater.com.

The ONLY filter certified to reduce Lead & Chromium
El ÚNICO filtro certificado que reduce el plomo y el cromo

	Leading Brand (standard model) Marca principal (modelo estándar)	ZeroWater
LEAD / PLOMO		✔
CHROMIUM (HEXAVALENT) / CROMO (HEXAVALENTE)		✔

Data reflected on this table was derived from the NSF International website. For a complete list visit www.ZeroWater.com. / Los datos de esta tabla se tomaron del sitio Web de NSF International. Si desea ver la lista completa visite www.ZeroWater.com.

ZeroWater® PERFORMANCE DATA SHEET. FOR MODELS: ZD-013D, ZD-013W, ZD-018, ZP-001, ZP-006, ZP-010, ZS-008, ZD-010RP, ZD-023-1, ZD-012RP, ZP-007RP, ZR-0810, ZR-0910G, ZBD-040, ZD-030RP, ZD-20RP, ZS-011RP //IMPORTANT NOTICE: Read this Performance Data Sheet and compare the capabilities of this unit with your actual water treatment needs. It is recommended that before purchasing a water treatment unit you have your water supply tested to determine your actual water treatment needs. All contaminants reduced by this water treatment device are not necessarily in your water supply. While testing was performed under standard laboratory conditions, actual performance may vary.

This system has been tested according to NSF/ANSI 42 and NSF/ANSI 53 for reduction of the substances listed below. The concentration of the indicated substances in water entering the system was reduced to a concentration less than or equal to the permissible limit for water leaving the system, as specified in the relevant standard.

Rated service life is 20 gallons. It is recommended to change the filter with replacement element ZR-001/ZF-201 at this point. Service flow rate is 2 gallons per day. Operating temperature is 40-90°F. This water treatment device is intended only for use with potable water. Do not use water that is microbiologically unsafe or of unknown quality without proper disinfection before or after the system.

HOJA DE DATOS DE RENDIMIENTO de ZeroWater® PARA LOS MODELOS: ZD-013D, ZD-013W, ZD-018, ZP-001, ZP-006, ZP-010, ZS-008, ZD-010RP, ZD-023-1, ZD-012RP, ZP-007RP, ZR-0810, ZR-0810G, ZBD-040, ZD-030RP, ZD-20RP, ZS-011RP //AVISO IMPORTANTE: Lea esta Hoja de datos de rendimiento y compare las capacidades de esta unidad con sus necesidades reales de tratamiento de agua. Se recomienda que antes de comprar una unidad de tratamiento de agua haga una prueba de su abastecimiento de agua para determinar sus necesidades reales de tratamiento de agua. No todos los contaminantes reducidos por este dispositivo de tratamiento de agua están necesariamente en su abastecimiento de agua. Aunque las pruebas se realizaron en condiciones estándar de laboratorio, el rendimiento real puede variar.

Este sistema ha sido probado conforme NSF/ANSI 42 y NSF/ANSI 53 para la reducción de las sustancias enumeradas a continuación. La concentración de las sustancias indicadas en el agua que ingresa al sistema se redujeron a una concentración menor o igual al límite permitido para que el agua salga del sistema de acuerdo a como lo especifica la norma correspondiente.

La vida útil nominal es de 20 galones (76 l). En ese momento, se recomienda cambiar el filtro con el elemento de reemplazo ZR-001/ZF-201. El caudal de servicio es de 2 galones (7.5 l) por día. La temperatura de funcionamiento es de 40-90°F (4.4-32.2°C). Este dispositivo de tratamiento de agua está diseñado solo para su uso con agua potable. No se use con agua microbiológicamente antihigiénica o de calidad desconocida sin desinfectar adecuadamente el sistema antes o después.

This system has been tested and certified by NSF International under NSF/ANSI Standards 53 or 42 for the reduction of substances listed below.
Este sistema ha sido probado y certificado por NSF International bajo las normas NSF/ANSI 53 o 42 para la reducción de sustancias

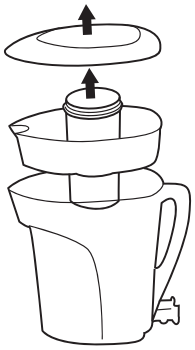
SUBSTANCE SUSTANCIA	Overall Percent Reduction	Influent Challenge Concentration (mg/L)	Maximum Effluent Concentration (mg/L)	Maximum Permissible Effluent Concentration (mg/L)
NSF/ANSI Standard 53 - Health Effects				
Norma NSF/ANSI 53 - Efectos sobre la salud				
Chromium, Tri and Hexavalent, pH 6.5	98.6	0.2 ± 10%	0.003	0.050
Chromium, Tri and Hexavalent, pH 8.5	96.6	0.2 ± 10%	0.002	0.050
Lead, pH 6.5	99.7	0.15 ± 10%	0.000	0.010
Lead, pH 8.5	99.9	0.15 ± 10%	0.0005	0.010
Mercury, pH 6.5	95.7	0.10 ± 10%	0.0070	0.010
Mercury, pH 8.5	96.0	0.10 ± 10%	0.0062	0.010
NSF/ANSI Standard 42 - Aesthetic Effects				
Norma NSF/ANSI 42 - Efectos estéticos (sabor, olor y apariencia)				
Chlorine	97.0	2.0 ± 10%	0.06	0.002
	Reducción porcentual total	Concentración de referencia de agua prefiltrada (mg/L)	Concentración máxima de agua filtrada (mg/L)	50% of influent Concentración máxima permisible de agua filtrada (mg/L)

System Tested and Certified by NSF International against NSF/ANSI Standard 42 for reduction of hydrogen sulfide and chlorine taste and odor and against NSF/ANSI Standard 53 for reduction of lead, chromium and mercury.
Sistema probado y certificado por NSF International con respecto a la norma NSF/ANSI 42 en reducción de sabor y olor de azufre de hidrógeno y cloro, y con respecto a la norma 53 NSF/ANSI en reducción de plomo, cromo y mercurio.

www.zerowater.com

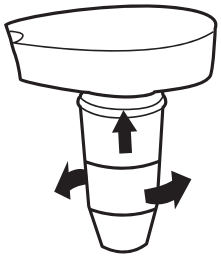
ASSEMBLY INSTRUCTIONS
6 CUP, 8 CUP, 10 CUP, 12 CUP

INSTRUCTIONS D'ASSEMBLAGE
6 TASSES, 8 TASSES, 10 TASSES, 12 TASSES



1 **REMOVE** lid and water reservoir from top of the pitcher and remove filter from packaging. Unscrew the blue protective cap (if applicable).

ENLEVEZ le couvercle et le réservoir d'eau du dessus de la carafe puis retirez le filtre de son emballage. Dévissez le capuchon de protection bleu (le cas échéant).

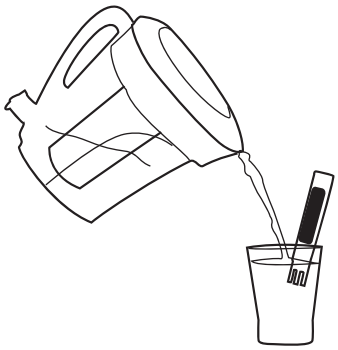


2 **TWIST** filter into the bottom of reservoir (from below) and tighten filter to obtain a complete seal with the reservoir. ***Do not drop the filter in from above.*** Tighten until there is a complete seal between the filter, o-ring and reservoir.

VISSEZ le filtre dans le fond du réservoir (par en-dessous) et serrez-le pour obtenir une étanchéité totale avec le réservoir. ***Ne pas installer le filtre en le laissant tomber du dessus.*** Serrez jusqu'à ce qu'il y ait une étanchéité totale entre le filtre, le joint torique et le réservoir.

3 **FILL** reservoir with cold tap water and place lid on top. Allow all water to pass through the filter before filling again.

REMPLISSEZ le réservoir d'eau froide et placez le couvercle dessus. Laissez toute l'eau s'écouler à travers le filtre avant de le remplir à nouveau.



4 **POUR OR DISPENSE** using spigot (if applicable) to fill your cup or glass once the reservoir has emptied into the body.

VERSEZ à l'aide du robinet (le cas échéant) pour remplir votre verre une fois le réservoir vide.

CLEANING INSTRUCTIONS
Clean your device in warm water using mild soap. Rinse and dry thoroughly.

INSTRUCTIONS DE NETTOYAGE
Nettoyez votre appareil à l'eau tiède avec un détergent doux. Rincez et séchez complètement.

ZEROWATER®
IF IT'S NOT ALL ZEROS - IT'S NOT ZEROWATER

THANK YOU FOR YOUR PURCHASE OF A NEW ZEROWATER® PRODUCT

Other valuable information enclosed:

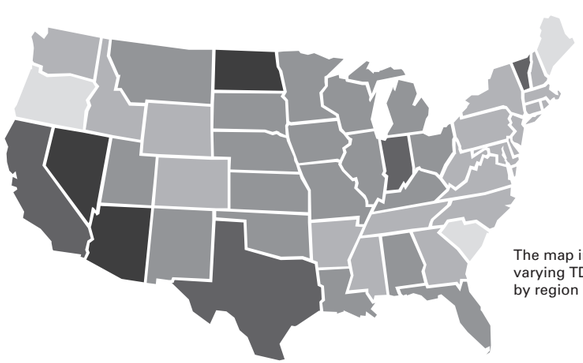
- **$30.00 in future filtration savings**
- **How ZeroWater improves the taste of drinking water**

Visit us at **www.zerowater.com** or find us on Facebook

DO YOU HAVE HIGH TDS?

Very high TDS will reduce filter life more quickly. Since ZeroWater is removing virtually all TDS from your tap water, your filters may wear out faster.

Contact ZeroWater today to find out about saving more on your filter purchases. Call **1-800-503-2939** and ask about the ZeroWater Continuity Program and start saving today!



The map indicates varying TDS levels by region

002-050 | 051-200 | 201-300 | 301-400 | 401+

ZeroWater customer readings as of May 2010

SHARE & COMPARE

Enter your tap water's TDS reading at www.zerowater.com to save on future filter purchases.

ZEROWATER'S PATENTED 5-STAGE FILTER
vs.
STANDARD 2-STAGE FILTER

ZeroWater's Patented 5-Stage Filter

2-Stage Filter (Old Technology)

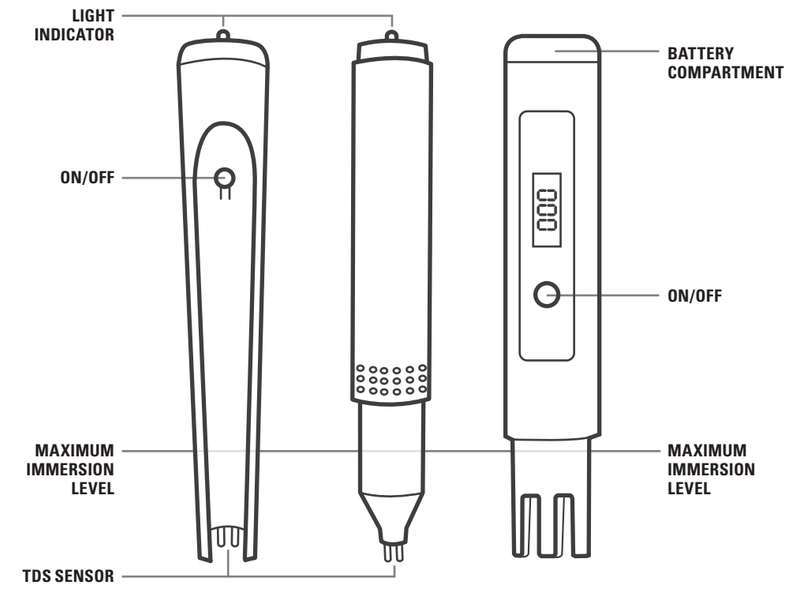
THE BIG DIFFERENCE

Most conventional carbon filters only filter certain substances from your water. ZeroWater's patented Ion Exchange System, with **FIVE** combined technologies, provides the only filtered water that meets the FDA definition of purified bottled water.*

*Filtered potable tap water tested by an independent lab (not the FDA) to meet specifically the water quality requirements for using the label "purified." Compared to water produced by leading gravity fed filters.

A TDS METER WILL SHOW YOUR TAP WATER READING

Visit **www.zerowater.com** and purchase your own TDS meter.
Enter "**mymeter**" at checkout for a discount.



TDS meters included with select ZeroWater pitchers/dispensers

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ZEROWATER FILTER DISPENSER, PITCHER & TDS METER WARRANTY

Zero Technologies, LLC warrants to the consumer for the period of ninety (90) days from the date of purchase, the ZeroWater Dispenser/Pitcher (except for the filter cartridge which is warranted for 30 days) against all defects in materials and workmanship, when used in compliance with the Owner's Manual. During this 90-day period, if you discover that any parts of the ZeroWater Dispenser/Pitcher are damaged or broken, due to any manufacturing defects, we will replace the parts free of charge by calling: 1-800-503-2939 in the United States. The warrantor assumes no responsibility for incidental or consequential damages; for damages arising out of misuse of the product or the use of any unauthorized attachment. Some states do not allow the exclusion or limitation of incidental or consequential damages, the above limitation or exclusion may not apply to you. To the extent permitted by local law, this warranty is in lieu of any other warranty, express or implied, including any implied warranty of merchantability or fitness and precludes any other obligation on the part of the manufacturer, distributor, or dealer, including any liability for special, incidental or consequential damages. This warranty gives your specific legal rights, and you may also have other rights which vary from state to state in the United States.

REPLACEMENT FILTER CARTRIDGE WARRANTY & RETURN POLICY

Though replacement filter cartridges do have a 30 day warranty for manufacturing defects, there is no money back guarantee otherwise. To place a claim for a defective cartridge, you must first speak to a customer service representative who will help you trouble shoot any problems. If a problem is found that may be due to a manufacturing defect, they will then give you instructions on how to send back the cartridges to be tested by our laboratory. Depending on whether or not the lab determines the cartridges to be defective, they will either be replaced or returned to you. Please remember that we do not and cannot warrant the life of the filter cartridges since there are many variables that affect the life of each cartridge, including: weather, your local treatment facility, consumption rate, etc. We can only provide estimates based on the experiences of other customers. A shortened cartridge life alone does not necessarily mean that you have a defective cartridge.

RETURN POLICY

We want you to be completely satisfied with your purchase. We stand behind our products with a 30 day, money back guarantee. If for any reason you are not completely happy with the water filter systems that you receive, just return to us within 30 days of receiving the merchandise for a refund of your product purchase price (less shipping and handling). Returns must be received within 30 days of your receipt of the item. Returns after 30 days may not be accepted at all or may be subject to restocking/refurbishing charges. Return policy applies to direct sales only, retail sales do not apply. Please also note that all components of a filter system, including the digital TDS water meter, must be returned in good condition to be accepted as returned merchandise.

Should service be required or you have any questions regarding how to use your ZeroWater product, please call Customer Service toll free 8am-8pm CT, Mon-Fri, at 1-800-503-2939, or visit our website at: www.zerowater.com

Complete warranty registration at **www.zerowater.com**

Zero Technologies, LLC,
4510 Adams Circle, Suite G, Bensalem, PA 19020

THREE WAYS TO SAVE!

1. Register at **zerowater.com** OR call customer service at 1-800-503-2939
2. Fill out the form below and mail to: **ZeroWater Savings 4510 Adams Circle, Unit G • Bensalem, PA 19020**

Sign me up to receive coupons for ZeroWater® Patented Ion Exchange Filter Replacements by mail.

Name:_____ E-mail:_____

Street Address:_____

City:_____ State/Province:_____ Zip/Postal Code:_____

3 IMMEDIATE SAVINGS

MANUFACTURER'S COUPON | EXPIRES 12/31/15

$2.50 OFF

2-Pack ZeroWater® Replacement Filters

storefinder at www.zerowater.com

0188781-008487

5 88781 00084 1

CONSUMER: Take this coupon to the checkout stand and save $2.50 on a 2-Pack of ZeroWater Replacement Filters. Limit one coupon per store visit. No doubling of coupon allowed. Coupon cannot be assigned, transferred or reproduced. Coupon good only on product indicated, any other use constitutes fraud. **RETAILER:** You will be reimbursed for the face value of this coupon plus .08 cents handling allowance, if submitted in compliance with Standard Coupon Redemption Policies. Manufacturer reserves the right to request invoices proving purchase of sufficient stock to cover coupons presented for redemption. Void where taxed, restricted, prohibited, or presented by other than retailers of our products. Cash Value: 1/100th of a cent. Coupon must be redeemed by 12/31/15. **MAIL TO:** PMCI $2.50 Coupon Offer Dept. 6356, PO BOX 5011, Stacy, MN 55078-5011. © 2014 Zero Technologies, LLC.

MANUFACTURER'S COUPON | EXPIRES 12/31/15

$2.50 OFF

4-Pack ZeroWater® Replacement Filters

storefinder at www.zerowater.com

0188781-008488

5 88781 00084 1

CONSUMER: Take this coupon to the checkout stand and save $2.50 on a 4-Pack of ZeroWater Replacement Filters. Limit one coupon per store visit. No doubling of coupon allowed. Coupon cannot be assigned, transferred or reproduced. Coupon good only on product indicated, any other use constitutes fraud. **RETAILER:** You will be reimbursed for the face value of this coupon plus .08 cents handling allowance, if submitted in compliance with Standard Coupon Redemption Policies. Manufacturer reserves the right to request invoices proving purchase of sufficient stock to cover coupons presented for redemption. Void where taxed, restricted, prohibited, or presented by other than retailers of our products. Cash Value: 1/100th of a cent. Coupon must be redeemed by 12/31/15. **MAIL TO:** PMCI $2.50 Coupon Offer Dept. 6356, PO BOX 5011, Stacy, MN 55078-5011. © 2014 Zero Technologies, LLC.

ZEROWATER®
IF IT'S NOT ALL ZEROS - IT'S NOT ZEROWATER

MERCI DE VOTRE ACHAT DU NOUVEAU PRODUIT ZEROWATER®

Sont inclues les informations importantes suivantes:

- **Économies de 30,00 $ sur des achats ultérieurs de filtres**
- **La façon dont ZeroWater améliore le goût de l'eau potable**

Visitez notre site à **www.zerowater.com** ou retrouvez-nous sur Facebook

EST-CE QUE VOTRE TAUX DE MTD EST ÉLEVÉ?

Un taux de MTD très élevé réduit la vie utile du filtre. Dans la mesure où ZeroWater prélève pratiquement toutes les MTD de l'eau du robinet, les filtres peuvent s'user plus rapidement.

Contactez ZeroWater aujourd'hui pour obtenir de plus amples informations sur les économies que vous pourriez réaliser sur des achats des filtres. Appelez le +1 (800) 503-2939 pour obtenir de plus amples informations sur le programme ZeroWater Continuity et commencez dès aujourd'hui à faire des économies!

La carte indique les divers niveaux de MTD par région

002-050	051-200	201-300	301-400	401+

Relevés des clients ZeroWater à compter du mois de mai 2010

PARTAGER ET COMPARER

Saisissez le relevé de vos MTD de l'eau du robinet sur le site www.zerowater.com et constatez les économies que vous pourriez réaliser sur les futurs achats des filtres.

FILTRE BREVETÉ 5 ÉTAPES DE ZEROWATER
vs.
FILTRE STANDARD 2 ÉTAPES

Filtre à 5 étapes breveté de ZeroWater

Filtration en 2 étapes (ancienne technologie)

LA GRANDE DIFFÉRENCE

La plupart des fi ltres carbones traditionnels ne fi ltrent que certaines substances de votre eau. Le système breveté échangeur d'ions de ZeroWater, avec **CINQ** technologies combinées, offre la seule eau fi ltrée qui réponde à la défi nition de la FDA de l'eau en bouteille purifi ée.*

*Eau du robinet potable filtrée testée par un laboratoire indépendant (qui n'est pas la FDA) afin de satisfaire aux exigences de qualité de l'eau pour pouvoir utiliser le label « purifiée ». Comparée à l'eau produite en la conduisant à des filtres d'alimentation par gravité.

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GARANTIE POUR LE DISTRIBUTEUR ET LA CARAFE Á FILTRE ET L'APPAREIL DE MESURE DES MDT DE ZEROWATER
Zero Technologies, LLC garantit au consommateur pour une période de quatre-vingt-dix (90) jours á partir de la date d'achat, le distributeur/la carafe ZeroWater (sauf la cartouche á filtre qui garantie 30 jours) pour tout défaut des matériaux ou de fabrication quand ils sont utilises conformément au manuel d'utilisation. Durant cette période de 90 jours, si vous découvrez qu'une piéce du distributeur/de la carafe ZeroWater est endommagée ou cassée á cause d'un défaut de fabrication, nous remplacerons la piéce gratuitement si vous appelez le 1-800-503-2939 aux Etats-Unis. Le garant n'assume aucune responsabilité pour les dommages accidentels ou indirects; pour les dommages résultant d'une mauvaise utilisation du produit ou l'utilisation de tout accessoire non autorisé. Certains états ne permettent pas l'exclusion ou la limitation des dommages accidentels ou indirects, la limitation ou l'exclusion susmentionnée peut ne pas vous être appliquée. Dans la mesure où cela est permis par la loi locale, cette garantie tient lieu et place de toute autre garantie, formelle ou implicite, y compris toute garantie implicite de commercialisation ou de conformité et exclut toute autre obligation de la part du fabricant, du distibuteur ou du revendeur, y compris toute responsabilité pour des dommages spéciaux, accidentels ou indirects. Cette garantie vous donne des droits légaux spécifiques et vous autorise également á avoir d'autres droits pouvant varier d'un état á l'autre aux Etats-Unis.

GARANTIE DE REMPLACEMENT ET POLITIQUE DE RETOUR DE LA CARTOUCHE Á FILTRE
Bien que les cartouches á filtre de remplacement ont une garantie de 30 jours pour les défauts de fabrication, il n'existe pas d'autre garantie de remboursement. Pour déposer une plainte pour une réclamation en cas de cartouche défectueuse, vous devez d'abord contacter un représentant du service clientéle qui vous aidera á résoudre le probléme quel qu'il soit. Si un probléme est constaté pouvant être dû á un défaut de fabrication, il vous sera alors donné des instructions sur la façon de renvoyer les cartouches sont defectueuses, elles seront remplacées ou vous seront renvoyées. Veuillez garder en mémoire que nous ne garantissons pas et ne pouvons pas garantir la durée de vie des cartouches á filtre car bon nombre de variables impactent la vie de chaque cartouche, comme : les conditions météorologiques, votre installation locale de traitement, le taux de consommation, etc… Nous pouvons seulement fournir des estimations basées sur l'expérience d'autres clients. Une durée de vie courte de la cartouche ne signifie pas nécessairement que vous ayez une cartouche défectueuse.

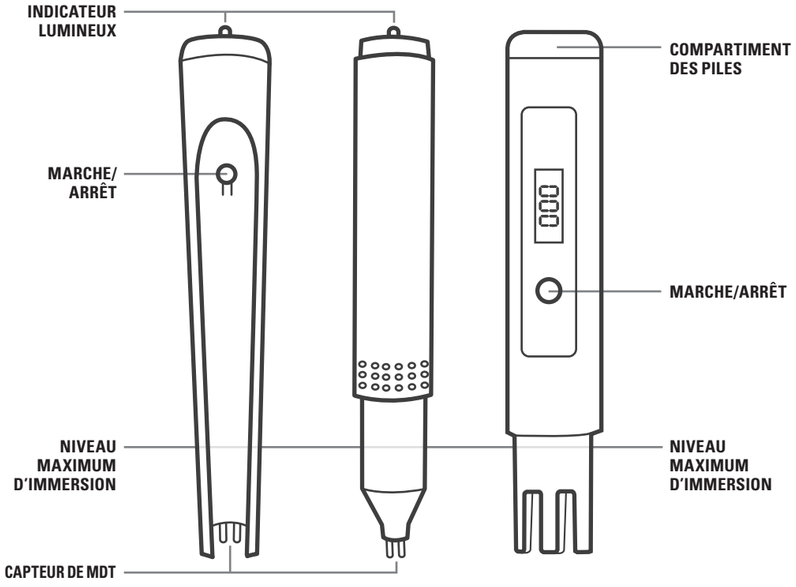
POLITIQUE DE RETOUR
Nous voulons que vous soyez pleinement satisfait de votre achat. Nous répondons de nos produits par une garantie de remboursement de 30 jours. Si pour une raison quelconque vous n'êtes pas complétement satisfait des systémes de filtration d'eau que vous recevez, il vous suffit de nous renvoyer le produit dans les 30 jours suivant la reception de la merchandise pour le remboursement de votre produit au prix d'achat (moins les frais d'expédition et de traitement). Les retours doivent être acceptés ou peuvent être soumis á des frais de restockage / de remise á neuf. La politique de retour ne s'applique qu'aux ventes directes, non aux ventes au detail. Veuillez également noter que tous les composants d'un systéme de filtrage, y compris l'appareil numérique de mesure des MDT dans l'eau, doivant être retournés en bon état pour être acceptes comme merchandise retournée.

Si vous avez besoin d'un service ou si vous avez des questions concernant la façon d'utiliser votre produit ZeroWater, veuillez appeler le service clientele gratuitement entre 8h00 et 20h00 CT, du lundi au – vendredi au 1-800-503-2939, ou visitez notre site Web á: www.zerowater.com

Zero Technologies, LLC,
4510 Adams Circle, Suite G, Bensalem, PA 19020

UN COMPTEUR DE MTD INDIQUERA LE RELEVÉ DE L'EAU DE VOTRE ROBINET

Consultez notre visite **www.zerowater.com** pour acheter votre compteur TDS.
Saisissez **« mymeter »** lorsque vous passez à la caisse pour bénéficier d'une remise.



Le compteur de MTD (matières dissoutes totales) inclut un pichet/distributeur ZeroWater

DUEX FAÇONS D'ÉCONOMISER!

1. S'inscrire sure **zerowater.com** OU appeler le serice clientele au 1-800-503-2939
2. Renseigner le formulaire ci-dessous et l'envoyer á:
   ZeroWater Savings
   4510 Adams Circle, Unit G
   Bensalem, PA 19020

Inscrivez-moi pour recevoir les coupons pour des remplacements de filter échangeur d'ions brevet ZeroWaterMD par courrier.

Nom:_____

Adresse:_____

Ville:_____ State/Province:_____ Zip/Postal Code:_____

Courriel: _____

APPENDIX C - RESIDENT LETTER

DENVER WATER

DENVER WATER

1600 West 12th Ave
Denver, CO 80204-3412
303.628.6000
denverwater.org

7/10/2019

Dear Denver Water Customer,

Denver Water wants your help with the Filter Lead Out of Water pilot study

We need your help and participation in a study on the use of water pitchers in the home. Why? Because the age of your home indicates that your service line may be made of lead.

At Denver Water, your safety is our most important responsibility. While the water we provide is safe and lead-free, lead can get into the water as it moves through household plumbing and customer-owned service lines — the pipes that bring water from Denver Water's pipe in the street to the plumbing in your home.

As we continue to help address this community issue, we're launching a Filter Lead Out of Water pilot study, in partnership with two local nonprofit organizations, Groundwork Denver and Mile High Youth Corps. Your help in this study will provide us with a better understanding of how customers may use these filters for everyday drinking and cooking activities.

We are providing you with a water pitcher filter and a three-month supply of replacement cartridges that are certified to significantly reduce lead concentrations, if present, in your household drinking water. In addition to the water pitcher filter, we are also sending set-up instructions and a few short survey questions.

Next Steps:

- Use your filter for drinking water, cooking and preparing infant formula.
- Complete the survey you received with your filter kit, as well as follow-up surveys mailed in the future.

If you are interested in an in-home meeting to talk more about lead or your filter experience, please contact us at flow@denverwater.org or 303-628-6655.

To learn more about lead in drinking water and what you can do to reduce your exposure to lead in drinking water, visit denverwater.org/Lead.

We appreciate your help in this important study. Please return the survey you received in your filter kit and follow-up surveys that will be mailed in the future.

Sincerely,

Denver Water

DENVER WATER

1600 West 12th Ave
Denver, CO 80204-3412
303.628.6000
denverwater.org

7/10/2019

Estimado(a) Cliente de Denver Water,

Denver Water quiere su ayuda con el estudio piloto Filtre el plomo del agua

Necesitamos su ayuda y participación en un estudio sobre el uso de jarras de agua en el hogar. ¿Por qué? Porque la fecha de construcción de su casa indica que su línea de servicio principal de agua puede ser hecha de plomo.

En Denver Water su seguridad es nuestra principal responsabilidad. A pesar de que el agua que suministramos es segura y sin plomo, este puede meterse al agua a medida que pasa por las tuberías de la casa y por las líneas de servicio principales particulares, que son las tuberías que llevan el agua desde la tubería de Denver Water en la calle, hasta las tuberías en su hogar.

Al tiempo que abordamos este problema de la comunidad, estamos lanzando el estudio piloto llamado Filtre el plomo del agua, en asociación con dos organizaciones locales sin fines de lucro, Groundwork Denver y Mile High Youth Corps. Su ayuda en este estudio nos permitirá entender mejor cómo los clientes pueden usar estos filtros para el agua de beber diaria y la de cocinar.

Le estamos suministrado una jarra con filtro para el agua y los cartuchos de repuesto para tres meses, que están certificados para reducir de manera considerable la concentración de plomo, si está presente en el agua potable de su hogar. Además de la jarra con filtro para el agua, le estaremos enviando instrucciones de uso y una encuesta corta.

Los siguientes pasos:

- Use su filtro para el agua que va a beber, con la que va a cocinar y preparar biberones.
- Complete la encuesta que recibió con el kit del filtro, así como las encuestas de seguimiento que recibirá por correo más adelante.

Si le interesa que alguien venga a su hogar para hablarle sobre el plomo o sobre su experiencia con el filtro, comuníquese con nosotros en flow@denverwater.org o al 303-628-6655.

Para obtener más información sobre el plomo en el agua potable y sobre lo que usted puede hacer para reducir su exposición al plomo en el agua potable, visite la página web denverwater.org/Lead.

Agradecemos su ayuda en este importante estudio. Por favor complete la encuesta que recibió con su kit del filtro, así como las encuestas de seguimiento que recibirá por correo más adelante.

Cordialmente,

Denver Water

APPENDIX D - SURVEY QUESTIONS

DENVER WATER

DENVER WATER

Filter Pilot Survey Question Matrix

Questions	Initial Survey (5116)	Use Survey (5122)	Alternative Filter Survey (5125)	Ongoing Surveys (5132)
1. Do you use your filter for drinking water? • Yes • No		X	X	X
2. Do you use your filter for water used for cooking? • Yes • No		X	X	X
3. Do you have a lead service line? • Yes • No • I do not know	X			
4. What is your household's primary source of drinking water? (Check one) ☐ Unfiltered faucet ☐ Bottled water ☐ Filtered - refrigerated water/ice dispenser ☐ Filtered - pitcher filter ☐ Filtered - under sink filter ☐ Filtered - faucet mounted filter ☐ Filtered - whole house filter ☐ Other (specify)	X			
5. What is your household's primary source of water used for cooking? (Check one) ☐ Unfiltered faucet ☐ Bottled water ☐ Filtered - refrigerated water/ice dispenser ☐ Filtered - pitcher filter ☐ Filtered - under sink filter ☐ Filtered - faucet mounted filter ☐ Filtered - whole house filter ☐ Other (specify)	X			

DENVER WATER

Filter Pilot Survey Question Matrix

Questions	Initial Survey (5116)	Use Survey (5122)	Alternative Filter Survey (5125)	Ongoing Surveys (5132)
6. If you have an existing water filter system, what is the make and model number for your filter? (Fill in)	X			
7. Do you currently or do you plan in the future to use filtered or bottled water for infant formula? Yes/No/NA	X	X	X	X
8. If you do not primarily use the water filter provided, what issues are you experiencing? (Check all that apply) ☐ Filter pitcher isn't large enough ☐ Filter pitcher doesn't fit in refrigerator ☐ The filter pitcher takes too much time to fill ☐ It's too much effort to use the filter pitcher ☐ I'm not interested in filtering my drinking water ☐ Other, please specify: (fill in the blank) ☐ Not Applicable (no issues)		X		X
9. If the water filter provided does not meet your needs, would you be more likely to use an alternative filter? (Check one) ☐ Faucet-mounted filter ☐ Refrigerator filter ☐ Larger pitcher filter ☐ Not Applicable (the water filter meets my needs)		X		X
10. Are you familiar with filter maintenance and cartridge replacement requirements? E.g. replacing the filter cartridge, cleaning the pitcher (if applicable)? Yes/No		X	X	X
11. What questions or comments do you have about the filter pilot?	X	X	X	X
12. How could we improve the filter pilot?	X	X	X	X
13. Want to stay informed about the FLOW pilot? Provide your email or phone number.	X	X	X	X

To be added to every survey: FILTER LEAD OUT OF WATER

Please provide your email address or mailing address to receive your Amazon gift card.
Email: _____ Mailing Address: _____

Survey Lead-Ins:

Initial Survey

Thank you for participating in Denver Water's FLOW Pilot. Your feedback will help us understand information about how water is used in your home for drinking and cooking activities. Please use the ZeroWater® pitcher provided and return your completed survey by mail or online within two weeks of receiving the filter kit. **As our way of thanking you for your feedback and using your filter, upon receipt of the completed survey, Denver Water will send you a $15 Amazon gift card.** For an online survey, go to denverwater.org/Lead-survey or scan the QR code at the bottom of this survey.

Use Survey

Thank you for participating in Denver Water's FLOW Pilot. Your feedback will help us understand information about how water is used in your home for drinking and cooking activities and your preference for filters. Please use the ZeroWater® pitcher provided and return your completed survey by mail or online by July 31, 2019. **As our way of thanking you for your feedback and using your filter, upon receipt of the completed survey, Denver Water will send you a $15 Amazon gift card.** For an online survey go to denverwater.org/FLOW-survey or scan the QR code at the bottom of this survey.

Alt Survey

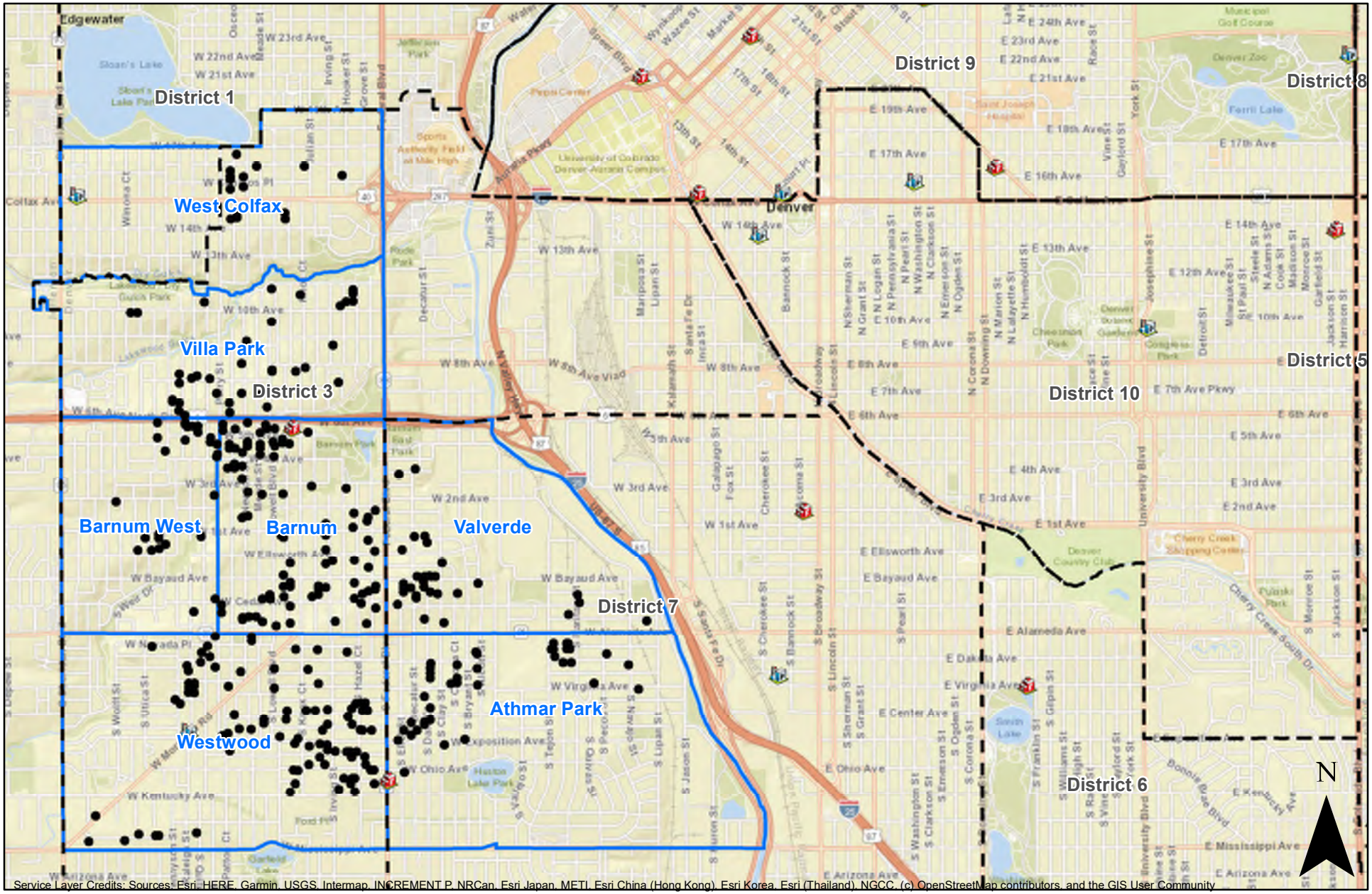
Thank you for participating in Denver Water's FLOW Pilot. Your feedback will help us understand information about how water is used in your home for drinking and cooking activities. Please use the alternative filter provided and return your completed survey by mail or online by August 30, 2019. **As our way of thanking you for your feedback and using your filter, upon receipt of the completed survey, Denver Water will send you a $15 Amazon gift card.** For an online survey go to http://bit.do/LSL-AltFilter or scan the QR code at the bottom of this survey.

Ongoing Surveys

Thank you for participating in Denver Water's FLOW Pilot. Your feedback will help us understand information about how water is used in your home for drinking and cooking activities. Please use your provided filter and return your completed survey by mail or online by TBD. **As our way of thanking you for your feedback and using your filter, upon receipt of the completed survey, Denver Water will send you a $15 Amazon gift card.** For an online survey go to http://bit.do/LSL-Ongoing or scan the QR code at the bottom of this survey.

APPENDIX E - MAPS

DENVER WATER



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0 0.25 0.5 1 1.5 2 Miles

Fire Stations

Police Stations

Filter Pilot Locations (331)

Council Districts

Neighborhoods

Registered Neighborhood Organizations

Filter Pilot Area

DENVER WATER

Author: R. Avery

Map Date: 2019-07-08

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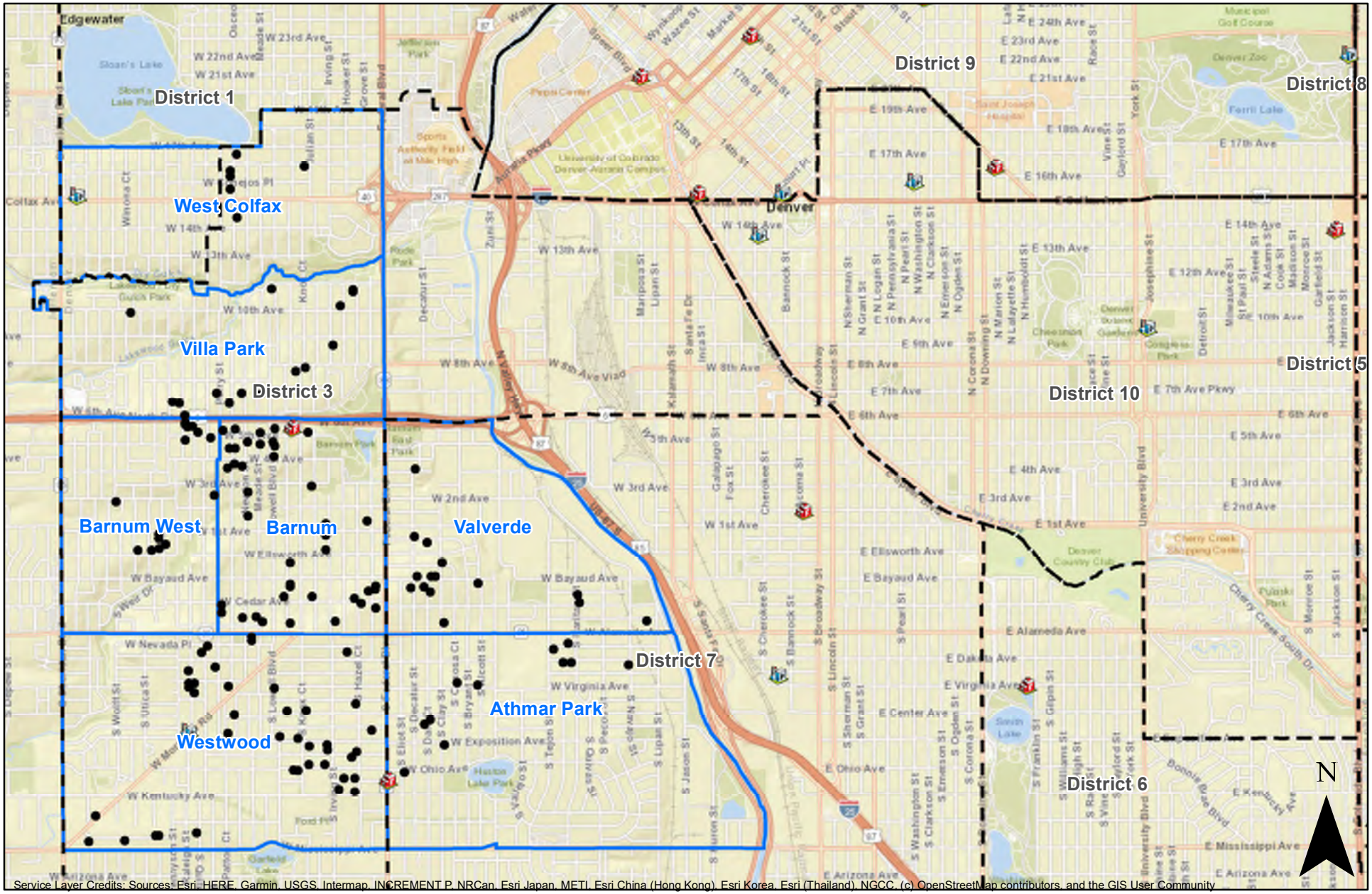

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0 0.25 0.5 1 1.5 2 Miles

Filter Pilot Hand Delivery Locations

Fire Stations

Police Stations

Filter Pilot Hand Delivery Locations (142)

Council Districts

Neighborhoods

Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery

Map Date: 2019-07-08

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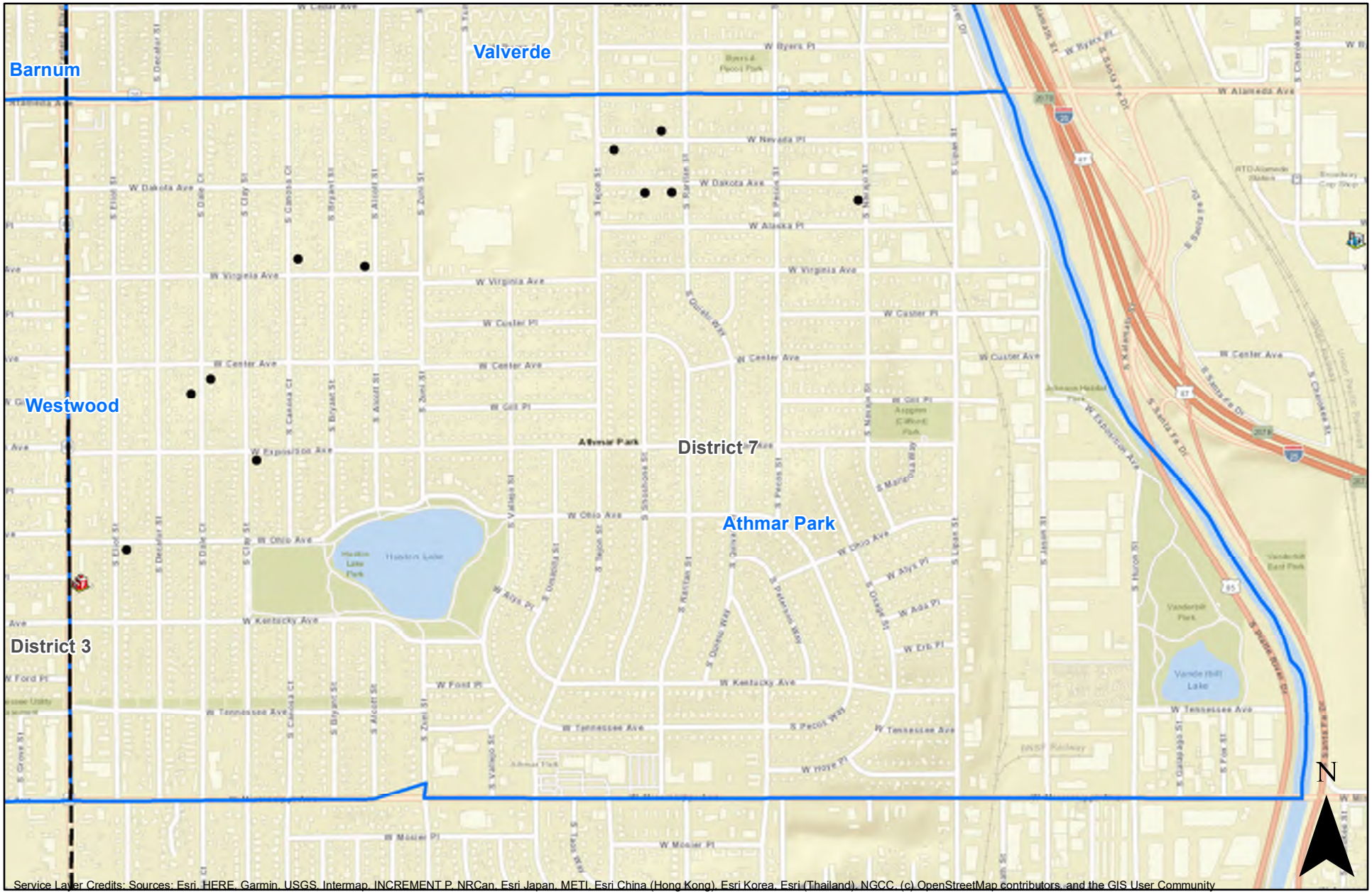

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0 420 840 1,680 2,520 3,360 Feet

Filter Hand Delivery Locations: Athmar Park

Fire Stations
Police Stations
Filter Pilot Hand Delivery Locations (11)
Council Districts
Neighborhoods
Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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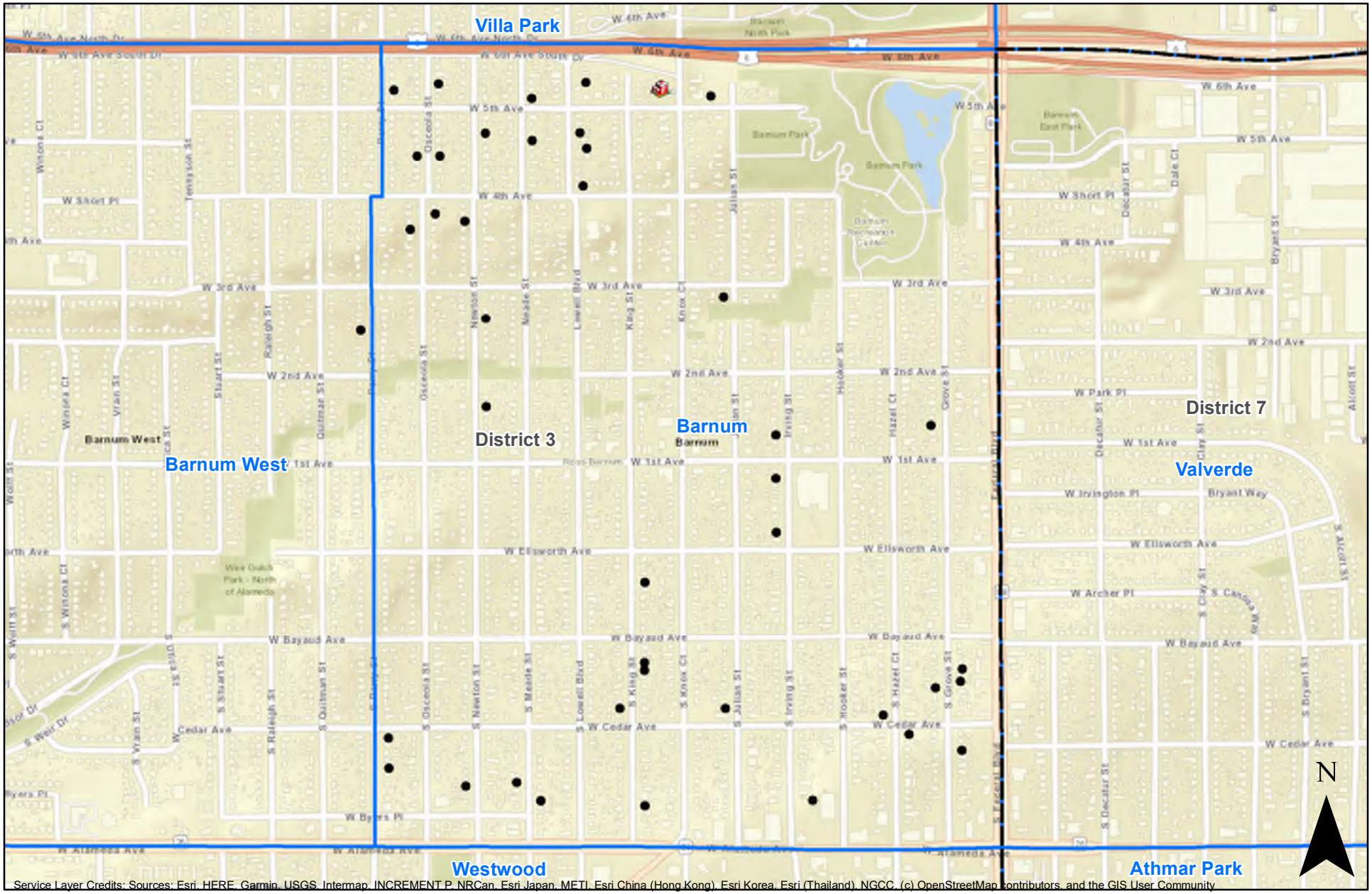

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0 365 730 1,460 2,190 2,920 Feet

Filter Hand Delivery Locations: Barnum

Fire Stations
Police Stations
Filter Pilot Hand Delivery Locations (41)
Council Districts
Neighborhoods
Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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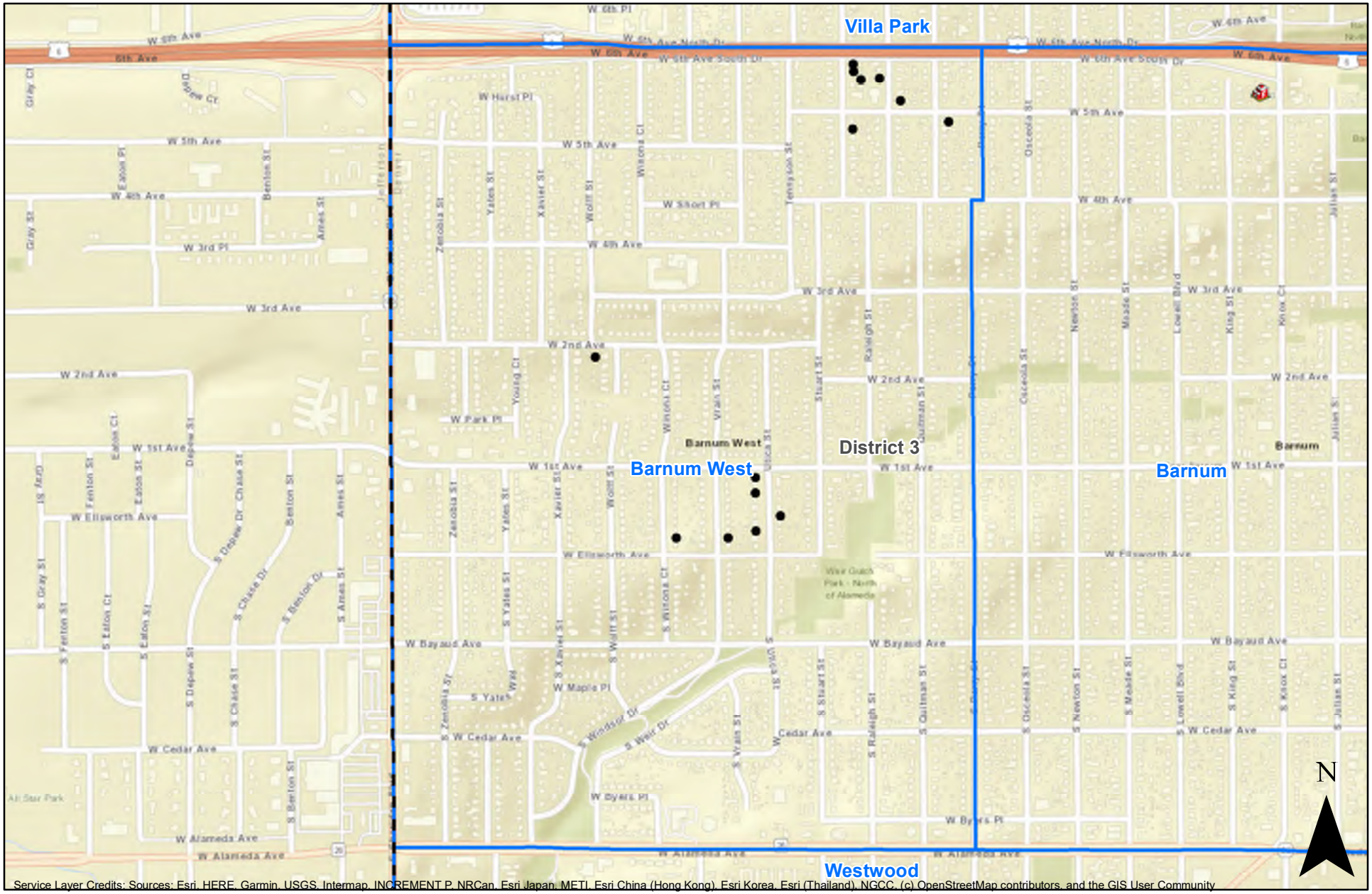

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0 365 730 1,460 2,190 2,920 Feet

Filter Hand Delivery Locations: Barnum West

Fire Stations
Police Stations
Filter Pilot Hand Delivery Locations (14)
Council Districts
Neighborhoods
Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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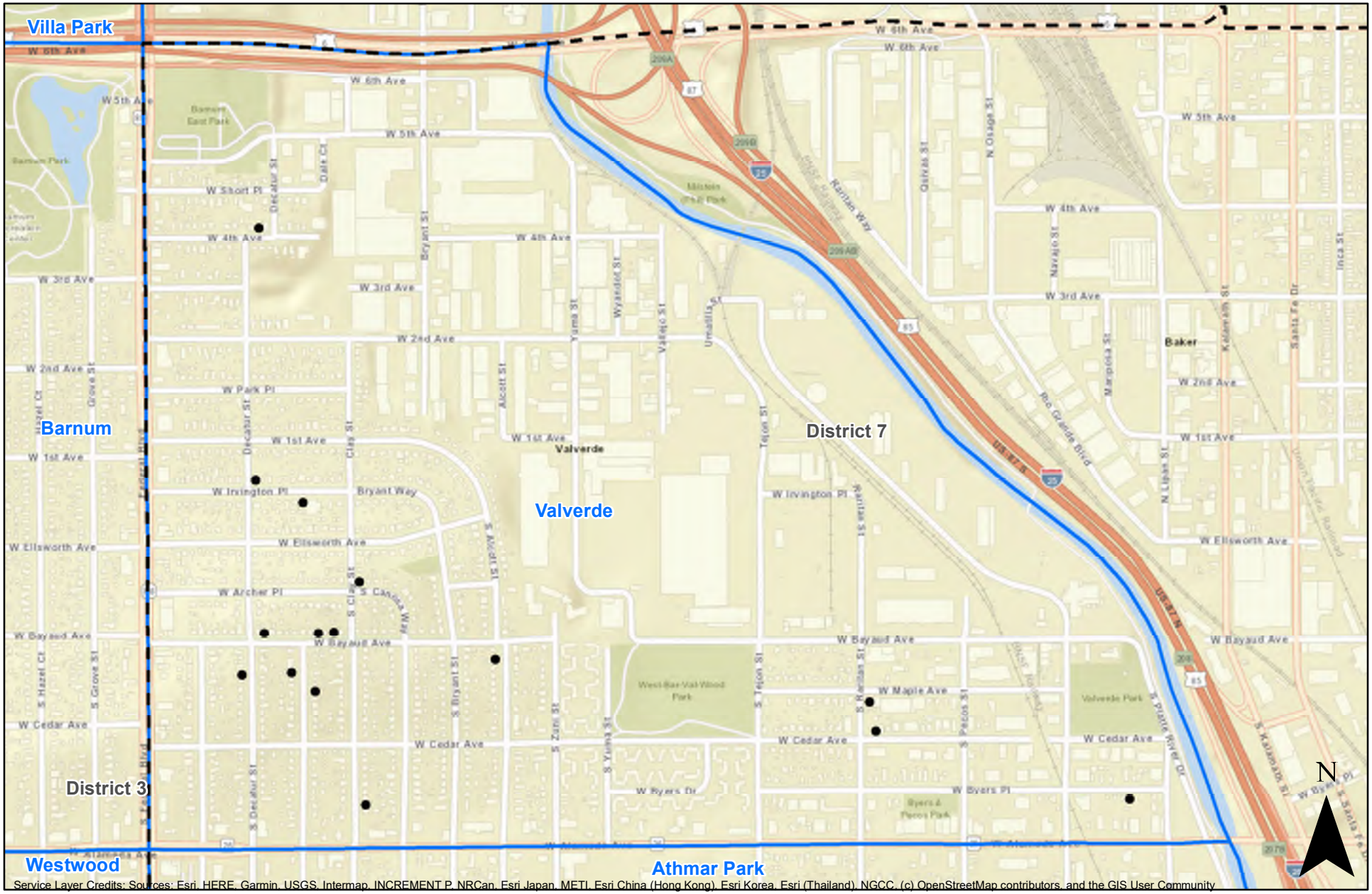

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0 362.5 725 1,450 2,175 2,900 Feet

Filter Hand Delivery Locations: Valverde

Fire Stations

Police Stations

Filter Pilot Hand Delivery Locations (15)

Council Districts

Neighborhoods

Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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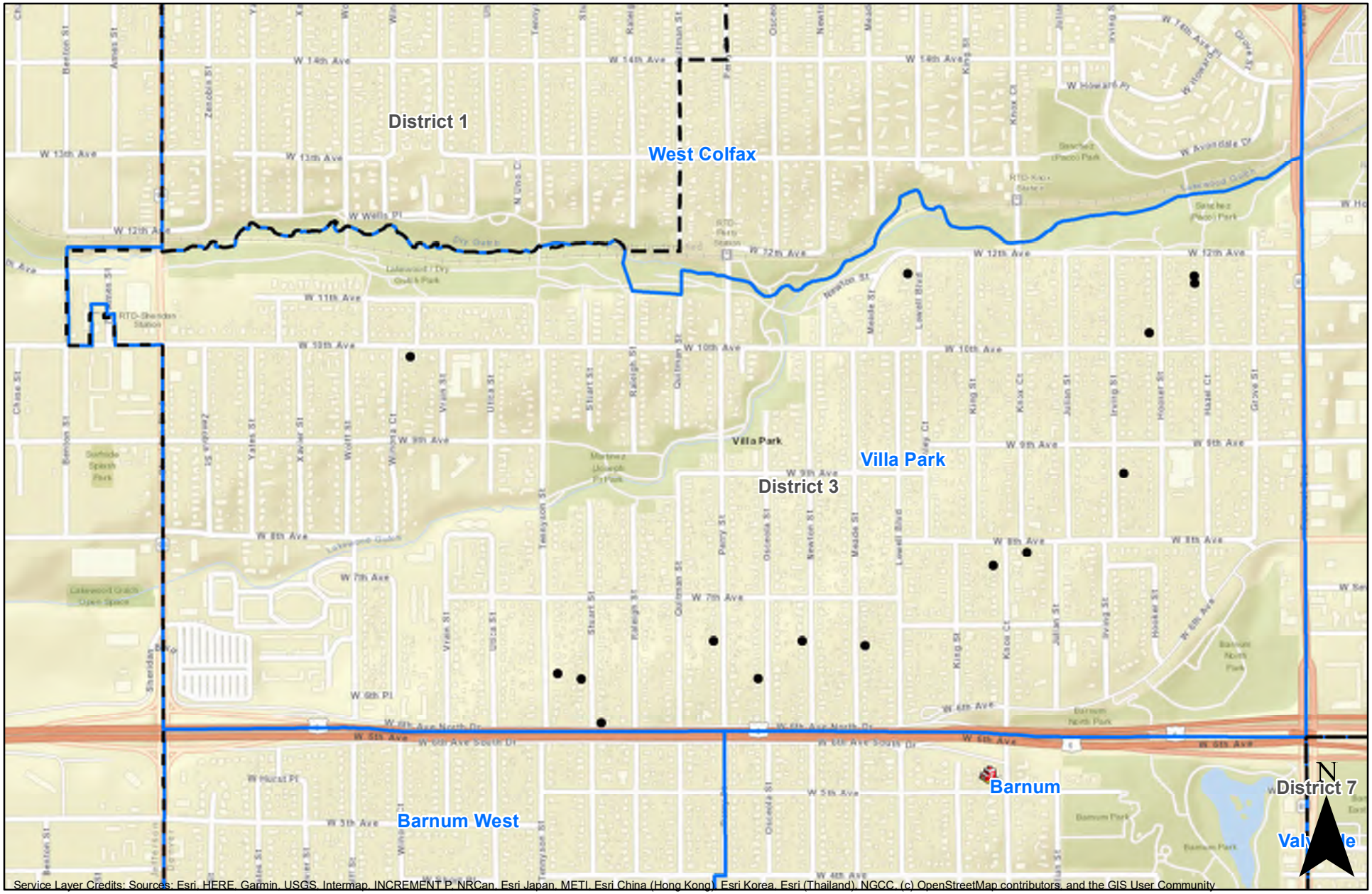

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0 385 770 1,540 2,310 3,080 Feet

Filter Hand Delivery Locations: Villa Park

Fire Stations
Police Stations
Filter Pilot Hand Delivery Locations (15)
Council Districts
Neighborhoods
Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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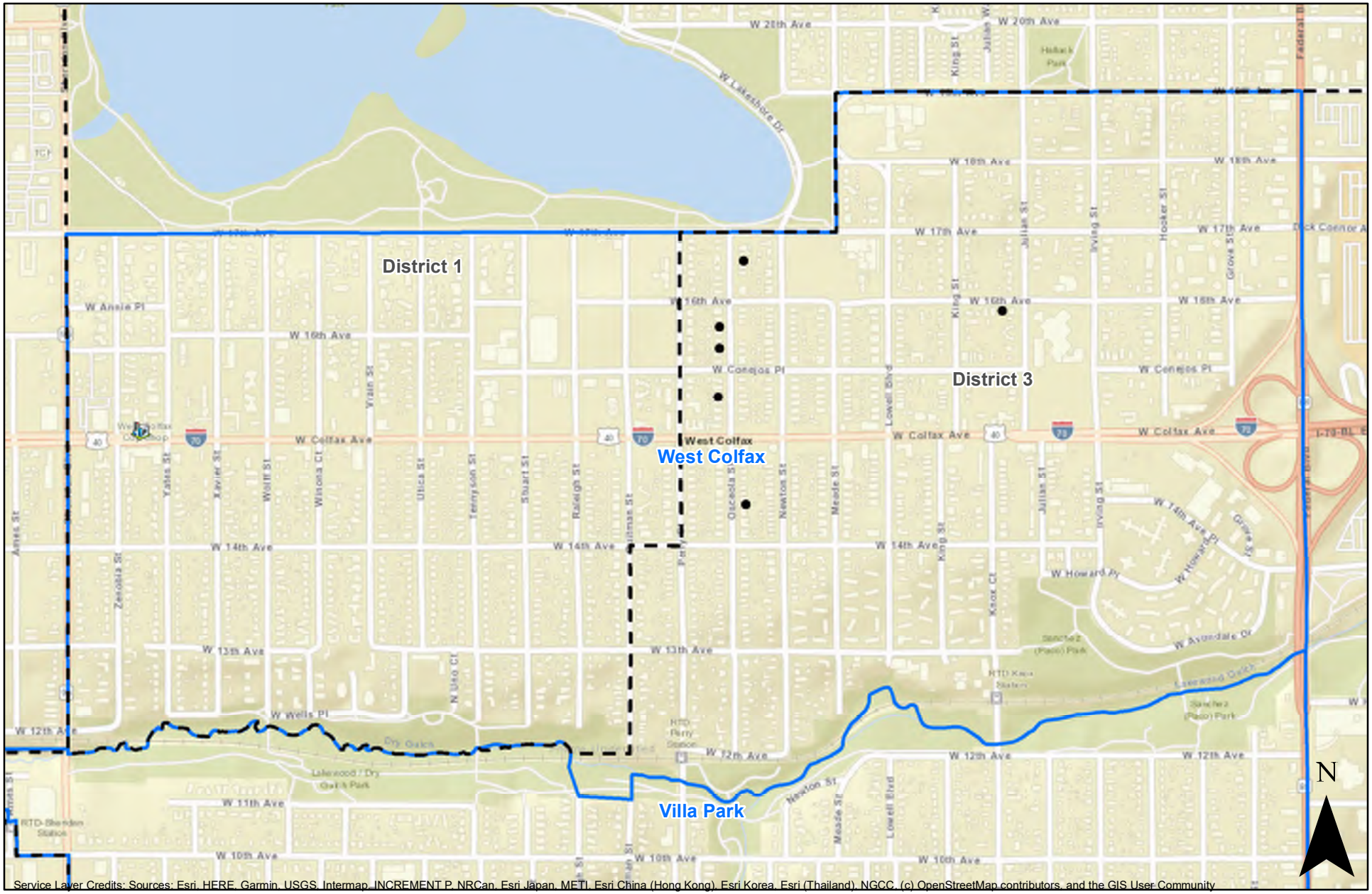

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0 355 710 1,420 2,130 2,840 Feet

Filter Hand Delivery Locations: West Colfax

Fire Stations

Police Stations

Filter Pilot Hand Delivery Locations (6)

Council Districts

Neighborhoods

Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery

Map Date: 2019-07-08

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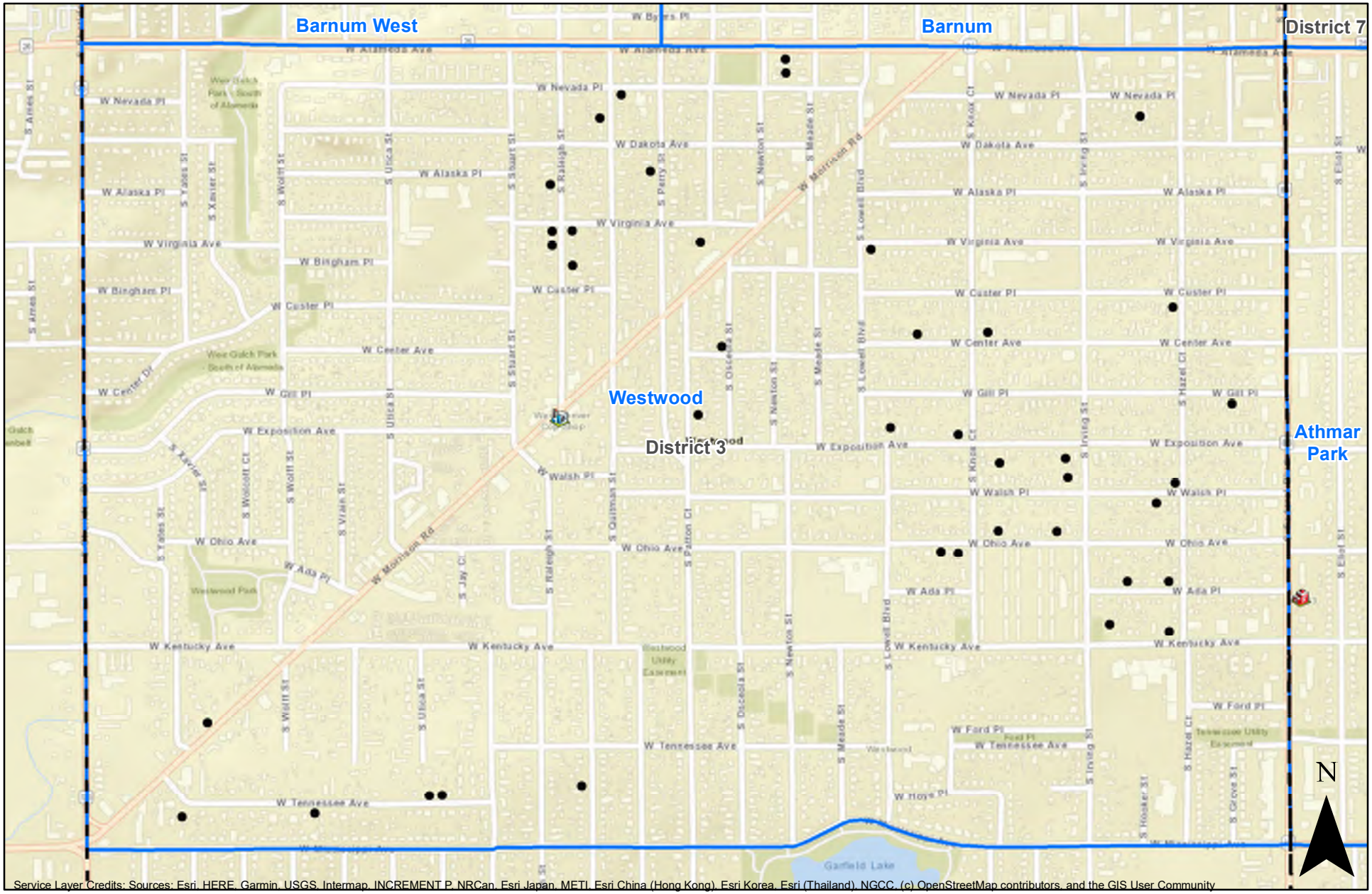

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0 370 740 1,480 2,220 2,960 Feet

Filter Hand Delivery Locations: Westwood

Fire Stations
Police Stations
Filter Pilot Hand Delivery Locations (40)
Council Districts
Neighborhoods
Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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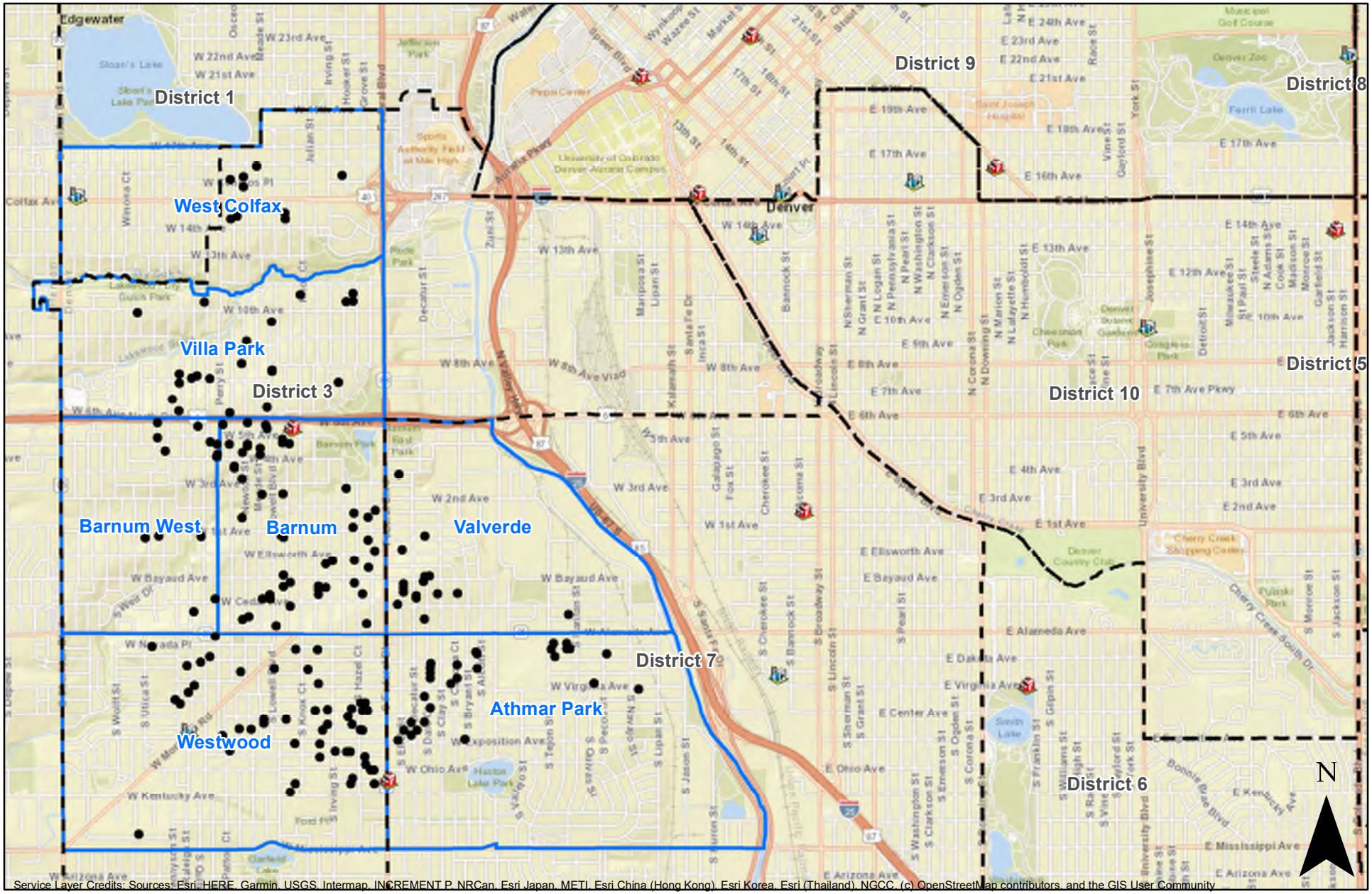

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0 0.25 0.5 1 1.5 2 Miles

Filter Pilot Mail Delivery Locations

Fire Stations
Police Stations
Filter Pilot Mail Delivery Locations (189)
Council Districts
Neighborhoods
Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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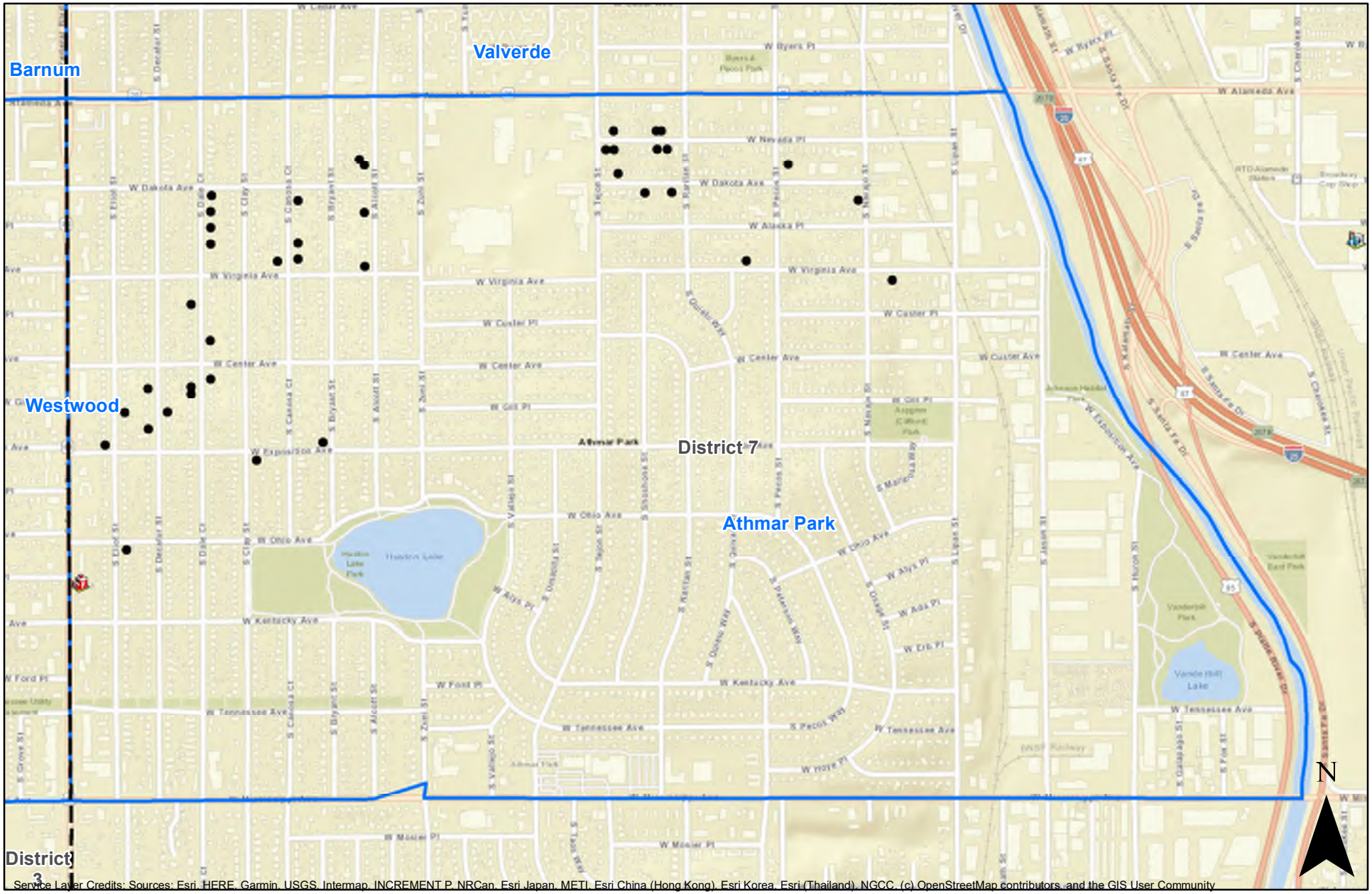

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0 420 840 1,680 2,520 3,360 Feet

Filter Pilot Locations: Athmar Park

Fire Stations
Police Stations
Filter Pilot Locations (39)
Council Districts
Neighborhoods
Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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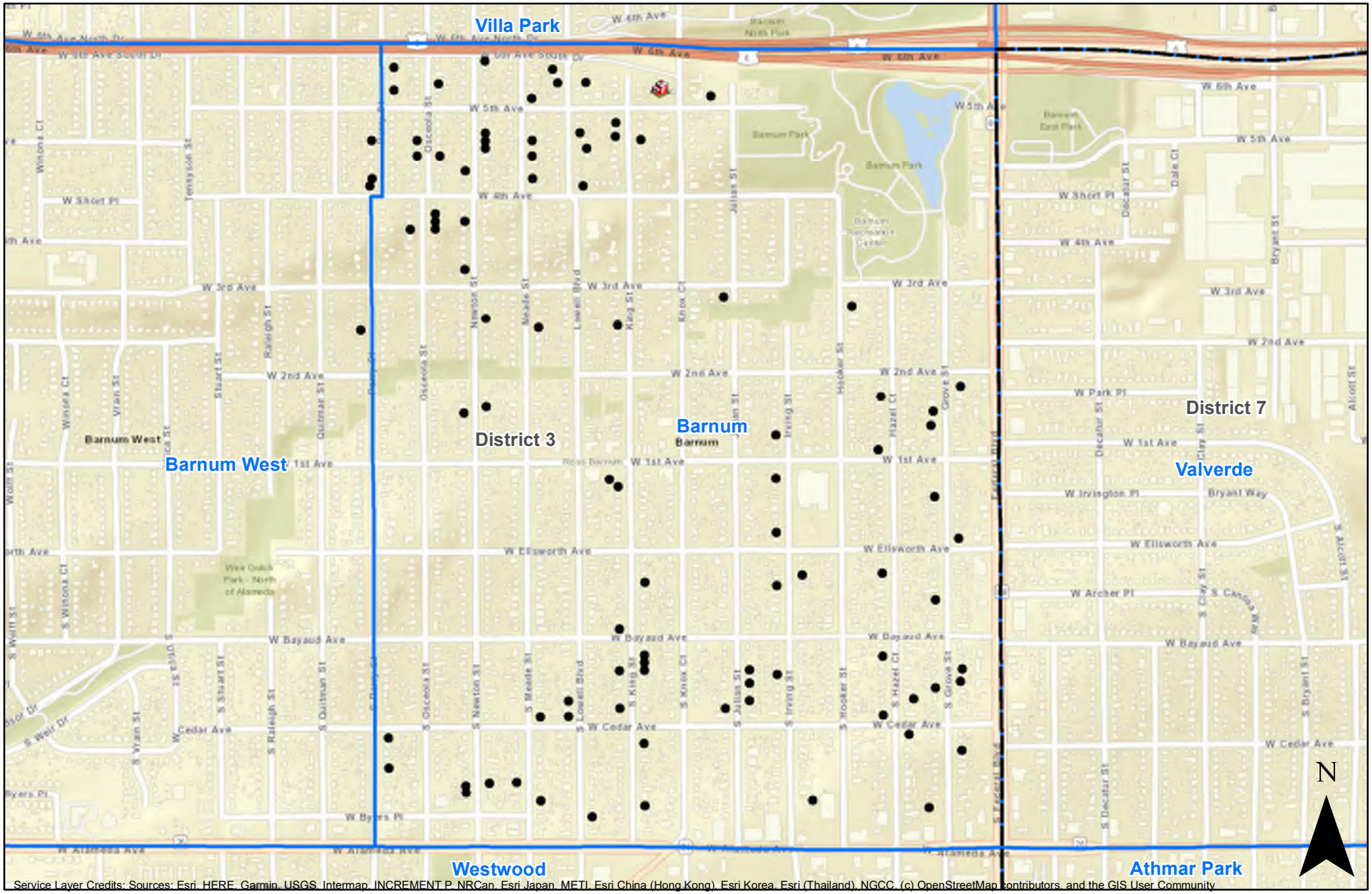

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0 365 730 1,460 2,190 2,920 Feet

Filter Pilot Locations: Barnum

Fire Stations
Police Stations
Filter Pilot Locations (93)
Council Districts
Neighborhoods
Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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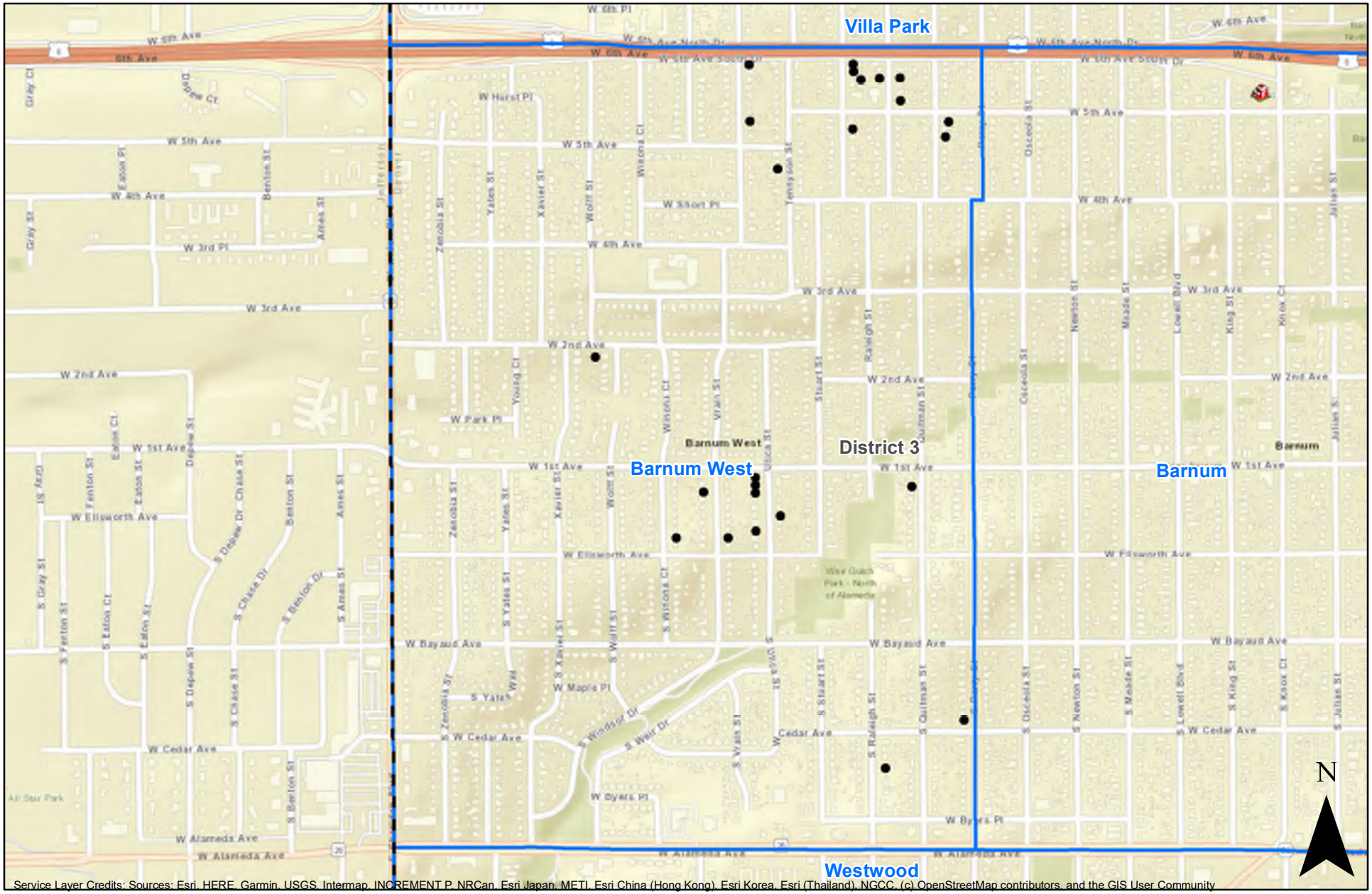

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0 365 730 1,460 2,190 2,920 Feet

Filter Pilot Locations: Barnum West

Fire Stations
Police Stations
Filter Pilot Locations (24)
Council Districts
Neighborhoods
Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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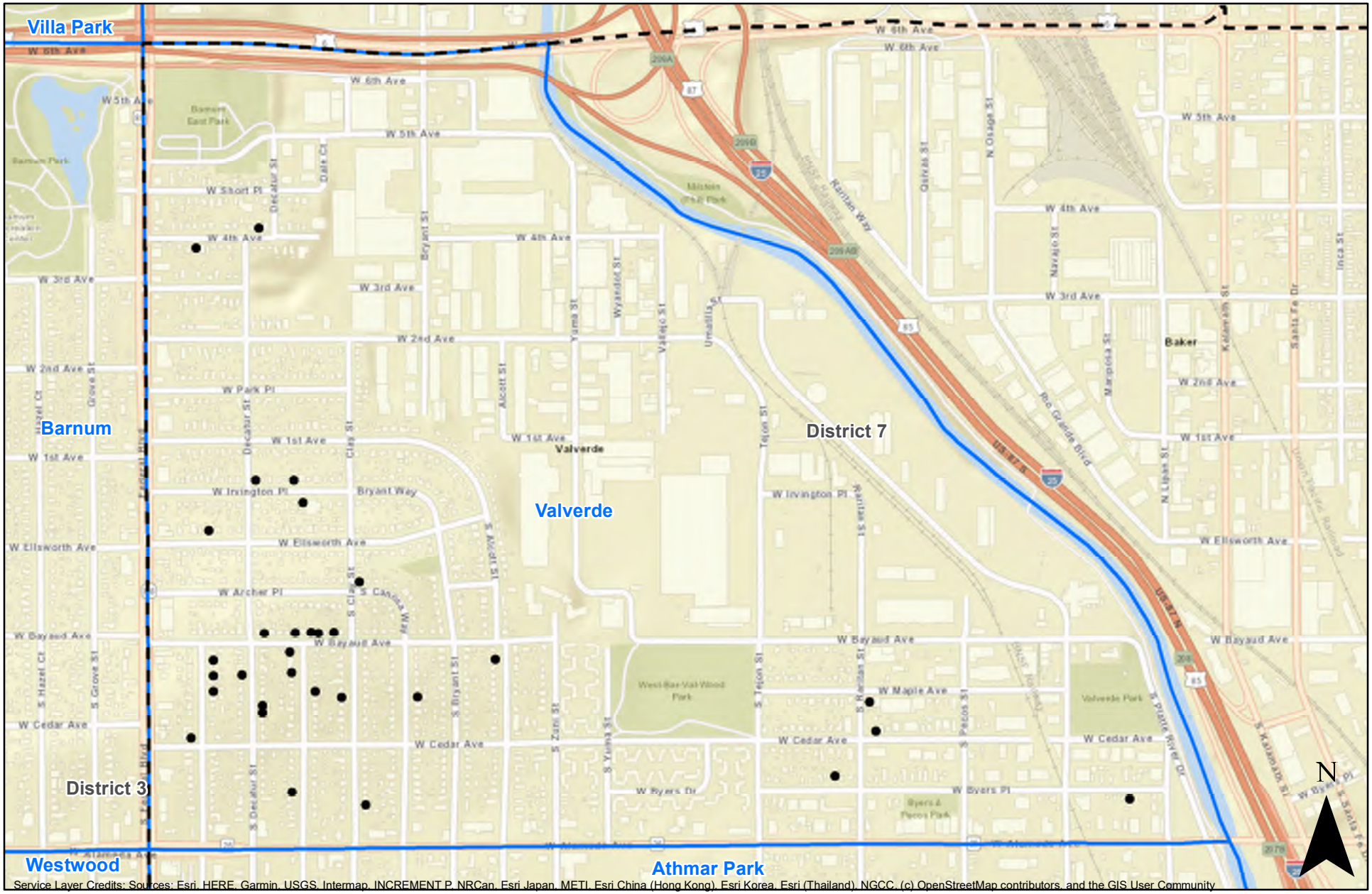

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Filter Pilot Locations: Valverde

Fire Stations
Police Stations
Filter Pilot Locations (31)
Council Districts
Neighborhoods
Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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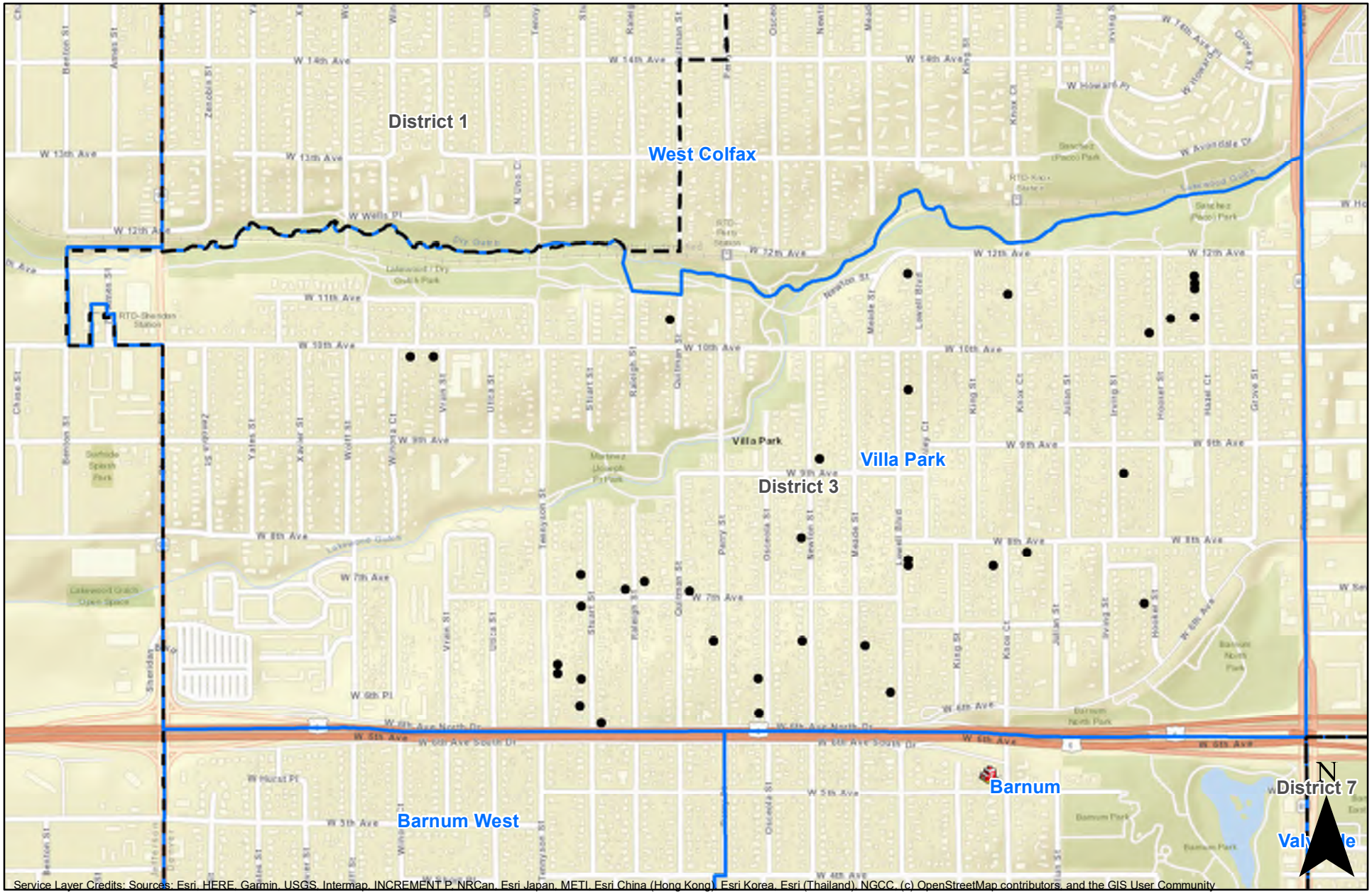

0 385 770 1,540 2,310 3,080 Feet

Filter Pilot Locations: Villa Park

Fire Stations
Police Stations
Filter Pilot Locations (36)
Council Districts
Neighborhoods
Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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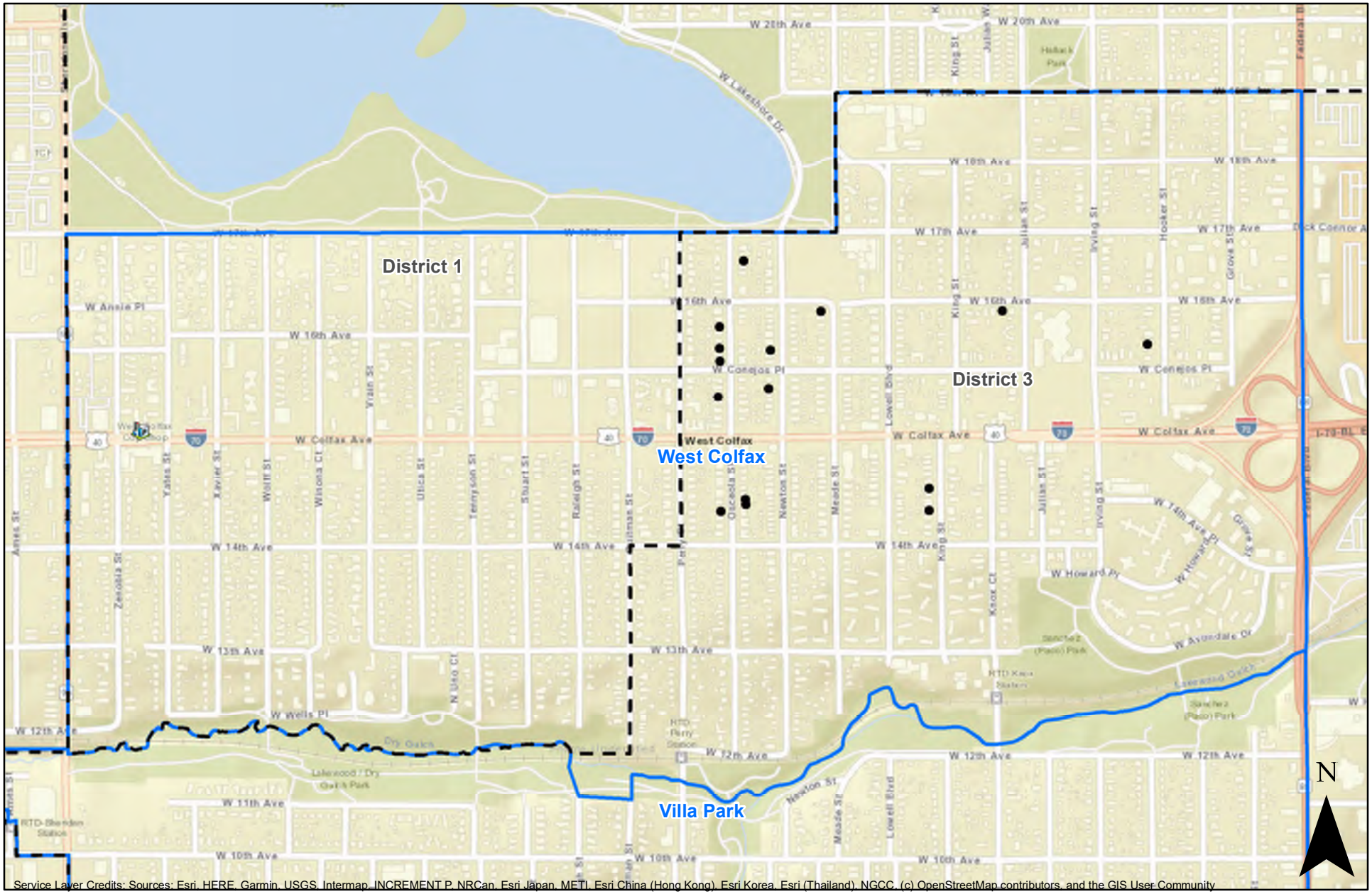

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0 355 710 1,420 2,130 2,840 Feet

Filter Pilot Locations: West Colfax

Fire Stations
Police Stations
Filter Pilot Locations (15)
Council Districts
Neighborhoods
Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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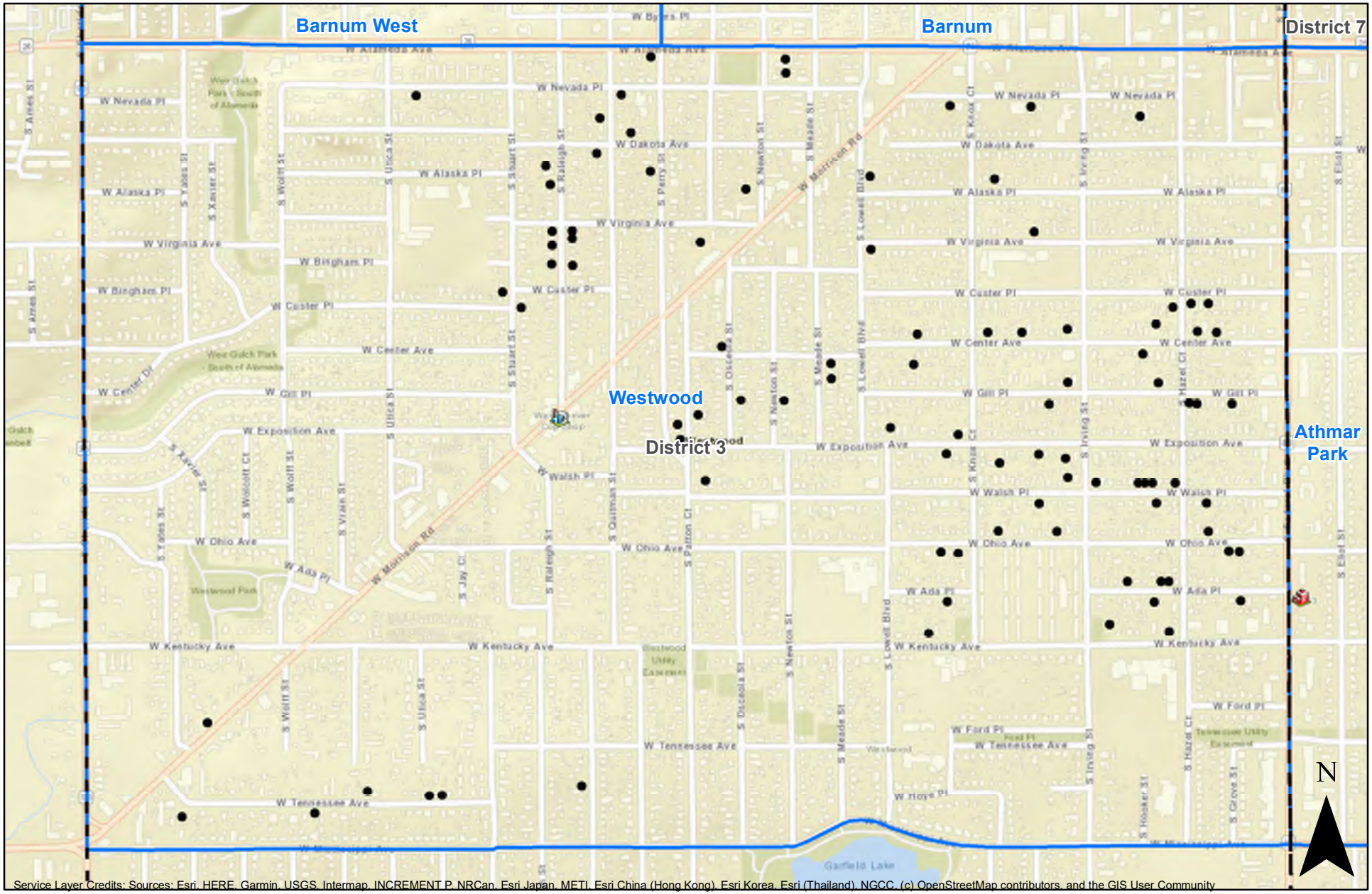

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0 370 740 1,480 2,220 2,960 Feet

Filter Pilot Locations: Westwood

Fire Stations

Police Stations

Filter Pilot Locations (93)

Council Districts

Neighborhoods

Registered Neighborhood Organizations

DENVER WATER

Author: R. Avery
Map Date: 2019-07-08

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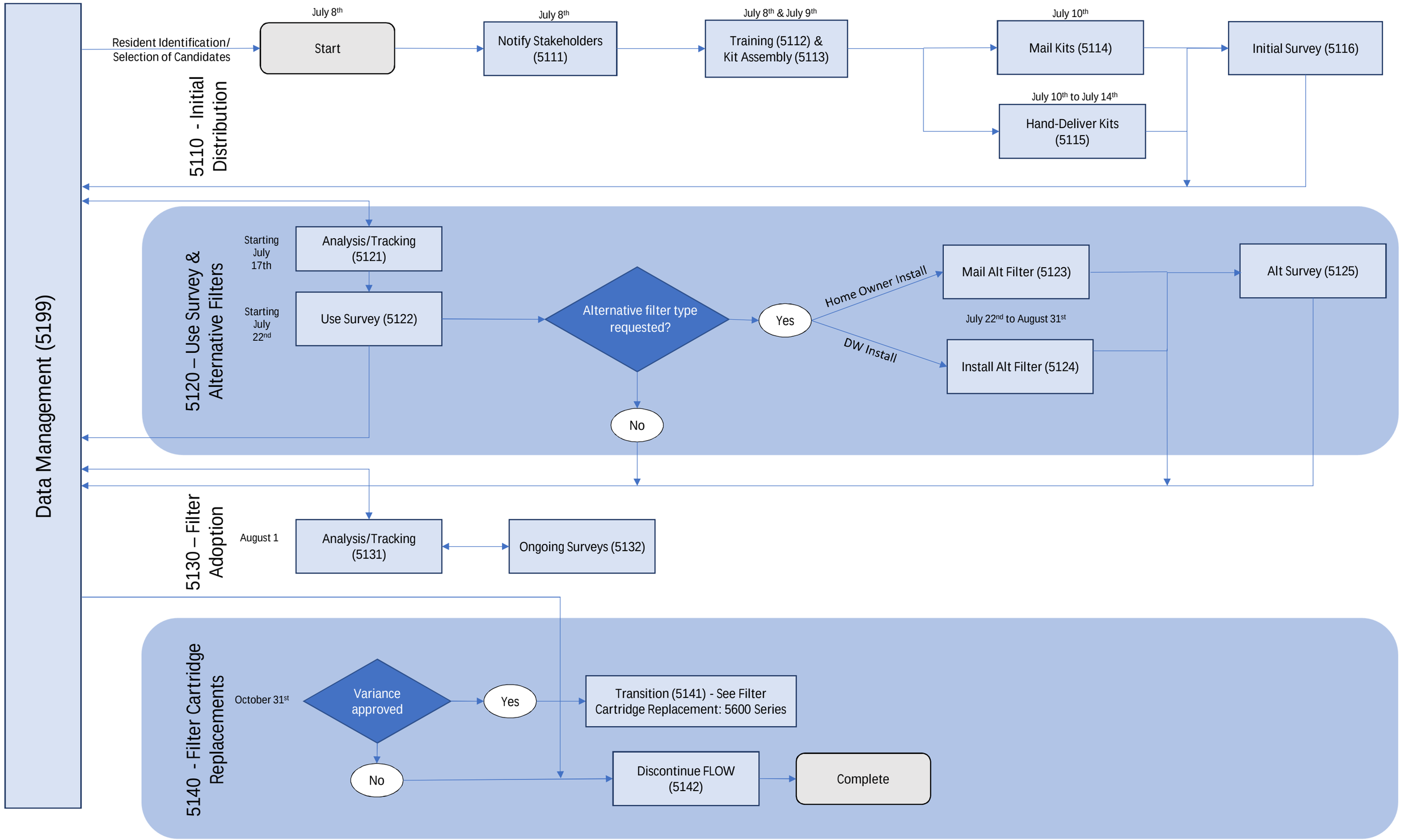
APPENDIX F - FLOW PILOT FLOWCHART

DENVER WATER

FILTER PILOT – 5100 SERIES: WORKFLOW/FLOWCHART



APPENDIX G - COE

DENVER WATER

Community Outreach and Education (COE)

The overarching Lead Reduction Program Communication's Strategy, process, procedures, and guidelines will apply to the Filter Lead Out of Water (FLOW) Pilot. The success of the FLOW Pilot is paramount to provide Denver Water with the necessary data and information to support the variance request.

The collateral developed for the filter kit will be transitioned into the full-scale filter distribution effort. All COE materials will be bilingual for ease of use. The FLOW Pilot kit included the following COE materials:

Introduction Letter (Appendix C)

The introduction letter was our first touch point with Denver Water households who received the filter kit via USPS and door-to-door delivery. This letter provided the context as to why the Denver Water household received a filter kit, shared information about the FLOW Pilot, and provided contact information for additional support and questions.

Frequently Asked Questions (FAQ) (Appendix G1)

The FAQ document provided additional information beyond the introduction letter for recipients of the FLOW Pilot. The FAQ developed specifically for the FLOW Pilot has duplicative information from the full-scale FLOW Program initiative FAQ approved by the EPA and CDPHE, with additional context as to why participants are receiving the filter kit, the length of the FLOW Pilot, information about the surveys, and more.

Magnet Reminder Card (Appendix G2)

A refrigerator magnet was provided as a reminder to encourage filter pitcher use for infant formula, drinking, and cooking. The magnet provides a reminder to users to change their filter cartridge every 30-days. Program contact information is included on the magnet.

Door-hanger (Appendix G3)

100 of the 300 FLOW Pilot participants will have door-to-door delivery of the filter kits. For these 100 FLOW Pilot participants, a door-hanger was left on doors with the filter kit to notify Denver Water households of the FLOW Pilot, inform them of the contents of the filter kit, and provide contact information, should the Denver Water household residents not be home during the initial door to door delivery attempt.

Survey Card (Appendix G4)

An initial survey was included in the filter kit. FLOW Pilot participants were encouraged to complete the initial survey and return their comments to Denver Water within two weeks of receiving their filter kit. Future surveys will be mailed to the FLOW Pilot participants with incentives such as Amazon gift cards offered for the completion of each survey.

The designs of other materials used for the FLOW Pilot, including T-shirts, tote bags, and information cards are also included in this appendix.

LEAD REDUCTION PROGRAM
FREQUENTLY ASKED QUESTIONS

How does lead get into drinking water?

The water delivered to homes and businesses is lead-free, but lead can get into water as it moves through customers' lead-containing household plumbing and service lines (the pipes that bring water from Denver Water's main in the street to the plumbing in your home or building).

If Denver Water's water is lead-free, why is Denver Water focusing on lead reduction?

When it comes to lead in drinking water, no levels are safe. That is why Denver Water is working with the Colorado Department of Public Health and Environment and the Environmental Protection Agency to reduce the risks of lead exposure as drinking water moves through those homes and businesses.

In 2012, water quality sample results exceeded the level the EPA requires for taking action. The action level is an indicator that additional steps may need to be taken to optimize corrosion control treatment. While Denver Water has not exceeded the lead action level since 2012, it is committed to implementing the best method to permanently reduce lead in tap water.

In the meantime, Denver Water has already taken a number of measures to minimize the presence of lead in water, such as:

- Using a pH adjustment to reduce the risk of lead, copper and other metals from getting into drinking water from service lines or household plumbing.
- Replacing customer lead service lines free of charge when such piping is discovered during normal operations and maintenance activities.
- Partnering with Denver Public Schools, Douglas County Schools and Littleton Public Schools to develop and assist with their own lead-testing programs, testing over 15,000 samples.
- Offering free lead testing for customers.

What solutions are being considered?

Denver Water conducted a study on multiple treatment options to reduce the potential for lead entering drinking water from lead service lines and household plumbing. Based on the results, CDPHE, the state regulatory agency that oversees drinking water regulations, required Denver Water to begin adding orthophosphate in accordance with regulatory requirements. Orthophosphate, a food additive, would be added to all drinking water provided by Denver Water to provide additional coating for pipes to minimize corrosion and reduce the amount of lead released from lead-containing pipes and fixtures.

While orthophosphate has been safely and successfully used for decades across the country, concerns have been raised about the potential impacts of this additive to wastewater treatment plants and downstream reservoirs, streams and rivers. CDPHE, Denver Water and others are studying these potential impacts to determine ways to protect the environment if this approach moves forward.

Denver Water is proposing an alternative, holistic approach that directly tackles the biggest issue, customer-owned lead service lines, at its source by accelerating the removal of those lines through a Lead Reduction Program. The approach has multiple components:

- Increasing the pH level, which reduces the corrosivity of the water.
- Providing at-home water filters for all customers in Denver Water's service area with a suspected lead service line, free of charge.
- Replacing the estimated 50,000 to 90,000 lead service lines with copper lines in Denver Water's service area at no charge to the customer over the next 15 years.

DENVER WATER

LEAD REDUCTION PROGRAM
FREQUENTLY ASKED QUESTIONS

The EPA will begin accepting comments about this option this summer and is expected to decide whether Denver Water's proposed alternative meets Safe Drinking Water Act requirements by the end of the year. CDPHE will then make a decision whether to change the March 2018 orthophosphate designation, if appropriate. Regardless of whether the alternative option is selected, the implementation of optimal corrosion control will begin in March 2020.

How can I find out if I have a lead service line and what can I do about it?

In Denver Water's experience, homes and buildings most likely to have lead service lines are those built before 1951 in the Denver metro area (**denverwater.org/neighborhod-age**). Homes built before 1987 may have lead solder in their plumbing. Homes that do not fall within these two categories are less likely to be at risk for lead contamination in the water.

All Denver Water customers can get a free, at-home water quality test for lead by visiting **denverwater.org/Lead** or calling 303-893-2444. For those who are not Denver Water customers, we recommend you contact your local water utility or a certified lab in your area.

If your home has a lead service line, the best long-term action is to replace it with a copper service line. We recommend using a certified plumber. The cost of replacing a lead service line is approximately $5,000-$10,000, which can be a financial challenge. Denver Water has a partnership with the Denver Urban Renewal Authority to provide financing for homeowners to replace lead service lines. Under the program, DURA issues eligible property owners no- or low-interest loans based on income. DURA obtains bids and oversees the contractors retained. If you are interested, contact DURA at 303-534-3872 to learn the eligibility requirements for this limited-time program.

It is worth noting that Denver Water is currently working to develop a program that could replace property owners' lead service lines at no cost to them. Decisions on whether to implement this program may not occur until the end of 2019.

If you suspect your home has lead in the plumbing, there are a few immediate steps you can take to minimize exposure:

Use a filter certified by the National Safety Foundation to remove lead for drinking and cooking. Replace the filter cartridge according to the manufacturer's instructions.

Use only cold water for drinking, cooking and making baby formula. Remember, boiling water does not remove lead from water and hot water often contains higher levels of lead than cold water.

If water has not been used in the home for a few hours, such as first thing in the morning or when getting home from work, run the kitchen or any bathroom faucet for five minutes (remember to capture the water and reuse it!). You can also run the dishwasher, take a shower, or do a load of laundry to help flush water in your internal plumbing before drinking or cooking.

Regularly clean your faucet's screen (also known as an aerator). View step-by-step instructions at **denverwater.org/lead-flushing.**

Where can I go to ask questions and get more information?

You can call Denver Water at 303-893-2444, visit **denverwater.org/Lead** or email **lead@denverwater.org**.

DENVER WATER

FILTER LEAD OUT OF WATER
FREQUENTLY ASKED QUESTIONS

What is the purpose of the Filter Lead Out of Water (FLOW) pilot?

As part of the ongoing analysis this summer for Denver Water's proposed alternative to orthophosphate, Denver Water is conducting the FLOW pilot with a small number of customers with known lead service lines to better understand preferences and usage around water filters. This will help inform how the full-scale program would be implemented.

How were customers identified to participate in the FLOW pilot?

Customers were identified based on properties, with suspected lead service lines, in neighborhoods reflecting a diverse base of Denver Water customers, namely West Colfax, Villa Park, Barnum West, Barnum, Valverde, Westwood and Athmar Park. Identified properties are also owner-occupied.

Is the water in my home safe to use for drinking and cooking?

Based on Denver Water's ongoing inventory analysis, it is believed participants for the FLOW pilot likely have a customer-owned lead service line. This means that there is potential for lead to leach into your water as it moves through your service line. No levels of lead in drinking water are safe, which is why we are recommending the use of a filter for all of the water you use for drinking and cooking.

Should I use my water filter pitcher for all cooking and food preparation?

It is recommended to use filtered water for food preparation, such as preparing rice, beans, soup and other recipes where water is a base ingredient or absorbed into the dish. Keep in mind that boiling water does not remove lead. Filtered water should also be used to prepare infant formula.

Is my water safe for pets?

Changes in pet behavior as a result of drinking lead contaminated water are not likely to be noticeable. In general, pets are more likely to obtain lead as a result of eating an object containing much higher lead levels (lead paint chips). To be safe, check with your veterinarian and/or give your pet filtered water.

Is my water safe to use for a shower or bath?

Yes, bathing and showering is safe for you and your children, even if the water contains lead over EPA's action level. Human skin does not absorb lead in water at levels that cause a health concern.

Where can I go to ask questions and get more information on the filter pilot?

Call 303-628-6655 or email **flow@denverwater.org** for more information on the filter pilot. You can also go to **denverwater.org/Lead** to learn more about Denver Water's Lead Reduction Program.

denverwater.org/Lead
flow@denverwater.org
303-628-6655

DENVER WATER

PROGRAMA DE REDUCCIÓN DE PLOMO
PREGUNTAS FRECUENTES

¿Cómo llega el plomo al agua potable?

El agua que llega a las casas y negocios no contiene plomo, pero el plomo puede meterse en el agua a medida que pasa por las líneas de servicio y tuberías residenciales que contienen plomo (las tuberías que llevan el agua desde la tubería principal de Denver Water localizada en la calle, hasta su hogar o edificio).

Si el agua de Denver Water no contiene plomo, ¿por qué Denver Water se está enfocando en la reducción de plomo?

Cuando se trata de plomo en el agua, ningún nivel es seguro. Es por esto que Denver Water está trabajando con el Departamento de Salud Pública y del Medio Ambiente en Colorado y con la Agencia para la Protección del Medio Ambiente, para reducir los riesgos de exposición al plomo a medida que el agua potable pasa por esos hogares y negocios.

En 2012, los resultados de muestras de control de la calidad del agua sobrepasaron el nivel en el que EPA exige tomar medidas. Este nivel es un indicador de que puede ser necesario tomar medidas adicionales para mejorar el tratamiento para el control de la corrosión. A pesar de que desde 2012 Denver Water no ha sobrepasado el nivel en el que se deben tomar medidas, la entidad está comprometida a implementar el mejor método para reducir de manera permanente el plomo en el agua potable.

Mientras esto pasa, Denver Water ya ha tomado varias medidas para minimizar la presencia de plomo en el agua, como son:

- Hacer un ajuste al pH para reducir el riesgo de que el plomo, cobre u otros metales pasen al agua potable desde las líneas de servicio o la tubería del hogar.
- Reemplazar las líneas de servicio de plomo de manera gratuita para los clientes, cuando dichas tuberías sean descubiertas durante actividades normales de operación y mantenimiento.
- La asociación con las escuelas públicas de Denver, escuelas del condado de Douglas y escuelas públicas de Littleton para el desarrollo y ayuda con sus propios programas de hacer pruebas de plomo, examinando más de 15,000 muestras.
- Ofrecer a los clientes pruebas de plomo gratuitas.

¿Qué soluciones se están considerando?

Denver Water llevó a cabo un estudio sobre varias opciones de tratamiento para reducir la posibilidad de que el plomo llegue al agua potable debido a la existencia de líneas de servicio y tuberías de plomo en el hogar. Basado en los resultados, CDPHE, la agencia estatal reguladora que supervisa las regulaciones de agua potable, le exigió a Denver Water que agregara ortofosfato según los requerimientos reglamentarios. El ortofosfato, un aditivo alimentario, se agregaría a toda el agua potable provista por Denver Water, con el objetivo de brindar un recubrimiento adicional a las tuberías para reducir la corrosión y la cantidad de plomo liberado de las tuberías y griferías que contienen plomo.

A pesar de que el ortofosfato se ha usado por décadas de manera segura y con éxito en todo el país, ha surgido la preocupación del impacto que este aditivo pueda tener en las plantas de tratamiento de aguas residuales, arroyos, ríos y los depósitos a donde llega esa agua agua.

CDPHE, Denver Water y otros están estudiando estos posibles efectos para determinar maneras de proteger el medio ambiente si esta propuesta sigue adelante.

Denver Water propone una alternativa, con un enfoque holístico, que aborda directamente el asunto principal que son las líneas de servicio de plomo particulares, agilizando el remplazo de estas líneas a través del programa de reducción de plomo. Este enfoque tiene varios componentes:

- Aumentar el nivel de pH, lo cual reduce el factor corrosivo del agua.
- Proveer, sin costo alguno, filtros de agua para los hogares de todos los clientes en el área de servicio de Denver Water en donde se sospecha existen líneas de servicio de plomo.
- Reemplazar con cobre, sin costo alguno para los clientes y durante los siguientes 15 años, las estimadas 50,000 a 90,000 líneas de servicio de plomo, en el área de servicio de Denver Water.

PROGRAMA DE REDUCCIÓN DE PLOMO
PREGUNTAS FRECUENTES

La EPA empezará este verano a recibir comentarios sobre esta opción, y se espera que al final del año se decida si la alternativa propuesta por Denver Water cumple con las exigencias de la Ley de Agua Potable Segura. A continuación, y de ser apropiado, CDPHE decidirá si va a cambiar la designación de marzo de 2018 sobre el ortofosfato. Independientemente de si se selecciona la opción alternativa, la implementación del control óptimo de corrosión empezará en marzo de 2020.

¿Cómo averiguo si tengo líneas de servicio de plomo y qué puedo hacer al respecto?

Con base en la experiencia de Denver Water, los hogares y edificios con más probabilidad de tener líneas de servicio de plomo son aquellos construidos antes de 1951 en la zona metropolitana de Denver (**denverwater.org/neighborhod-age**). Los hogares construidos antes de 1987 pueden tener soldadura de plomo en sus tuberías. Los hogares que no estén en ninguna de estas dos categorías tienen menos probabilidad de estar en riesgo de contaminación de plomo en el agua.

Todos los clientes de Denver Water reciben de manera gratuita una prueba para revisar la presencia de plomo en el agua, visitando **denverwater.org/Lead** o llamando al 303-893-2444. A aquellas personas que no son clientes de Denver Water, les recomendamos se pongan en contacto con la compañía local de agua o con un laboratorio certificado local.

Si su hogar tiene una línea de servicio de plomo, la mejor solución a largo plazo es reemplazarla con una línea de servicio de cobre. Recomendamos que use un plomero certificado. El costo de reemplazar una línea de servicio de plomo es aproximadamente entre $5,000 y $10,000, lo que puede presentar una dificultad económica. Denver Water se ha asociado con Denver Urban Renewal Authority para ofrecer financiamiento a los propietarios para que reemplacen las líneas de servicio de plomo. Con este programa, DURA emite préstamos sin interés o de bajo interés, de bajo interés, basados en ingresos, para los propietarios elegibles. DURA hace las licitaciones y supervisa a los contratistas asignados. Si le interesa, comuníquese con DURA al 303-534-3872 para obtener más información sobre las condiciones de elegibilidad para este programa de tiempo limitado.

Vale la pena notar que Denver Water está trabajando en el desarrollo de un programa que podría reemplazar las líneas de servicio de plomo de los propietarios sin costo alguno para ellos. La decisión sobre la implementación de este programa puede que no se conozca hasta finales de 2019.

Si sospecha que su casa tiene plomo en las tuberías, hay unas medidas que puede tomar inmediatamente para reducir la exposición a este material:

Use un filtro certificado por la Fundación Nacional de Seguridad para eliminar el plomo del agua para beber y cocinar. Reemplace el cartucho del filtro siguiendo las instrucciones de fabricante.

Use solamente agua fría para tomar, cocinar y preparar biberones. Recuerde que hervir el agua no elimina el plomo del agua y el agua caliente generalmente contiene niveles más altos de plomo que el agua fría.

Si no se ha usado el agua en casa por unas horas, como a primera hora en la mañana o cuando llega a casa del trabajo, abra 5 minutos el grifo del fregadero o el de cualquier baño (¡recuerde recoger esta agua y reusarla!). También puede usar el lavavajillas, tomar una ducha o lavar una carga de ropa para ayudar a descargar el agua en su tubería interna, antes de beber o cocinar.

Limpie con frecuencia el filtro de su grifo (conocido también como el aireador). Vea las instrucciones paso a paso en **denverwater.org/lead-flushing.**

¿A dónde puedo ir a hacer preguntas y obtener más información?

Puede llamar a Denver Water al 303-893-2444, visitar denverwater.org/Lead o enviar un correo electrónico a **lead@denverwater.org**.

DENVER WATER

FILTRE EL PLOMO DEL AGUA
PREGUNTAS FRECUENTES

¿Cuál es el propósito del programa piloto Filtre el plomo del agua (FLOW)?

Como parte del análisis en marcha este verano para la propuesta de la alternativa al uso del ortofosfato, Denver Water está llevando a cabo el piloto del programa FLOW con un número pequeño de clientes de quienes se conoce tienen líneas de servicio para entender mejor las preferencias y uso de los filtros de agua. Esto nos ayudará a reunir más información para saber cómo se debería implementar el programa a gran escala.

¿Cómo se identificaron los clientes para participar en el programa piloto FLOW?

Los clientes se identificaron con base en las propiedades en las que se sospecha que hay líneas de servicio de plomo, en vecindarios con una composición cultural diversa de clientes de Denver Water, específicamente West Colfax, Villa Park, Barnum West, Barnum, Valverde, Westwood y Athmar Park. Las propiedades que se identificaron también estaban habitadas por los propietarios.

¿Es el agua de mi hogar segura para beber y cocinar?

Con base en el análisis en marcha del inventario de Denver Water, se cree que los participantes del programa piloto FLOW probablemente tienen una línea de servicio de plomo particular. Esto significa que existe la posibilidad de que el plomo entre al agua a medida que pase por su línea de servicio. No existe ningún nivel de plomo seguro en el agua potable, por lo cual estamos recomendando el uso de un filtro para toda el agua que usa para beber o cocinar.

¿Debería usar mi jarra para filtrar el agua para todo lo que cocine y prepare de comer?

Se recomienda usar agua filtrada para la preparación de alimentos como para preparar arroz, frijoles, sopas y otras recetas en donde el agua es el ingrediente base o se absorbe en los ingredientes. Tenga en cuenta que hervir el agua no elimina el plomo del agua. El agua filtrada también debe usarse para preparar biberones y lavarlos, así como para el agua de beber de los bebés.

¿Es el agua de mi hogar segura para las mascotas?

Es probable que no se note un cambio en el comportamiento de las mascotas como resultado de beber agua contaminada con plomo. En general, las mascotas tienen más probabilidad de ingerir plomo por haber comido un objeto que contiene niveles mucho más altos de plomo (pedazos de pintura con plomo). Para mayor seguridad, pregunte a su veterinario o de a su mascota agua filtrada.

¿Es el agua de mi hogar segura para ducharse o tomar un baño?"

Sí, bañarse o tomar una ducha es seguro para usted y sus niños, incluso si el agua contiene plomo a un nivel en el que la EPA exige tomar medidas. La piel humana no absorbe plomo en el agua en un nivel que pueda causar un problema de salud.

¿A dónde puedo ir a hacer preguntas y obtener más información sobre el programa piloto de filtros?

Llame al 303-628-6655 o escriba a **flow@denverwater.org** para obtener más información sobre el programa piloto de filtros. También puede visitar **denverwater.org/Lead** para obtener más información sobre el programa piloto de filtros.

denverwater.org/Lead
flow@denverwater.org
303-628-6655

DENVER WATER

DW_Magnet_6.25x8.25_2019-06-22_FNL.pdf 1 6/24/19 4:08 PM

FILTER LEAD OUT OF WATER

Denver Water delivers safe, lead-free water, but lead can get into water from plumbing and pipes in the home.

REMINDER

Use your filter for:

Drinking Water

Cooking

Infant Formula

Change your filter cartridges every 30 days on:

FILTRE EL PLOMO DEL AGUA

Denver Water provee agua segura y sin plomo, pero el plomo puede pasar al agua por medio de las tuberías de la casa.

RECORDATORIO

Use su filtro para:

Beber Agua

Cocinar

Preparar Biberones

Cambie los cartuchos del filtro cada 30 días el:

denverwater.org/Lead

flow@denverwater.org **303-628-6655**

DENVER WATER

WE MISSED YOU!

Our crews stopped by today and left a water filter pitcher kit at your front door for your household's use.

The water filter pitcher kit is being provided as a precautionary measure. The age of your home indicates that you may have or had a lead service line. If so, there may also be lead particles present in your service line or plumbing. This water pitcher is certified to remove 99.6% of detectable dissolved solids, including lead, if present.

The kit includes:

- NSF certified 10-cup filter pitcher.
- A three-month supply of replacement cartridges.
- Filter Lead Out of Water program info.
- A reminder magnet.
- A reusable tote bag.

denverwater.org/Lead
flow@denverwater.org
303-628-6655

DENVER WATER

¡SENTIMOS NO HABERLE ENCONTRADO!

Hoy pasamos a visitarle y le dejamos
un kit en la puerta de su casa de una jarra con filtro
para el agua de uso en el hogar.

Le estamos dando este kit de jarra con filtro como una medida de precaución. La fecha de construcción de su casa indica que puede tener o haber tenido tuberías de plomo. De ser así, puede haber partículas de plomo en las tuberías o en la línea de suministro principal. La jarra para el agua está certificada para filtrar el 99.6% de sólidos disueltos detectables, incluso plomo, de estar presente.

El kit incluye:

- Jarra con filtro para 10 tazas, certificada por la NSF.
- Cartuchos de repuesto para tres meses.
- Información sobre un programa para filtrar el plomo del agua.
- Un imán de recordatorio.
- Una bolsa reusable.

denverwater.org/Lead
flow@denverwater.org
303-628-6655

DENVER WATER

FILTER LEAD OUT OF WATER

Thank you for participating in Denver Water's FLOW pilot. Your feedback will help us understand information about how water is used in your home for drinking and cooking activities. Please use the ZeroWater® pitcher provided and return your completed survey by mail or online within two weeks of receiving the filter kit. **As our way of thanking you for your feedback and using your filter, upon receipt of the completed survey, Denver Water will send you a $15 Amazon gift card. For an online survey, go to denverwater.org/Lead-survey or scan the QR code at the bottom of this survey.**

Please provide your email address so that we can send you the Amazon gift card. _____

Without your email address we will not be able to send you the gift card.

1. Do you know if you have a lead service line?

☐ Yes ☐ No
☐ I do not know

2. What is your household's primary source of drinking water? (Check one)

☐ Unfiltered faucet ☐ Bottled water
☐ Filtered – refrigerated water/ice dispenser
☐ Filtered – pitcher filter
☐ Filtered – under sink filter
☐ Filtered – faucet mounted filter
☐ Filtered – whole house filter
☐ Other (specify) _____

3. What is your household's primary source of water used for cooking? (Check one)

☐ Unfiltered faucet ☐ Bottled water
☐ Filtered – refrigerated water/ice dispenser
☐ Filtered – pitcher filter
☐ Filtered – under sink filter
☐ Filtered – faucet mounted filter
☐ Filtered – whole house filter
☐ Other (specify) _____

4. If you have an existing water filter system, what is the make and model number for your filter? (Fill in)

_____

5. Do you currently or do you plan in the future to use filtered or bottled water for infant formula?

☐ Yes ☐ No ☐ NA

6. What questions or comments do you have about the filter pilot?

_____
_____

7. How could we improve the filter pilot?

_____
_____

8. Want to stay informed about the FLOW pilot? Provide your email or phone number.

Email: _____
Phone: _____

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DENVER WATER
LEAD REDUCTION PROGRAM
1600 W 12TH AVE
DENVER CO 80204-9963

FILTRE EL PLOMO DEL AGUA

Gracias por participar en el programa piloto FLOW de Denver Water. Sus comentarios nos van a ayudar a entender cómo se usa el agua para beber y cocinar en su hogar. Por favor use la jarra para agua de ZeroWater® que le hemos dejado y envíe por correo o en línea su encuesta completa, en las primeras dos semanas después de haber recibido el kit. **Una vez recibamos su encuesta completa, como agradecimiento por sus comentarios y por usar el filtro, Denver Water le enviará una tarjeta de regalo de Amazon por un valor de $15. Para completar la encuesta en línea, visite denverwater.org/Lead-survey o escanee el código QR al final de la encuesta.**

Incluya su correo electrónico de modo que podamos enviarle la tarjeta de regalo de Amazon. _____

Sin su correo electrónico no podremos enviarle la tarjeta de regalo.

1. ¿Sabe si tiene una líneas de servicio principal de agua hecha de plomo?

☐ Sí ☐ No
☐ No sé

2. ¿Cuál es la principal fuente de agua potable en su hogar? (Marque una)

☐ Agua sin filtrar del grifo ☐ Embotellada
☐ Filtrada – Del refrigerador o dispensador de hielo.
☐ Filtrada – Jarra con filtro
☐ Filtrada – Filtro debajo del fregadero
☐ Filtrada – Filtro instalado en el grifo
☐ Filtrada – Filtro para toda la casa
☐ Otra (Especifique) _____

3. ¿Cuál es la fuente principal de agua para cocinar en su hogar?

☐ Agua sin filtrar del grifo ☐ Embotellada
☐ Filtrada – Del refrigerador o dispensador de hielo.
☐ Filtrada – Jarra con filtro
☐ Filtrada – Filtro debajo del fregadero
☐ Filtrada – Filtro instalado en el grifo
☐ Filtrada – Filtro para toda la casa
☐ Otra (Especifique) _____

4. Si tiene un sistema de filtro para el agua, ¿cuál es la marca y el número del modelo del filtro? (Escríbalos)

_____

5. ¿Usa o piensa usar agua filtrada o embotellada para preparar biberones?

☐ Sí ☐ No ☐ No aplica

6. ¿Qué preguntas o comentarios tiene sobre el programa piloto de filtros?

_____
_____

7. ¿Cómo podemos mejorar el programa piloto de filtros?

_____
_____

8. ¿Quiere mantenerse informado(a) sobre el programa piloto FLOW? Incluya su correo electrónico o número telefónico.

Correo electrónico: _____
Teléfono: _____

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DENVER WATER
PROGRAMA DE REDUCCIÓN DE PLOMO
1600 W 12TH AVE
DENVER CO 80204-9963

FILTER LEAD OUT OF WATER

Thank you for participating in Denver Water's FLOW Pilot. Your feedback will help us understand information about how water is used in your home for drinking and cooking activities and your preference for filters. Please use the filter pitcher provided and return your completed survey by mail or online by July 31, 2019. **As our way of thanking you for your feedback and using your filter, upon receipt of the completed survey, Denver Water will send you a $15 Amazon gift card. For an online survey go to denverwater.org/FLOW-survey or scan the QR code at the bottom of this survey.**

Please provide your email address or mailing address to receive your Amazon gift card. Email: _____

Mailing Address: _____

1. **Do you use your filter for drinking water?**
   ☐ Yes ☐ No
2. **Do you use your filter for water used for cooking?**
   ☐ Yes ☐ No
3. **Do you currently or do you plan in the future to use filtered or bottled water for infant formula?**
   ☐ Yes ☐ No ☐ NA
4. **If you do not primarily use the water filter provided, what issues are you experiencing? (Check all that apply)**
   ☐ Filter pitcher isn't large enough
   ☐ Filter pitcher doesn't fit in refrigerator
   ☐ The filter pitcher takes too much time to fill
   ☐ It's too much effort to use the filter pitcher
   ☐ I'm not interested in filtering my drinking water
   ☐ Other (specify) _____
   ☐ Not applicable (no issues)
5. **If the water filter provided does not meet your needs, would you be more likely to use an alternative filter? (Check one)**
   ☐ Faucet-mounted filter ☐ Refrigerator filter
   ☐ Larger pitcher filter ☐ Not applicable (the water filter meets my needs)
6. **Are you familiar with filter maintenance and cartridge replacement requirements? E.g., replacing the filter cartridge, cleaning the pitcher (if applicable)?**
   ☐ Yes ☐ No
7. **What questions or comments do you have about the filter pilot?**
   _____
   _____
8. **How could we improve the filter pilot?**
   _____
   _____
9. **Want to stay informed about the FLOW pilot? Provide your email or phone number.**
   Email: _____
   Phone: _____

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DENVER WATER
LEAD REDUCTION PROGRAM
1600 W 12TH AVE
DENVER CO 80204-9963

FILTRE EL PLOMO DEL AGUA

Gracias por participar en el programa piloto FLOW de Denver Water. Sus comentarios nos ayudarán a entender cómo usted usa el agua para beber y cocinar en su hogar, así como su preferencia en filtros. Por favor use la jarra para agua de que le hemos dejado y complete su encuesta por correo o por internet a más tardar el 31 de julio de 2019. **Una vez que recibamos su encuesta completa, como agradecimiento por sus comentarios y por usar el filtro, Denver Water le enviará una tarjeta de regalo de Amazon con un valor de $15. Para completar la encuesta en línea, visite denverwater.org/FLOW-survey o escaneé el código QR al final de la encuesta.**

Por favor escriba su correo electrónico o dirección de residencia para recibir una tarjeta de regalo de Amazon.

Correo electrónico: _____ **Dirección de residencia:** _____

1. ¿Usted filtra el agua que toma?

☐ Si ☐ No

2. ¿Usted filtra el agua que usa para cocinar?

☐ Si ☐ No

3. ¿Usa agua filtrada o embotellada para preparar biberones de sus niños (o piensa usarla en el futuro)?

☐ Si ☐ No ☐ No aplica

4. Si usted generalmente no usa agua filtrada, ¿qué problemas está experimentando? (Seleccione todos los que apliquen)

☐ La jarra con filtro no es lo suficientemente grande.
☐ La jarra con filtro no cabe en el refrigerador.
☐ La jarra con filtro se demora mucho en llenarse.
☐ Es mucho trabajo usar la jarra con filtro.
☐ No me interesa filtrar el agua que voy a tomar.
☐ Otra razón. Por favor especifique: _____
☐ No aplica (no tengo problemas)

5. ¿Si la jarra con filtro que le dimos no satisface sus necesidades, ¿sería más probable que usara otro tipo de filtro como alternativa? (Marque una)

☐ Filtro instalado en el grifo ☐ Filtro en el refrigerador
☐ Una jarra con filtro más grande
☐ No aplica (el filtro de agua cubre mis necesidades)

6. ¿Conoce los pasos necesarios para hacerle mantenimiento al filtro y para reemplazar el cartucho del filtro? Por ejemplo, ¿sabe cómo reemplazar el cartucho del filtro o limpiar la jarra (si aplica)?

☐ Si ☐ No

7. ¿Qué preguntas o comentarios tiene sobre el programa piloto de filtros?

_____
_____

8. ¿Cómo podemos mejorar el programa piloto de filtros?

_____
_____

9. ¿Quiere seguir recibiendo información sobre el programa piloto FLOW? Escriba su correo electrónico o número de teléfono.

Correo electrónico: _____
Teléfono: _____

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DENVER
WATER

Lime Green Shirt
Bright White Ink

2.5" Wide per email

v2

Imprint dimensions: 5"w x 5.04" H

Ink Color = White

DENVER WATER

For more information about our Lead Reduction Program, please visit denverwater.org/Lead.

Para obtener más información sobre nuestro programa de reducción de plomo, visite la página web denverwater.org/Lead.

lead@denverwater.org 303-893-2444

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APPENDIX H - FILTER DATA SUMMARY

DENVER WATER

FILTER LEAD OUT OF WATER INITIAL SURVEY											
Online or Paper Survey	Date	Language	* Do you know if you have a lead service line?	* What is your household's primary source of drinking water?	If other, please specify	* What is your household's primary source of water used for cooking?	If other, please specify	If you have an existing water filter system, what is the make and model number for your filter?	* Do you currently or do you plan in the future to use filtered or bottled wate for infant formula?	What questions or comments do you have about the filter pilot?	How could we improve the pilot?
Online	7/11/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet		no I do not	Not applicable	I really like the option of either being able to pour it in my glass or i can use the spigot.	
Online	7/11/2019	English	I do not know	Filtered- refrigerated water/ice dispenser		Unfiltered faucet		I don't know how to find this information	Not applicable		
Online	7/14/2019	English	Yes	Unfiltered faucet		Unfiltered faucet			Yes	I would like to know the steps being taking to fix the lead problem in our tap water so we do not need to use a filter.	It would be nice for low income Families to be able to get free filters considering these do not last very long and also giving free mineral drops since this filter takes all the necessary minerals out of our water for our health.
Online	7/17/2019	Español	I do not know	Unfiltered faucet		Unfiltered faucet			Yes		
Online	7/17/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet			Not applicable	Will replacement filters be provided, or offered on a subscription basis?	
Online	7/18/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet		Refrigerator - Whirlpool WRS571CIDM01	Not applicable	Should I be concerned?	I think this is very impressive!
Online	7/22/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet			Yes	I appreciate the filter and will use it	Info on how to test home water for lead
Online	7/23/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet		N/A	Not applicable		
Online	7/23/2019	English	I do not know	Filtered- pitcher filter		Unfiltered faucet			Not applicable	How expensive are the replacement filters? Where do I get the replacement filters? What exactly does the zero water filter out? Is a 148 test really bad?	More information about all of it would be nice.
Online	7/24/2019	Español	I do not know	Unfiltered faucet		Unfiltered faucet			Yes	This is a good program and thank you for caring for the citizens.	An announcement on the tv or radio would be helpful to let the citizens know about issues of lead in water.
Online	7/24/2019	Español	I do not know	Bottled water		Filtered - whole house filter			Not applicable	Very good program, will help the economy of this family, since weekly bottled water is bought.	
Online	7/25/2019	English	I do not know	Bottled water		Unfiltered faucet			Yes		
Online	7/25/2019	English	I do not know	Filtered- refrigerated water/ice dispenser		Unfiltered faucet			Not applicable		
Online	7/25/2019	English	Yes	Filtered- refrigerated water/ice dispenser		Filtered- refrigerated water/ice dispenser		GE refrigerator	Not applicable		
Online	7/25/2019	English	I do not know	Bottled water		Filtered- refrigerated water/ice dispenser		Samsung	Not applicable	no	
Online	7/29/2019	English	No	Unfiltered faucet		Unfiltered faucet		None	No		
Online	8/4/2019	Español	Yes	Filtered- pitcher filter		Filtered- pitcher filter		n/a	Not applicable	me gusta	no se
Paper	7/12/2019	English	I do not know	Bottled water		Unfiltered faucet			Yes		
Paper	7/12/2019	English	I do not know	Bottled water		Unfiltered faucet		N/A We have none	Not applicable	How long is this pilot for? And will we be notified if the proposed alternative to orthophosphate is used?	
Paper	7/13/2019	English	I do not know	Filtered - refrigerated water/ice dispenser		Unfiltered faucet		N/A	Not applicable	N/A	N/A
Paper	7/17/2019	English	Yes	Unfiltered faucet		Unfiltered faucet		None	Yes	Good idea	Maybe a filter for sink in kitchen
Paper	7/25/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet			Not applicable	How could I figure out if I have lead service line?	
Paper	7/25/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet		N/A	Yes	How long will you provide filters?	
Paper	7/25/2019	English	I do not know	Filtered - pitcher filter		Filtered - pitcher filter			Not applicable	Does my home have lead pipes?	
Paper	7/19/2019	English	I do not know	Filtered - refrigerated water/ice dispenser		Unfiltered faucet		Amana fridge	Not applicable	The water tastes great!	The lid is hard to remove and replace
Paper	7/17/2019	English	Yes	Filtered - under sink filter		Filtered - under sink filter		Culligan RC E2-4	Not applicable	I'm glad this is happening, but let's replace the service lines!	This is a good first step, but you should be specifically notifying everyone who has lead.
Paper	7/15/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet			Not applicable		Provide refill filters
Paper	7/15/2019	English	I do not know	Filtered - pitcher filter		Unfiltered faucet		Brita filter	No	If there is lead in my water, when will my pipes be replaced?	
Paper	7/15/2019	English	I do not know	Filtered - under sink filter		Filtered - under sink filter		General Electric water filtration system GXSL55F	Not applicable	None	Need to know how to get my water tested for lead. What about blood tests for residents of home?
Paper	7/15/2019	English	Yes	Filtered - pitcher filter		Unfiltered faucet		Pur	No	Where to get more when they run out?	Excellent already
Paper	7/15/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet		N/A	No	Do I need to send the filters back in?	
Paper	7/15/2019	Spanish	I do not know	Filtered - refrigerated water/ice dispenser		Unfiltered faucet			Yes	Cada cuando hay que cambiar el filtro de la jarra? (When do you have to change the filter?)	Avernos quisado si quisieramos a ver aseptado participado en el programa? (Do you want to see if we participate in the program?)
Paper	7/16/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet		N/A	Not applicable	Good idea to see if I do have lead in my drinking/cooking water	Not sure at this time - just received in mail. Began using it on 7/15/2019

FILTER LEAD OUT OF WATER INITIAL SURVEY											
Online or Paper Survey	Date	Language	* Do you know if you have a lead service line?	* What is your household's primary source of drinking water?	If other, please specify	* What is your household's primary source of water used for cooking?	If other, please specify	If you have an existing water filter system, what is the make and model number for your filter?	* Do you currently or do you plan in the future to use filtered or bottled wate for infant formula?	What questions or comments do you have about the filter pilot?	How could we improve the pilot?
Paper	7/23/2019	English	I do not know	Filtered - pitcher filter		Unfiltered faucet		Brita/Generic Target filter	Not applicable	Thank you! Water definitely tastes better.	
Paper	7/23/2019	English	Yes	Filtered - pitcher filter		Unfiltered faucet			Not applicable		
Paper	7/26/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet			Not applicable	Water tastes better/just started using. Plan on using for cooking also.	Smaller filter
Paper	7/22/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet		N/A	No	Do we continue to receive filters after the first 3 months?	
Paper	7/22/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet		N/A	No	How bad is the water I have been drinking for the past 3 years?	Provide more filters
Paper	7/22/2019	English	I do not know	Bottled water		Unfiltered faucet			Not applicable	None	
Paper	7/23/2019	English	I do not know	Bottled water		Unfiltered faucet		Fridge filter	Not applicable		
Paper	7/23/2019	English	I do not know	Bottled water		Unfiltered faucet		None	Yes		
Paper	7/23/2019	English	No	Bottled water		Bottled water			No		
Paper	7/23/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet		N/A	Not applicable	Is my water safe to drink?	
Paper	7/24/2019	English	I do not know	Filtered - pitcher filter		Unfiltered faucet		Brita pitcher	Not applicable		
Paper	7/23/2019	English	Yes	Unfiltered faucet		Unfiltered faucet			No	How long can we expect help from Denver Water?	Home faucet filtration system
Paper	7/23/2019	English	I do not know	Bottled water		Unfiltered faucet			Not applicable		
Paper	7/23/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet			Not applicable		
Paper	7/27/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet			Yes	None	Not sure if it could get any better
Paper	7/26/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet		N/A	Not applicable	None - product is great. I need to buy a bigger one.	Not sure. Mine was reading 188 before filter. After filter, it reads 000.
Paper	7/26/2019	English	Yes	Unfiltered faucet		Unfiltered faucet		N/A	Not applicable	None	
Paper	7/26/2019	English	I do not know	Bottled water		Filtered - faucet mounted filter		Don't have one	Not applicable		At this time I don't have one, only a water heater, thank you.
Paper	7/26/2019	English	I do not know	Filtered - faucet mounted filter		Filtered - faucet mounted filter		Pur Maxion	Not applicable	None. It's a good idea.	
Paper	7/26/2019	English	Yes	Bottled water		Unfiltered faucet			No	Don't know yet.	?
Paper	7/29/2019	English	Yes	Other	5 gallon jugs refilled at grocery store	Other	5 gallon jugs refilled at grocery store		Not applicable	How long will filters be provided?	We're excited about it! Would love to learn if/when service line replacement is part of pilot program.
Paper	7/29/2019	English	Yes	Bottled water		Unfiltered faucet		Clear2H2O	No		
Paper	7/29/2019	English	No	Bottled water		Unfiltered faucet		No	Yes	How often do we need to change cartridges/filters?	It is a small container/jar. Can I buy or get bigger size?
Paper	7/29/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet		NA			
Paper	7/30/2019	English	I do not know	Filtered - faucet mounted filter		Filtered - faucet mounted filter		RF-9999	Yes	Only contact via email…DO NOT KNOCK ON MY DOOR!	
Paper	7/30/2019	English	Yes	Bottled water		Unfiltered faucet		None	No		
Paper	7/31/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet		NA	Not applicable	Why is there standing water in the upper (feed) reservoir?	A faster flow from the push button would be nice.
Paper	8/1/2019	English	I do not know	Filtered - refrigerated water/ice dispenser		Filtered - whole house filter			Not applicable		
Paper	8/1/2019	English	I do not know	Filtered - pitcher filter		Unfiltered faucet		Brita pitcher	Not applicable	Are lead pipes required to be replaced?	
Paper	7/22/2019	English	I do not know	Bottled water		Unfiltered faucet		NA	Yes	In the event water is tested and lead is found, but the resident is unable to replace due to finances, what will Denver Water's action be?	
Paper	8/3/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet			No		
Paper	8/3/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet			Yes	Will it continue on past what filters were provided?	Nothing. I'm very thankful!
Paper	8/6/2019	English	I do not know	Filtered - pitcher filter		Unfiltered faucet		Brita - less than 1 yr old	Not applicable	Why? Am I living in Flint, MI?! Feels sketch!	Educate us on why we need this. *sorry - read enclosed info after
Paper	8/6/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet		N/A	Not applicable	How much will it cost?	More than 3 months - 6 months at least
Paper	8/6/2019	English	No	Unfiltered faucet		Unfiltered faucet		N/A	Not applicable	Just starting out, but water tastes much better and looks cleaner	Right now, I don't know
Paper	8/12/2019	English	I do not know	Unfiltered faucet		Unfiltered faucet			Not applicable		

FILTER LEAD OUT OF WATER USE SURVEY											
Online or Paper Survey	Date	Language	*Do you use your filter for drinking water?	*Do you use your filter for water used for cooking?	Do you currently or do you plan in the future to use filtered or bottled wate for infant formula?	If you do not primarily use the water filter provided, what issues are your experiencing?	If other, please specify	If the water filter provided does not meet your needs, would you be more likely to use an alternative filter?	Are you familiar with filter maintenance and cartridge replacement requirements? e.g., replacing the filter cartridge, clenaing the pitcher?	What questions or comments do you have about the filter pilot?	How could we improve the filter pilot?
Online	7/24/2019	English	Yes	Yes	Not applicable	Not applicable (no issues)			Yes	Great idea!	Would be nice if more people could be in the program. Would be nice if the water department had a system to replace the piping.
Online	7/24/2019	English	Yes	Yes	Not applicable			Not applicable (the water filter meets my needs)	No		
Online	7/24/2019	English	Yes	Yes	Not applicable	Filter pitcher isn't large enough		Faucet-mounted filter	No		
Online	7/24/2019	English	Yes	No	Yes	Not applicable (no issues)		Not applicable (the water filter meets my needs)	No		
Online	7/25/2019	English	Yes	Yes	Yes	The filter pitcher takes too much time to fill		Faucet-mounted filter	Yes		A faucet filter would be great to have!
Online	7/25/2019	English	Yes	No	Not applicable	Other	Doesnt pour smoothly, too bulky, and takes a while to fill up. It's great! But the tester is reading 000 also for my tap water so not sure if that tester is working right.	Not applicable (the water filter meets my needs)	Yes		
Online	7/26/2019	English	Yes	No	Yes	The filter pitcher takes too much time to fill		Faucet-mounted filter	Yes	Please fix water line. What can we do to make program go thru?	Water delivery service
Online	7/26/2019	English	Yes	No	Not applicable	Not applicable (no issues)		Faucet-mounted filter	Yes	No	Everything has been great!
Online	7/26/2019	English	Yes	Yes	Not applicable	Filter pitcher isn't large enough		Faucet-mounted filter	No	Looking at installing his own filter	
Online	7/26/2019	English	Yes	Yes	Not applicable	Filter pitcher isn't large enough		Faucet-mounted filter	Yes		
Online	7/26/2019	English	Yes	No	No	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes	My water tastes better. Having a hard time working the reader, it isnt showing all 0's	
Online	7/27/2019	English	Yes	No	Not applicable	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes	Thanks for the pitcher, it's bigger than the one we had purchased ourselves	
Online	7/27/2019	English	Yes	No	Yes	The filter pitcher takes too much time to fill		Faucet-mounted filter	Yes	Having this filter pitcher you provided has made me more conscious of my water at home	A faucet mounted one would more useful for cooking purposes. But I like the pitcher for cold fridge water
Online	7/27/2019	English	Yes	No	Not applicable	Other	Too much effort to refil and use for cooking water	Faucet-mounted filter	Yes	A smaller pitcher for fridge would be helpful faucet filter might be preferable if it works with our current faucet	
Online	7/28/2019	English	Yes	Yes	No			Larger pitcher filter		Thank you for the filter I like it it really work and it help me out a lot	
Online	7/30/2019	English	Yes	Yes	Not applicable	Not applicable (no issues)		Faucet-mounted filter	No		Keep people informed on when our service line will be replaced. How can low-income households qualify to get these replaced sooner?
Online	7/30/2019	English	Yes	Yes	Not applicable	The filter pitcher takes too much time to fill		Faucet-mounted filter	Yes		It is unsettling to get this water filter and not to know what the quality of the water is. I work for a similar program with Aurora. I wish the initial materials had told us that our water is good but that our pipes may not be. Was left wondering how much at risk I am.
Online	7/30/2019	English	No	No	Not applicable	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes		
Online	7/31/2019	Español	No	No	Not applicable	Other	Didn't know what it was for, do buy bottled water for drinking	Refrigerator filter	No	Not sure, need to give it a try // Where do we get the filters?	For it to have a sign on it making it clear it was not sent in error - thought it was a mistake and meant for the neighbors or something
Online	7/31/2019	English	Yes	Yes	No	Not applicable (no issues)		Faucet-mounted filter	Yes		Water taste
Online	7/31/2019	English	Yes	Yes	Yes	Filter pitcher doesn't fit in refrigerator		Faucet-mounted filter	Yes		
Online	8/1/2019	English	Yes	Yes	Not applicable	The filter pitcher takes too much time to fill		Faucet-mounted filter	Yes		Sometimes the top lid falls off of the filter
Online	8/7/2019	English	Yes	Yes	No	Not applicable (no issues)		Faucet-mounted filter	Yes		
Online	8/7/2019	English	Yes	No	Not applicable	The filter pitcher takes too much time to fill		Faucet-mounted filter	Yes	Is the filter taking out any helpful minerals from our water?	
Online	8/12/2019	English	Yes	No	Yes	Other	Having a hard time pouring it out	Faucet-mounted filter	Yes	Pretty good size pitcher, and its helping us buy less bottled water	
Paper	7/23/2019	English	Yes	Yes	Yes	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes	Thankful, awesome program. Do it to other houses.	N/A
Paper	7/27/2019	English	Yes	Yes	NA	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes	N/A	N/A
Paper	7/27/2019	English	Yes	No	NA	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes	No	N/A
Paper	7/27/2019	English	Yes	Yes	NA	Not applicable (no issues)		Faucet-mounted filter	Yes		
Paper	7/27/2019	English	Yes	Yes	Yes	Not applicable (no issues)		Larger pitcher filter	Yes		
Paper	7/27/2019	English	Yes	No	Yes	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes		
Paper	7/27/2019	English	Yes	Yes	Yes	Filter Pitcher isn't large enough. The filter pitcher takes too much time to fill		Larger pitcher filter	No		Bigger pitcher/faster fill up
Paper	7/27/2019	English	Yes	Yes	NA	Filter Pitcher isn't large enough		Faucet-mounted filter	Yes	Nothing, thank you	Provide faucet filters for everyday use
Paper	7/27/2019	English	Yes	Yes	No	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes	Water tastes better	N/A
Paper	7/27/2019	English	Yes	Yes	Yes	The filter pitcher takes too much time to fill		Faucet-mounted filter	Yes	Want more info on lead	N/A
Paper	7/28/2019	English	Yes	No	No	The filter pitcher isn't large enough. The filter pitcher takes too much time to fill.		Faucet-mounted filter	Yes	Difficult for cooking	Faucet-mounted
Paper	7/28/2019	English	Yes	No	Yes	Filter pitcher doesn't fit in refrigerator			Yes	Use bottled water	Don't know
Paper	7/28/2019	English	No	No	Yes	Other	Taste is flat	Faucet-mounted filter	Yes	I'd like to know how much lead is in my pipes	
Paper	7/28/2019	English	Yes	Yes	No	Not applicable (no issues)		Refrigerator filter	Yes		
Paper	7/28/2019	English	Yes	No	Yes	Filter pitcher isn't large enough. Other	A lot of grandkids	Larger pitcher filter	Yes	Connect to faucet. Love the taste	
Paper	7/25/2019	English	Yes	Yes	NA	The filter pitcher takes too much time to fill		Faucet-mounted filter. Larger pitcher filter	Yes	The filters are expensive	
Paper	7/25/2019	Spanish	No	No	Yes	Filter pitcher doesn't fit in refrigerator. It's too much effort to use the filter pitcher. Other	I am 68 years old and with arthritis in my hands. It is very difficult to pour the water from the pitcher, but I really like filtered water.	Faucet-mounted filter	Yes	I think it is very good	I might like other types of filters, such as an under-sink filter
Paper	7/28/2019	English	Yes	Yes	NA	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes	None	N/A
Paper	7/29/2019	English	Yes	No	NA	Filter Pitcher isn't large enough. The filter pitcher takes too much time to fill		Faucet-mounted. Not applicable (the water filter meets my needs)	Yes	I use it. Nice gift	
Paper	7/29/2019	English	Yes	No	NA	Not applicable (no issues)		Faucet-mounted filter. Larger pitcher filter	No	Thank you!	Send more than one pitcher
Paper	7/30/2019	English	Yes	No	NA	Not applicable (no issues)		Faucet-mounted filter	Yes	Faucet-mounted filter would be great!	
Paper	7/30/2019	English	Yes	Yes	NA	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes	No. Thanks.	N/A
Paper	7/30/2019	English	Yes	Yes	Yes	Not applicable (no issues)		Faucet-mounted filter	Yes		
Paper	7/30/2019	English	No	No	NA	Not applicable (no issues)		Faucet-mounted filter	Yes		
Paper	7/27/2019	English	Yes	Yes	NA	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes		
Paper	7/27/2019	English	No	Yes	No	Filter pitcher isn't large enough. Not applicable (no issues)		Faucet-mounted filter	No	N/A	N/A
Paper	7/31/2019	English	Yes	Yes	NA			Faucet-mounted filter	Yes	None so far	I'm unsure
Paper	7/26/2019	English	Yes	Yes	Yes	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes	None	None
Paper	7/26/2019	English	Yes	Yes	NA	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes		
Paper	7/26/2019	English	Yes	No	NA	Filter pitcher isn't large enough		Faucet-mounted filter	Yes	More info on how to change the lead pipes would help	I do think more people in the house would use a faucet filter
Paper	7/26/2019	Spanish	Yes	Yes	Yes	Not applicable (no issues)		Refrigerator filter	Yes	No questions or comments	By keeping clean
Paper	7/26/2019	Spanish	Yes	Yes	NA						
Paper	7/25/2019	English	Yes	Yes	NA	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes	Will Denver Water continue to provide filters?	Provide the filters
Paper	7/27/2019	Spanish	Yes	Yes	NA	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes	It's good	With a faucet-mount filter
Paper	7/29/2019	English	Yes	Yes	No	Not applicable (no issues)		Larger pitcher filter	Yes	I think it works great! I have used others, and this is great!	
Paper	7/29/2019	English	Yes	Yes	NA	Filter pitcher isn't large enough		Larger pitcher filter. Refrigerator filter	Yes	Happy to learn about it/enroll, as we've been filtering on our own for years.	Offer options for financial assistance to replace service line.

FILTER LEAD OUT OF WATER USE SURVEY											
Online or Paper Survey	Date	Language	*Do you use your filter for drinking water?	*Do you use your filter for water used for cooking?	Do you currently or do you plan in the future to use filtered or bottled wate for infant formula?	If you do not primarily use the water filter provided, what issues are your experiencing?	If other, please specify	If the water filter provided does not meet your needs, would you be more likely to use an alternative filter?	Are you familiar with filter maintenance and cartridge replacement requirements? e.g., replacing the filter cartridge, clenaing the pitcher?	What questions or comments do you have about the filter pilot?	How could we improve the filter pilot?
Paper	7/29/2019	English	Yes	Yes	No	Filter pitcher isn't large enough		Larger pitcher filter. Faucet-mounted filter	Yes		
Paper	7/29/2019	Spanish	Yes	Yes	NA	Filter pitcher isn't large enough		Not applicable (the water filter meets my needs)	Yes	I can store containers with filtered water in my refrigerator	Mandar stickers y pegarlos con nombramientos de agua segura.
Paper	7/29/2019	English	Yes	Yes	NA	Filter pitcher doesn't fit in refrigerator. The filter pitcher takes too much time to fill		Faucet-mounted filter	Yes	The ZeroWater filter is good quality, but doesn't make enough water at a time.	An easier to use/more efficient filter or just helping us fix our pipes.
Paper	7/29/2019	English	Yes	Yes	NA	Filter Pitcher isn't large enough. The filter pitcher takes too much time to fill. It's too much effort to use the filter pitcher. It's too much effort to use the filter pitcher		Refrigerator filter	Yes	My water doesn't get to the "below 6" reading with the filter	Unsure of process. Will we get more filters?
Paper	7/29/2019	Spanish	No	No	NA	Not applicable (no issues)		Not applicable (the water filter meets my needs)	No	It's good for the health	Let the program continue.
Paper	7/29/2019	English	Yes	No	NA	The filter pitcher takes too much time to fill. It's too much effort to use the filter pitcher.		Refrigerator filter	Yes	None	It fine
Paper	7/31/2019	English	Yes	Yes	NA	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes	No	I am very happy with this item
Paper	8/1/2019	Spanish	Yes	Yes	NA	Filter pitcher isn't large enough. Filter pitcher doesn't fit in refrigerator		Larger pitcher filter	No	How often do I change the filter?	
Paper	7/30/2019	Spanish	Yes	Yes	No	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes		
Paper	7/30/2019	Spanish	Yes	No	Yes	Filter pitcher isn't large enough. Filter pitcher doesn't fit in refrigerator. The filter pitcher takes too much time to fill		Faucet-mounted filter. Refrigerator filter. Larger pitcher filter	Yes	We have always felt Denver had good water - why now we need filter?	Shape is odd and have to refill too often, lid hard to grab.
Paper	8/2/2019	English	Yes	Yes	NA	Filter pitcher isn't large enough. Other	Freezes	Faucet-mounted filter	Yes		
Paper	8/2/2019	English	Yes	No	NA	Not applicable (no issues)		Faucet-mounted filter	yes	N/A	N/A
Paper	8/6/2019	English	Yes	No	NA	Not applicable (no issues)		Not applicable (the water filter meets my needs)	Yes	N/A	N/A
Paper	8/8/2019	English	Yes	No	NA				Yes	None - just trying out	N/A
Paper	8/12/2019	English	Yes	Yes	NA	Filter pitcher isn't large enough. The filter pitcher takes too much time to fill. Other.	Spigot dispensing H2O is very slow	Larger pitcher filter	No	Do I have to buy filters? Do I foot the bill for replacement filters? How do I get them? How often should I test filtered H2O?	Include info about filters. I don't like the solid waste component of the filters. Recyclable?
Paper	8/12/2019	English	Yes	Yes	NA	Not applicable (no issues). Other.	Would be easier to use tap	Faucet-mounted filter	Yes		It's good. Thank you.
Paper	8/12/2019	English	Yes	Yes	NA	Not applicable (no issues)		Not applicable (no issues)	Yes		
Paper	8/12/2019	English	Yes	Yes	NA	Not applicable (no issues)		Not applicable (no issues)	Yes	I like it better than a Brita brand I had used prior.	Curious what happens in three months? Filters available?

APPENDIX III.C.3 - FILTER PROGRAM PLAN

September 2019

DENVER WATER

MOTT MACDONALD

TECHNICAL MEMORANDUM

To Denver Water
From Mott MacDonald
Date August 13, 2019
Project No. 507100139
Page Page 1 of 21
Subject Denver Water Lead Reduction Program (LRP)
Appendix III.C.3 Filter Program Plan

I. PURPOSE

The purpose of this Technical Memorandum (TM) is to summarize the framework for Denver Water's full-scale Filter Lead Out of Water (FLOW) Program, which targets properties with known, suspected, and possible lead service lines. The FLOW Program includes the distribution of filters to the target Denver Water households, on-going outreach / education to engage Denver Water households to filter their water for infant formula, drinking, and cooking and filter / filter cartridge replacement management. The basis for this TM is threefold:

1. Summarize the series for full-scale FLOW Program implementation.
2. Describe the methodology used to obtain confirmation of filter adoption by targeted Denver Water households for infant formula, drinking, and cooking:
   - **Adoption** = Additional reduction of lead through the use of a certified filter or use of an alternative source of lead-free water (i.e. bottled water).
   - **Non-Adoption** = Customer uses tap water.
3. Document how Denver Water will strive for 100% Filter Adoption over 15-years through use of the communications, outreach and education (COE) plan.

Denver Water's service line inventory dated August 8, 2019 includes:

- 319,700 service lines used for drinking water in the Denver Water service area.
- 84,546 service lines identified as known, suspected and possible lead service lines – these premises are candidates for FLOW.

Multi-family properties are included in the 84,546 service lines that are part of the filter program. A multi-family property has multiple household units. A household unit is an individual residence that receives a filter. Using available data, it is estimated that Filter Program participants consist of 119,250 Denver Water household units, with each household unit receiving a filter.

Presented herein is the background, filter distribution methods, customer notifications, filter kit materials, follow-up/survey information, filter use adoption validation basis, schedule, and reporting metrics.

II. BACKGROUND

General

Denver Water serves high-quality drinking water to approximately 1.4 million people and continuously monitors water quality. Drinking water entering the distribution system prior to the connection to the customer's service line is free of lead. However, lead may leach into the drinking water as it stagnates in the customer-owned lead service line and/or premise plumbing.

Denver Water is committed to taking steps to optimize its water system for control of lead by implementing a Lead Reduction Program (LRP). One element of Denver Water's LRP is the FLOW Program, which includes the distribution of filters certified to remove lead by NSF to approximately 119,250 Denver Water household units (84,546 service lines) with known, suspected, and possible lead service lines. Filters are used as the interim treatment barrier to remove lead from Denver Water households' drinking water until the lead service line is replaced. The filter provides a reliable barrier for dissolved and particulate lead. A Denver Water household will be removed from FLOW Program either six months after replacement of the lead service line or if a non-lead service line is confirmed at the property.

Denver Water is considering providing filters over 15 years as Denver Water progresses through the inventory of lead service line properties and replaces lead service lines. Denver Water will strive for 100% filter adoption to reduce lead exposure for all customers with a known, suspected, or possible lead service. Denver Water households not using a filter certified to remove lead by NSF will receive the benefit of a 40% to 65% reduction in lead levels from improved pH/alkalinity adjustment only. In addition to the pH/alkalinity adjustment, Denver Water households using a filter certified to remove lead by NSF will experience a >97% reduction in lead levels.

Upon LRP approval, it is expected that implementation of FLOW Program will commence immediately, following the multi-media public information campaign and customer notification model in accordance with the COE Plan. The success of the COE and FLOW Program is paramount to provide Denver Water with information and also to share information with Denver Water households that does as much as possible to encourage filter use and education. If the variance is not granted, filters will be distributed per Denver Water's current practices.

FLOW Program Participants

As presented earlier, FLOW participants consist of 119,250 Denver Water household units. The LSI map will be divided into 12 areas (approximately 10,000 filters per area) for use with distribution of the filters and communications within geographic areas.

The FLOW Program includes the distribution of filters to approximately 119,250 Denver Water household units by March 20, 2020 and the collection of follow-up surveys regarding adoption from a minimum of 1,059 randomly selected Denver Water households on an annual basis.

Filter Type

As part of Denver Water's current practice, a water pitcher filter is distributed to a Denver Water household:

- after the replacement of their lead service line, with five (5) months of replacement cartridges; or
- after potholing reveals a lead service line, with five (5) months of replacement cartridges.

Currently, Denver Water distributes a ZeroWater pitcher filter with the following features:

1. 10-cup capacity
2. NSF certified to remove lead
3. 5-stage filter with ion exchange that removes 99.6% of detectable dissolved solids, including lead and fluoride
4. filter cartridges replaced based upon average use (approximately 30-days for a Denver Water household household)

In addition to pitcher filters, other filters certified to remove lead by NSF include: filters attached to the kitchen faucet and refrigerators filters. Denver Water will purchase filters from multiple vendors that are NSF certified to remove lead and do not remove fluoride. A summary of available pitcher filters and available alternative filter types and replacement cartridges is included in Appendix A.

ZeroWater pitchers remove fluoride through ion exchange. Other filter types do not remove fluoride. Denver Water will distribute pitcher filters for FLOW that will remove nearly all the lead, but leave other important minerals, like fluoride.

Filter Kit

Each participant of the FLOW Program will receive a kit with the pitcher filter, a 6 month supply of filter cartridges, and education/outreach material. Details on the filter kit (education / outreach documents, pitcher filter and cartridge manufacturer instructions, packaging, and other contents) are included in Appendix B.

Filter Distribution

Denver Water households will be automatically enrolled and provided with a filter and replacement cartridges, based on the following three factors:

1. A known, suspected, or possible lead service line and included in the LSI.
2. Demographics for occupants at the property
3. Until the service line is confirmed to be non-lead or 6 months after a lead service line is replaced.

Denver Water will work closely with Distributors to determine if the notification/enrollment letter, filters, replacement cartridges, and COE will be provided directly by Denver Water or in collaboration with the appropriate Distributor.

The distribution of filters and replacement cartridges in the FLOW Program will be documented and tracked during the life of the LRP using an electronic database and GIS. The filters will be distributed to customers prior to implementation of the pH and alkalinity adjustment using various methods as follows:

PRIMARY (90%)

- Direct mail by Denver Water and/or distributor with delivery confirmation

SECONDARY (10%)

- Hand delivery by Denver Water or contractor via door-to-door canvasing
  - In-person transaction
  - Drop-off

EXCEPTIONS - DENVER WATER HOUSEHOLD PREFERENCE ONLY

- Pickup
  - Denver Water facility
  - Mobile unit
  - Community meetings / events
  - Other

Filter Cartridge Replacements

Replacement filter cartridges will be distributed to Denver Water households using the various methods identified for distribution of pitcher filters. It is estimated that approximately 690,000 pitcher and alternative filters and 2.8 million replacement cartridges will be distributed over the life of the FLOW Program (15-years), if only pitcher filters are implemented. As the LRP progresses, Denver Water will investigate the use of other filter types to promote filter adoption.

Filter Cartridge Waste Reduction

Some manufacturers provide solutions to mitigate waste created by lifetime filter cartridge replacements as follows:

1. The typical Brita pitcher filter life is 6 months. Brita recycles filter cartridges using Terracycle (https://www.terracycle.com/en-US/) using the following process:

   a. Brita cartridges are dried for a minimum of 3 days.
   b. Approximately 5 pounds of Brita cartridges are packaged for return to Terracycle.
   c. Shipping labels are printed from Brita's website with postage paid by Brita.
   d. The Brita cartridges are mailed to Terracyle for recycling.

   Brita's recycling system may be utilized by an individual Denver Water household or by Denver Water using cartridge drop-off locations placed throughout the city.

2. The typical DuPont pitcher filter life is 3 months. DuPont uses reusable cartridge housings:

a. The initial pitcher filter cartridge is a plastic housing for the media (carbon block).
b. Carbon blocks are provided separate from the plastic housing by DuPont.
c. Carbon blocks are placed into the plastic cartridge housing.
d. Used carbon blocks are removed from the cartridge housing, by the Denver Water household, following manufacturer's recommended safety precautions.
e. Plastic cartridge housings are replaced periodically when the housing has reached its service life (approximately 8 years).

Sustainable solutions will be investigated further during implementation and over the life of the FLOW Program.

Alternative Filters

Alternative filters (filters attached to the kitchen faucet and refrigerators filters) will be utilized throughout the FLOW Program, as the cartridges have a longer filter life, generally three to 10 months, providing a more sustainable approach for the 15-year lead service line replacement and filter plan. Alternative filters may require less maintenance, less involvement from FLOW Program staff, and may increase ease of use by Denver Water households, which may encourage filter adoption. They will be distributed to Denver Water households who have requested an alternative filter. Although typically a higher capital cost than a pitcher filter, alternative filters often have longer filter life and ease of use for infant formula, drinking, and cooking. Lessons learned from the FLOW Pilot regarding alternative filters will be implemented into the full-scale FLOW Program, as applicable. Alternative filters options are shown in Appendix A.

Alternative filters will be distributed to Denver Water households using the various methods identified for distribution of pitcher filters. It is anticipated that a portion of the alternative filters will require inspection and/or installation by Denver Water staff and/or contractors to assure correct installation.

It is anticipated that up to approximately 20% of the customers may request an alternative filter.

Customers will be provided with options for filter use and replacements as shown in Table III.C.3-1.

Table III.C.3-1 Alternative Filter Use and Replacement Options

Option	Replacements Provided
• One Pitcher Filter	Replacement pitchers after 8 years and cartridges
• Two Pitcher Filters	Replacement pitchers and cartridges
• Kitchen Faucet Filter	Replacement faucet filter and cartridges
• Refrigerator Filter	Replacement cartridges
• Refrigerator Filter and One Pitcher Filter	Replacement pitchers and cartridges

Replacement Filter Housing

It is anticipated that a typical pitcher filter will be usable for approximately eight years. Denver Water households will receive a replacement and/or additional pitcher filter and replacement cartridges as shown in Table III.C.3-2.

Table III.C.3-2 Replacement Pitcher Filter and Cartridge Distribution

Request Type	Identifier
Additional pitcher to supplement the initial pitcher to reinforce filter use	Denver Water household
Damaged and/or lost pitcher filters	Denver Water household
New homeowners and long-term rental property turnover	Denver Water billing changes, rental property owners, and management companies
Short term rental property (Air BnB, VRBO, etc.)	Rental property owners and management companies
Participant in the FLOW Program for eight years (replacement of filter pitcher in 8th year)	FLOW Program database

Notification Methods

Notification methods for the FLOW Program include:

- Direct mail and door-to-door delivery of filter kits (Appendix B) with a letter to the customer, detailed instructions regarding the FLOW Program, water filter cartridge use and replacement, survey/response form (multi language), a quick

response (QR) code for access to Denver Water's digital registration page (in lieu of mail in survey/response), and other related details. The material will be available on Denver Water's website (www.denverwater.org/lead).

- Door-to-door canvassing of neighborhoods campaigns
- Neighborhood meetings and additional strategic community outreach opportunities.
- Robocalls to impacted Denver Water households.
- Follow-up communication using mail, email, phone, and door to door survey.

Denver Water households that are confirmed as non-lead service lines that request a pitcher filter will receive educational materials regarding the FLOW Program and a water quality sample kit for assuring the Denver Water household that they are not required to filter their water, but may do so at their own expense.

In addition, water quality sampling and community outreach and education materials will be provided to customers not in the FLOW Program, as requested.

Survey

There are five categories of surveys to help gather information from FLOW Program participants about how filters are used for infant formula, drinking, and cooking activities. The surveys will be similar to the surveys used during the FLOW Pilot but will be revised as necessary during implementation of the FLOW Program to incorporate lessons learned.

- **Initial Survey:** The intent of this survey is to obtain initial feedback from the Denver Water household. This survey is included in the hand-delivered and mailed filter kits.
- **Use Survey:** The use survey will be sent to FLOW Program participants a few weeks after they have received their filter kit. The intent of this survey is to confirm if a Denver Water household is using the filter for infant formula, drinking, and cooking. This survey also includes an option for participants to elect for an alternative filter.
- **Adoption Survey:** Once a year, the adoption survey will be sent to approximately 1,250 random customers to generate the minimum 1,059 responses. Denver Water will use internal resources and community outreach services to enhance survey response rates. This survey will have the following three questions:
    - Do you use your filter or bottled water for drinking water? Yes/No
    - Do you use your filter or bottled water for water used in cooking? Yes/No
    - Do you use your filter or bottled water for infant formula preparation? Yes/No/Not Applicable (no infants)

  This survey question will be used for metrics to determine filter adoption. From June until December each year, follow-up calls and emails may be used in order

to achieve the 1,059 responses. In January, the adoption survey results will be submitted to CDPHE and EPA.

- **Alternative Survey:** Once a Denver Water household has an alternative filter installed, the alternative survey is sent to provide feedback on whether the FLOW Program participant is using their alternative filter for infant formula, drinking, and cooking.
- **Ongoing Surveys:** Twice a year, during the 15-year FLOW Program, ongoing surveys will be used to confirm if the Denver Water household is continuing to use the filter for infant formula, drinking, and cooking. This survey will also provide options for Denver Water households to opt for alternative filters and will obtain feedback of the COE and the FLOW Program.

The intent of the survey is to obtain confirmation of the primary water source used by FLOW Program participants for infant formula, drinking, and cooking:

- **Adoption** = Additional reduction of lead through the use of a certified filter or use of an alternative source of lead-free water (i.e. bottled water).
- **Non-Adoption** = Customer uses tap water.

Filter use data will be gathered using questions such as these and as included in Appendix C:

What is your household's primary source of drinking water? (Check one)

- ☐ Unfiltered Faucet
- ☐ Bottled water
- ☐ Filtered - refrigerated water/ice dispenser
- ☐ Filtered - pitcher filter
- ☐ Filtered - under sink filter
- ☐ Filtered - faucet-mounted filter
- ☐ Filtered - whole house filter
- ☐ Other (specify)

What is your household's primary source of water for cooking? (Check one)

- ☐ Unfiltered Faucet
- ☐ Bottled water
- ☐ Filtered - refrigerated water/ice dispenser
- ☐ Filtered - pitcher filter
- ☐ Filtered - under sink filter
- ☐ Filtered - faucet-mounted filter
- ☐ Filtered - whole house filter
- ☐ Other (specify)

What is your household's primary source of water for infant formula preparation? (Check one)

- ☐ Not Applicable (no infants)
- ☐ Unfiltered Faucet
- ☐ Bottled water
- ☐ Filtered - refrigerated water/ice dispenser
- ☐ Filtered - pitcher filter
- ☐ Filtered - under sink filter
- ☐ Filtered - faucet-mounted filter
- ☐ Filtered - whole house filter
- ☐ Other (specify)

Once a year in May, for return by July, a survey (the adoption survey) of a minimum of 1,059 randomly selected participants (Appendix C.III.1) will be undertaken to measure adoption rates (with at least a 95% confidence and no more than 5% error) and to determine reasons for non-adoption. Denver Water will use program resources, internal resources, and community outreach services to enhance survey response rates. From June until December each year, follow-up calls and emails will be used in order to achieve the 1,059 responses. In January, the adoption survey results will be submitted to CDPHE and EPA. More than 1,059 surveys may be sent out in order to achieve the minimum responses. Additional surveys of random customers may be issued between June and December to obtain the necessary minimum responses to support the adoption rate. The survey will evolve over time, as more is learned throughout the process of the FLOW Program.

The adoption survey will be random and proportional to the population of the total service area, in order to achieve a statistically sufficient number of responses for the area. Additional random surveys will be conducted of sub-areas to determine demographics but will not be considered as part of the annual adoption survey metrics.

For all surveys, Denver Water will provide an online survey option that is mobile friendly (Snap Survey).

For customers that either do not respond to the adoption survey or communicate that the filter was not used, Denver Water may follow-up with a phone-call, an email, or an in-person visit to provide additional education on methods to reduce lead exposure; determine whether or not an alternative lead reduction strategy is used; and to ultimately encourage the use of the filter.

Additionally, a survey of each customer will be provided during the Accelerated Lead Service Line Replacement (ALSLR) Program (approximately 4,267 surveyed based on the number of completed lead service line replacements each year). The results of the ongoing surveys will be evaluated and used to confirm adoption rates and make improvements to the Filter and COE Programs (learn-by-doing).

The FLOW Program will be adjusted based upon survey results and additional feedback acquired during public outreach and education. Specifically, "Adaptive Management" techniques will be implemented to adjust the COE to target and follow-up with specific sub-groups. The ALSLR Program may be advanced for a specific subgroup if it is determined that they are not participating in FLOW.

Vulnerable Populations

Vulnerable populations; such as pregnant women, children, and those of low socioeconomic standing; will be identified, contacted, and tracked using the following methods:

- Lead Service Inventory (LSI) - The lead service inventory will incorporate factors, such as proximity to schools, daycares, preschools, independent data sources, etc. to assist with the identification of vulnerable populations
- COE – Outreach to specific groups will be completed using focused community outreach, meetings, and individual interaction with Denver Water households using the tactics noted in Appendix III.A Communications, Outreach and Education Plan.
- Survey Questions - The survey questions will help identify expecting families, families with infants, and families of low socioeconomic standing.

The data above will be incorporated into the LSI for use with the predictive modelling effort (see LRP Plan Appendix III.B.3 Prediction Model and Prioritization), which will be used to prioritize and target filter distribution and annual ALSLR locations.

Filter Adoption

Filter adoption is defined as the following action by the customer to reduce lead in their infant formula, drinking, and cooking water by:

- Using and maintaining filters properly, as well as clean and/or replace the filter and cartridges at the appropriate time.

  or

- Using an alternative source of lead-free water (i.e. bottled water).

Filter adoption is assumed based on FLOW Program participant's responses to the adoption survey questions.

Based on a 2017 customer survey (1,432 responses) by Denver Water, the majority of customers reported that their household typically drink unfiltered tap water as shown by the survey results:

- 37% of customers use filters (type of filter and standard unknown)
- Less than one in ten customers reported that their household drinks bottled water regularly
- 54% of customers reported drinking unfiltered tap water

At a minimum, Denver Water must achieve filter adoption rates for customers with known, suspected, or possible lead service lines to at least 65% to provide equivalent protection to orthophosphate treatment.

Adoption Calculations

In order to achieve a minimum 65% filter adoption rate; 688 responses of 1,059 adoption surveys participants must indicate that the filters are being used for infant formula, drinking, and cooking. A failure of either of the adoption survey questions is considered a failure.

Minimum Survey Responses and Adoption:

- $Minimum\ 65\%\ Adoption: 1{,}059\ FLOW\ Survey\ Responses\ x\ 65\% = 688\ yes\ responses\ (for\ both\ drinking\ and\ cooking)$

Filter adoption rates will be tracked and data collected will be included in the annual adoption submittal to support filter adoption metrics. Filter adoption assumes customers are using and maintaining the filter properly, as well as replacing the filter cartridges at the appropriate time.

Denver Water will work with the LRP Leadership Committee to identify and implement additional outreach efforts directed at improving the adoption rate before the annual reporting date if the overall filter adoption rate is less than 65% by the end of year one. Failure to correct the non-adoption rate will trigger actions in accordance with the multi-tiered response plan.

Multi-Tiered Response Plan

If a customer chooses not to enroll in the FLOW Program and it cannot be determined if an alternative filter or drinking water supply is used, or does not employ a filter, the protocol that Denver Water may follow includes the following steps:

- Confirm materials of construction, pothole the property (if the service line material is suspected or unknown) and attempt to understand the materials used in premise plumbing (via visual inspection if allowed by the customer).
- Offer water quality sampling to quantify the magnitude of lead release, if not previously sampled.
- Interview the Denver Water households to determine whether or not an alternative means to reduce lead exposure is employed such as an existing filter system (confirmed NSF certified to remove lead) or if the Denver Water households rely on bottled water for infant formula, drinking, and cooking.
- Make two additional attempts to encourage the customer to use a filter, based on site specific information for materials of construction and the water quality sampling results.
- If the customer continues to choose to not filter (or opts out of the FLOW Program), the property will be placed on a Filter Non-Adoption List.

- Revisit on an annual basis to deliver additional education material and deliver a pitcher filter, replacement cartridges, and a water quality sampling kit.
- Regularly provide lead education with billing to encourage filter use until the lead service line is replaced or confirmed non-lead.
- Notify local health department at a frequency of every 6 months and request assistance by the local health department.
- Denver Water household contacted by the local health department and Denver Water coordination of next steps with the local health department.

Lessons Learned

Other entities have distributed filters to customers for lead and non-lead programs. The lessons learned from distribution of filters for other entities are shown in Table III.C.3-3.

Table III.C.3-3 Lessons Learned in Other Jurisdictions

Item No.	Description
1	Directions for filter use must be clear to ensure proper use of filters.
2	Reach out to Denver Water households through various methods: phone calls, emails, door-to-door, website videos, tables at community events, local TV stations, etc.
3	Impersonators may be an issue. Make sure all staff have ID badges and outreach material spells out what Denver Water households can expect from Denver Water staff.
4	Many man hours are needed for door-to-door delivery of pitchers.
5	Be prepared to field questions of why certain citizens are included in the filter program, and others are not. Make sure the criteria are clear and there is consensus on who is in the filter program and who may be added, as more information is gathered.

Lessons learned from the FLOW Pilot that will be implemented into the full-scale FLOW Program are shown in Table III.C.3-4.

Table III.C.3-4 Lessons Learned From the Filter Pilot Program

Item No.	Description
1	Provide advance targeted communications, outreach and education prior to filter distribution to introduce the program and explain the importance of filter use.
2	Reinforce the importance of using the filter for cooking and infant formula preparation (in addition to drinking water).
3	Inform participants the filters and replacement cartridges are provided at no cost to the customer for the duration of the program.
4	Provide alternative filters such as refrigerator, larger pitchers, and faucet mount.

Item No.	Description
5	Provide additional Spanish-speaking staff for field crews for initial distribution and follow-up visits.
6	Have one adoption survey after the participants have been contacted, are aware of the program, and have been using the filter for period of time.
7	Send filters addressed to tenants, not owners of the homes, if renters reside in the household.
8	Print individual participant's survey access codes directly on their survey in order to easily track the participant's responses.
9	Make survey questions clear, so that each answer doesn't have more than one meaning.
10	Have more outreach materials educating customers about how the service line is owned by the homeowner and how they can request a lead test kit.
11	Simplify outreach materials.
12	Update phone numbers in the database as project progresses.
13	Provide alternative filters and additional filters as filling the pitcher is cumbersome and slow.
14	Younger generation prefer online survey responses and electronic communications.
15	Not all residents have email addresses and internet access and hard copy surveys should continue to be provided.
16	Follow-up calls should be made from a Denver Water phone number.
17	Outreach staff should fill out and request a water quality sampling kit for concerned residents.
18	Include lead service line replacement information and talking points with filter program.
19	Follow-up visits and door-to-door outreach is not preferred for all participants. Some have requested communication via email only.
20	Simplify survey questions to prevent confusion.

General Water Quality - Flushing

To reduce your exposure to lead in drinking water, we recommend flushing your faucet before using the water, unless a faucet filter that removes lead is installed and cannot be

bypassed during flushing, following the steps highlighted on www.denverwater.org. (https://www.denverwater.org/your-water/water-quality/lead/reduce-your-risk)

When using water for drinking, cooking and making ice, beverages and infant formula:

- *Use cold water. Hot water dissolves lead faster and is likely to contain higher levels of lead.*
- *If water has not been used for a few hours, run the kitchen or any bathroom faucet for a few minutes. You also can run the dishwasher or take a shower.*

Flushing the faucet is not required if a faucet filter that removes lead is installed and cannot be bypassed. Flushing water through a faucet filter that cannot be bypassed will shorten the life of the filter.

III. FLOW PROGRAM

The framework for the FLOW Program consists of the following series:

- 5200 – Data Management
- 5300 – Distribution
- 5400 – Alternative Filters
- 5500 – Twice a Year Follow-Up
- 5600 – Transition off FLOW

Below is a general summary of each series. Separate from this TM, Denver Water will further develop each series by identifying the key steps, processes and workflows prior to implementation. For each series, office and field staff supporting the FLOW Program will be trained. Efforts outlined herein do not include COE tasks.

A. Data Management – 5200 Series:

A geodatabase will be developed and used to track & manage the FLOW Program:

- Initial FLOW Program Participants - Premise / Denver Water household data for 84,546 properties / 119,250 Denver Water household units.
- Change of Denver Water household (Move In/Move Out) – Denver Water billing changes, new account rental property owner registration, rental property management companies, others. Denver Water will provide monthly updates.
- Add/Delete Premise – Based upon field data, including service line material type, replacement of lead service, others.
- Field Data Collection - The Mott MacDonald Field Inspection Tools (MMFIT) application will be available during the ALSLR Program and the FLOW Program to field collect Denver Water household data regarding both lead service lines and filter use.
- Integration with Denver Water CIS/CC&B
- FLOW Program Surveys - Filter recipients will be asked to respond to several online surveys related to filter use. The surveys will be administered using the

survey tool, Snap Survey, to seamlessly collect data directly from FLOW participants.

A dashboard for tracking metrics and adoption rates for the FLOW Program will be developed.

B. Distribution – 5300 Series

- **Initial Distribution**
  - **Procure Filter Kits:** Coordinate with the suppliers to procure pitcher filters, cartridges, boxes, bags and other contents for 119,250 filter kits. Coordinate delivery to pick and pack warehouse in the Denver Area. It is expected that deliveries will be divided into 12 batches (10,000 filters) for use with distribution of the filters and communications within geographic areas.
  - **Training:** Office and field staff supporting FLOW will be trained.
    - Finalize filter kit education/outreach material, surveys, phone / in-person scripts, FAQs, and other key references, as included in Appendix D.
    - Conduct in-person training.
  - **Kit Assembly:** The filter kit contents (Appendix B) will be assembled for hand delivery and mailing.
  - **Mail Kits:** Boxed filter kits will be mailed directly to 90% of Denver Water households. Those Denver Water households that are enrolled in the Denver Water email subscription will also be emailed the letter highlighting that the filter kit package has been mailed, encourage participation, and request for the Denver Water household to contact Denver Water if the Denver Water household does not receive the kit within 5 days. The intent is to split into 12 batches (approximately 9,100 kits in a batch) to allow targeted distribution to specific areas within the Denver Water service area and provide staggered follow-up as required. The plan includes the goal of mailing one batch per week. The first batch will include the initial Denver Water households identified for lead service line replacement in 2020 to allow for adequate distribution and use prior to the start of the ALSLR Program in January 2020.
  - **Hand-Deliver Kits:** Bagged filter kits will be hand delivered (drop off) to 10% of Denver Water households. Those Denver Water households that are enrolled in the Denver Water email subscription will also be emailed the letter, highlighting that the filter kit package will be delivered and encourage participation in the FLOW Program. The intent is to split into 12 batches (approximately 1,000 kits in a batch) in coordination with the mailed kits to allow targeted distribution to specific areas within the Denver Water service area and provide staggered follow-up as required. Field staff will carry a Denver Water photo identification and for ease of identification.

- **Initial Survey**

- **Second Distribution** – It is estimated that pitcher filters should be replaced every 8 years. As technology advances, the 8-year replacement time period will be reviewed and adjusted, as needed. The Second Distribution will follow the same framework as the Initial Distribution.
- **Individual Distributions** – Throughout the FLOW Program, it is expected that new Denver Water households will be added due to move in / move outs, services added to LSI, and other reasons. Also, previously delivered kits may have been missing, lost or damaged. Individual distribution of filter kits, filters or filter cartridges will be mailed within two weeks to the Denver Water household.

C. Alternative Filters - 5400 Series

- **Analysis/Tracking:** Data gathered from the filter kit distribution, door-to-door visits, surveys, and other feedback received will be captured in a centralized database. Data will be further analyzed related to the participant's filter use and requests for alternative filters.
- **Use Survey**
- **Mail Alternative Filter**: If an alternative filter has been requested by the Denver Water household and they have opted for a home-owner-installed alternative filter, the alternative filters will be directly mailed to the Denver Water household. This option is predicted to be used for alternative filters that are easily installed.
- **Install Alternative Filter:** If an alternative filter has been requested by the Denver Water household and they have opted for Denver Water to install, an appointment will be made and the alternative filter will be installed, at no cost to the Denver Water household. Before installing the filter, Denver Water will conduct a visual inspection of the service line as it enters the house. With the aid of the homeowner, the entry point for the service line will be identified. Field staff will carry a Denver Water photo identification for ease of identification.
- **Alternative Survey**

D. Twice a Year Follow-Up – 5500 Series

Upon LRP approval, a twice a year follow-up will commence 6 months after the initial distribution and continue through the end of the FLOW Program in 15 years. The intent is to distribute the next 6 month supply of filter replacement cartridges, further outreach / education material, and survey.

- **Replacement Cartridges:** The next 6 month supply of filter replacement cartridges and outreach / education material will be distributed.

- **Mail**: Pitcher filter replacement cartridges will be directly mailed to the Denver Water household. Also, alternative filter cartridges that are easily installed will be mailed to the Denver Water household.
- **Install:** If an alternative filter is used and they have opted for Denver Water to install, an appointment will be made and the filter replacement cartridge will be installed. Field staff will carry a Denver Water photo identification for ease of identification.

- **Adoption Survey** - once per year
- **On-going Surveys**

E. Transition Off the FLOW Program – 5600 Series

- **Individual:** A Denver Water household will be removed from the FLOW Program, either six months after replacement of the lead service line, or if a non-lead service line is confirmed at the property.
  - Replacement cartridges will be provided for the 6 month period following the lead service line replacement. The Denver Water household will be notified via letter.
  - A Denver Water household will be transitioned off the FLOW Program if a non-lead service line is confirmed at the property in accordance with Appendix III.D.1 Accelerated Lead Service Line Replacement Plan. No additional replacement cartridges will be provided. The Denver Water household will be notified via letter at the end of a 6 month period.
- **FLOW Program Discontinued:** If Denver Water transitions off the FLOW Program, no additional replacement cartridges will be provided. The Denver Water households will be notified via letter.

IV. FILTER USE METRICS

Metrics were developed for use in the FLOW Program and a table of metrics is provided in the Lead Reduction Program Plan (LRP Plan).

V. DEMOGRAPHICS EVALUATION

As part of the use survey, it is important to determine the adoption rate amongst the diverse populations in the Denver Water service area. The American Community Survey (ACS) is part of the U.S. Census Bureau's Decennial Census Program and is designed to provide current social, economic, housing, and demographic estimates throughout the decade. Combining American Census Survey (ACS) data with FLOW data allowed for the estimation of trends between levels of diversity in a neighborhood and filter adoption rates within the FLOW neighborhoods. ACS information at the Block Group Level will be taken from the 2013 to 2017 American Community Survey estimates. The information was adjusted for the Hispanic representation included as a category to reflect additional available diversity information. The information was linked to the Survey Census Block

Groups to develop a geographic component to the data. The survey data was then evaluated by Diversity Categories By Block Group (ACS Data for B02001) as follows:

- Hispanic alone
- White (Non-Hispanic) alone
- Black or African American alone
- American Indian and Alaska Native alone
- Asian alone
- Native Hawaiian and Other Pacific Islander alone
- Some other race alone

As an example, the FLOW Pilot survey results were geolocated based on the address, tap number, or other available spatial information. The geolocation allows the data collected from the FLOW Pilot to be associated to a location and a block group for further analysis of the adoption rates and other survey results compared to the available diverse population statistics for each area. The following evaluations were completed for the Filter Pilot premises:

1. The comparison of the adoption rate noted on completed surveys to the diverse population for each surveyed area.
2. The comparison of areas where surveys where sent but not returned or the adoption rate is low.
3. The identification of specific diverse populations where surveys were sent but not returned or the adoption rate is low.
4. The comparison of the survey results between different areas and diverse groups to establish trends by ethnic population.
5. The populations where filters were sent but surveys not returned.
6. The comparison of adoption rate to the baseline approved adoption metric.

The survey results were then compared to the neighborhood demographics. The COE program can be adjusted if there is a lack of survey results or negative feedback from a certain area are identified. If an area is systemically not participating in FLOW, then the areas' criticality (and thus risk) will be ranked as higher priority in the ALSLR Program.

A summary of the FLOW Pilot demographics evaluation, for three of the seven neighborhoods, is shown in Table III.C.3-5.

Table III.C.3-5 Survey Results by Diversity Analysis (sample results)*

Neighborhood	1	2	3
White Hispanic (%)	62	64	61
White Non-Hispanic (%)	29	16	18.6
Black or African American (%)	3	1	0.1
American Indian and Alaska Native (%)	2	1	0
Asian (%)	0	9	19
Native Hawaiian and Other Pacific Islander (%)	0	0	1
Other (%)	4	9	0.3
Number Using Filter for Drinking	8	4	2
Number Using Filter for Cooking	6	4	2
Initial Survey Completed	7	8	0
Filter Use Survey Completed	9	6	2
Using for Drinking (%)	89	67	100
Using for Cooking (%)	67	67	100
Initial Survey Completed (%)	64	73	0
Filter Use Survey Completed (%)	82	55	9

**The demographic data was developed using limited survey data from August 2, 2019 and available census data. The demographic data is provided as an example and will be further developed with the full-scale filter plan.*

The data indicate that at least 67% of the population surveyed use the filter for drinking and cooking in three (3) of the seven neighborhoods where White Hispanics make up the majority of the population. Other considerations may be affecting neighborhood 3, which shows a markedly lower adoption rate. A geographic strategy analysis will be conducted to determine how the COE plan should be adjusted in neighborhood 3 as opposed to modifying the overall COE efforts specified for the White Hispanic population. Neighborhood 3 has a larger Asian population and this information will be used to provide guidance for increased COE for filter adoption in this neighborhood.

VI. FILTER PLAN 2019/2020 TIMELINE EXAMPLE

Date	Activity	Comments
Based on an October 20, 2019 Variance Approval		
July – October 2019	Develop FLOW Plan	
September 30, 2019	Denver Water contract with • pitcher filter kit content suppliers • pick and pack warehouse • distribution team • program management	
October 21, 2019	Variance Approval Expected	Go / No-Go from Denver Water on FLOW Program
October 23, 2019	Order pitcher filter kit supplies	Confirm pitcher filter supplies and coordinate with suppliers
October 23, 2019	COE	Launch Denver Water internal COE plan
November 11, 2019	Training/Kit Assembly	Training materials and filter kits are ready for distribution
November 13, 2019	Commence Distribution of Batch 1	Coordinate outreach and delivery
November 20, 2019	Commence Distribution of Batch 2	Coordinate outreach and delivery
December 2, 2019	Commence Distribution of Batch 3	Coordinate outreach and delivery
December 9, 2019	Commence Distribution of Batch 4	Coordinate outreach and delivery
December 16, 2019	Commence Distribution of Batch 5	Coordinate outreach and delivery
January 6, 2020	Commence Distribution of Batch 6	Coordinate outreach and delivery
January 13, 2020	Commence Distribution of Batch 7	Coordinate outreach and delivery
January 20, 2020	Commence Distribution of Batch 8	Coordinate outreach and delivery
January 27, 2020	Commence Distribution of Batch 9	Coordinate outreach and delivery
February 3, 2020	Commence Distribution of Batch 10	Coordinate outreach and delivery
February 10, 2020	Commence Distribution of Batch 11	Coordinate outreach and delivery
February 17, 2020	Commence Distribution of Batch 12	Coordinate outreach and delivery

Date	Activity	Comments
March 20, 2020	Confirm pitcher filter distribution to all Denver Water households with known, suspected, and possible lead service lines	
Starting May 2020 & every 6 months	Twice a Year Follow-up following the same batch sequence • Analysis/Tracking • Use Survey • Distribute filter cartridge replacements	• Feedback and collection of data • Determine alternative filter type requested • Follow-up phone calls
Starting May 2020 & every year	• Adoption Survey	• Track Filter Adoption
Starting July 2020	• Mail Alternative Filters • Install Alternative Filters • Alternative Survey	• Order, delivery, and installation of alternative filter equipment • Feedback and collection of data
Starting October 1, 2020.	Analyze surveys on filter usage submitted from approximately 4,267 Denver Water households as part of the ALSLR Program, 1,059 FLOW Program Participants, and others	
December 2020	Progress Meeting	• Feedback and collection of data
June through December every year	Follow-up on Adoption Survey	• COE
Every January	Report Adoption Survey results to CDPHE and EPA	

APPENDIX A – FILTER TYPES

DENVER WATER

Filter Types

Federal regulations do not exist for residential water treatment filters. Voluntary national standards and National Sanitation Foundation (NSF) / American National Standards Institute (ANSI) protocols have been developed to establish minimum requirements for the safety and performance of residential water treatment filters. NSF/ANSI Standards 42 and 53 are applicable for water quality and lead removal, as described, below.

- **NSF/ANSI 42**

  Filters are certified to reduce aesthetic impurities such as chlorine, taste, and odor. Filters can be point-of-use (POU) (faucet filter, water pitcher, etc.) or point-of-entry (POE) (whole house) treatment systems.

- **NSF/ANSI 53**

  Filters are certified to reduce a contaminant with a health effect, such as lead. The standard establishes health effects as regulated by the U.S. Environmental Protection Agency (EPA). Both standards 42 and 53 include adsorption and filtration treatment.

NSF established laboratories that may test and certify filters that meet the NSF protocols for lead removal. The certified laboratories include: NSF International, CSA International, Water Quality Association (WQA), International Association of Plumbing and Mechanical Officials, Underwriters Laboratory, Truesdail, and Intertek.

A summary of filter pitchers, cost estimates, and features is shown in Table A1. A summary of different types of filters, certification laboratory to NSF/ANSI Standards 42 and 53, and associated filter life is shown in Table A2. The general range of filter life for pitcher filters is 1-6 months and the general range of filter life for alternative filters is 1-10 months. Product detail sheets are attached.

DENVER WATER

Table A1: Pitcher Filters									
Brand/Model	**Certification Laboratory**	**Filter Life**	**Percent Lead Reduction at pH 8.5**	**Removes Fluoride**	**Unit Cost - Retail**	**Wholesale Cost**	**Size of Packaging (L X W X H)**	**Weight**	**Inventory and Lead Time**
Brita Monterey (#OB50) 10-cup pitcher with Longlast filter (#OB06)[1]	WQA	6 months	99.6%	No	$34.99[2]	TBD	TBD	TBD	TBD
DuPont 8-cup pitcher (WFPT100) with WFPTC100N filter[3]	WQA	3 months	97.4%	No	$18.71[4]	TBD	7 X 9 ¼ X 9 ½”	1.8 lbs	TBD
DuPont WFTP200 10-cup pitcher with WFPTC100N filter[5]	WQA	3 months	97.4%	No	$24.96[6]	TBD	5 3/8 X 11 ½ X 11 ¼”	2.4 lbs	TBD
ZeroWater 10-cup filter pitcher (ZP-010)[7]	NSF	1 month	99.0%	Yes	$34.99[7]	TBD	12 ¼ X 6 X 11 5/8”	3.75 lbs	TBD

DENVER WATER

Table A1: Pitcher Filters									
Brand/Model	**Certification Laboratory**	**Filter Life**	**Percent Lead Reduction at pH 8.5**	**Removes Fluoride**	**Unit Cost - Retail**	**Wholesale Cost**	**Size of Packaging (L X W X H)**	**Weight**	**Inventory and Lead Time**
Pur Classic 11-cup pitcher (PPT111WV1) with lead reduction filter (PPF951K)[8]	WQA	2 months	97.9%	No	$34.99[8]	TBD	TBD	TBD	TBD

Notes:

1. *https://www.brita.com/water-pitchers/monterey-longlast/?ds_rl=1238837&gclid=Cj0KCQjw9JzoBRDjARIsAGcdIDUi8xyyMENARquLCz_NAqDULqUppLOhn01Pd3XbXRcXZGGWDHWOyLgaAslGEALw_wcB&gclsrc=aw.dshttp://www.protectplus.com/PD-Water-Filtration-82/DuPont-Traditional-Water-Filter-Pitcher-WFPT100-653*
2. *https://www.homedepot.com/p/Brita-Monterey-10-Cup-Water-Filter-Pitcher-in-Blue-with-Longlast-Filter-BPA-Free-6025836304/308802800*
3. *http://www.protectplus.com/PD-Water-Filtration-82/DuPont-Mirage-Water-Filter-Pitcher-WFPT200-652*
4. *https://www.amazon.com/DuPont-WFPT100X-Traditional-Filter-Pitcher/dp/B007VZ2OTM/ref=sr_1_1?keywords=dupont+8-cup+pitcher&qid=1561675034&s=hi&sr=1-1*
5. *http://www.protectplus.com/PD-Water-Filtration-82/DuPont-Mirage-Water-Filter-Pitcher-WFPT200-652*
6. *https://www.amazon.com/DuPont-WFPT200X-Mirage-Filter-Pitcher/dp/B007VZ2OTC*
7. *https://ww.zerowater.com/products-10-Cup-Pitcher?gclid=Cj0KCQjw9JzoBRDjARIsAGcdIDWhrdUxnskz0UuAp4CIuQcDKJ27qwbOVoqxdOPq9XYFa3QJlVwIK2YaAhvzEALw_wcB*
8. *https://www.pur.com/water-filter-pitchers-and-dispensers/pur-ultimate-pitcher-filtration-system-with-lead-reduction*

Table A2: Point-of-Use Filter Types

Filter Type	Brand/Model	Certification Laboratory	Filter Life	Percent Lead Reduction at pH 8.5
Water Dispenser	ZeroWater 20-cup water filter jug (ZD-20RP)[1]	NSF	1 month	99.0%
	ZeroWater 30-cup water filter jug (ZD-30RP)[2]	NSF	1 month	99.0%
	ZeroWater 40-cup water filter jug (ZBD-040)[3]	NSF	1 month	99.0%
Water Dispenser	Brita Ultramax 18-cup Dispenser (#OB24) with Brita Longlast filter (#OB06)[4]	WQA	6 months	99.6%
Faucet-Mount	DuPont WFFM100 Faucet Mount Filter with WFFMC100 or WFFMC300 filter[5]	WQA	5 months	99%
	DuPont WFFM350 with Ultra Protection Filter (WFFMC300)[6]	WQA	10 months	99%
	Brita Faucet Filtration System FF-100 with FR-200 filter[7]	NSF & WQA	5 months	99.3%
	Brita Basic Faucet Filtration System SAFF-100 with FR-200 filter[8]	NSF & WQA	5 months	99.3%
Faucet-Mount	Pur PFM400H Faucet with MineralClear Filter (RF9999)[9]	WQA	3 months	99.9%

DENVER WATER

Table A2: Point-of-Use Filter Types

Filter Type	Brand/Model	Certification Laboratory	Filter Life	Percent Lead Reduction at pH 8.5
Refrigerator Filters	Frigidaire PureSource 3 (WF3CB)[11]	NSF	6 months	99.1%
	Maytag Refrigerator Water Filter (UKF8001)[12]	NSF	6 months	99.3%

Notes:

1. *https://www.brita.com/water-pitchers/monterey-longlast/?ds_rl=1238837&gclid=Cj0KCQjw9JzoBRDjARIsAGcdIDUi8xyyMENARguLCz_NAqDULgUppLOhn01Pd3XbXRcXZGGWDHWOyLgaAslGEALw_wcB&gclsrc=aw.dshttp://www.protectplus.com/PD-Water-Filtration-82/DuPont-Traditional-Water-Filter-Pitcher-WFPT100-653*
2. *http://www.protectplus.com/PD-Water-Filtration-82/DuPont-Mirage-Water-Filter-Pitcher-WFPT200-652*
3. *http://www.protectplus.com/PD-Water-Filtration-82/DuPont-Mirage-Water-Filter-Pitcher-WFPT200-652*
4. *https://ww.zerowater.com/products-10-Cup-Pitcher?gclid=Cj0KCQjw9JzoBRDjARIsAGcdIDWhrdUxnskz0UuAp4CIuQcDKJ27qwbOVoqxdOPq9XYFa3QJlVwIK2YaAhvzEALw_wcB*
5. *https://www.pur.com/water-filter-pitchers-and-dispensers/pur-ultimate-pitcher-filtration-system-with-lead-reduction*
6. *https://ww.zerowater.com/products-20-Cup-Ready-Pour*
7. *https://ww.zerowater.com/products-30-Cup-Ready-Pour*
8. *https://ww.zerowater.com/products-40-Cup-Ready-Pour*
9. *https://www.brita.com/water-dispensers/ultramax-longlast/*
10. *http://www.protectplus.com/PD-Water-Filtration-82/DuPont-Premier-Faucet-Mount-Drinking-Water-Filter-WFFM100-647*
11. *http://www.protectplus.com/PD-Water-Filtration-82/DuPont-Deluxe-Faucet-Mount-WFFM350-646*
12. *https://www.brita.com/faucet-systems/complete/*
13. *https://www.brita.com/faucet-systems/basic/*
14. *https://www.pur.com/faucet-filtration-systems/pur-advanced-faucet-filtration-system-with-mineralclear-filter*
15. *https://www.frigidaire.com/Filters--Accessories/Filters/water-filters/WF3CB/?gclid=CjwKCAjwuqfoBRAEEiwAZErCsqQkifIHCX2HhuFjxt_hL213qbrqvzOJ96upk87nk6SIa4b2_4hT2BoCuXYQAvD_BwE&gclsrc=aw.ds*
16. *https://www.homedepot.com/p/Maytag-UKF8001-Refrigerator-Water-Filter-UKF8001/100671093*

APPENDIX B – FILTER KIT CONTENTS

DENVER WATER

Filter Kit Contents

Each participant of the Filter Lead Out of Water (FLOW) Program will receive a filter kit via direct mail or door-to-door hand delivery. Each filter kit includes the following:

Kit Items:

- Frequently Asked Question (FAQ) summary for Lead Service Lines (LSL) and FLOW Program questions
- One (1) water filter pitcher - NSF certified to remove lead
- 6-month supply of replacement filter cartridges
- Pitcher filter instructions and maintenance guidelines in multiple languages
- Initial Survey
- Reusable bag
- Magnet with reminders to use filtered water for infant formula, drinking, and cooking, cartridge date change information, program contact information, website, and telephone number
- Door hanger

The filter pitcher should be used for all infant formula, drinking water, and cooking. The manufacturer's instructions for use and maintenance should be followed and the filter should be replaced in accordance with the manufacturer's guidelines.

APPENDIX C - SURVEY QUESTIONS

DENVER WATER

DENVER WATER

FLOW Program Survey Question Matrix

Questions	Initial Survey	Use Survey	Adoption Survey	Alternative Filter Survey	Ongoing Surveys
1. Do you use your filter or bottled water for drinking water? • Yes • No		X	X	X	X
2. Do you use your filter or bottled water for water used for cooking? • Yes • No		X	X	X	X
3. Do you use your filter or bottled water for water used for infant formula preparation? • Yes • No • Not Applicable (no infants)		X	X	X	X
4. Do you have a lead service line? • Yes • No • I do not know	X				
5. What is your household's primary source of drinking water? (Check one) ☐ Unfiltered faucet ☐ Bottled water ☐ Filtered - refrigerated water/ice dispenser ☐ Filtered - pitcher filter ☐ Filtered - under sink filter ☐ Filtered - faucet mounted filter ☐ Filtered - whole house filter ☐ Other (specify)	X				

DENVER WATER

FLOW Program Survey Question Matrix

Questions	Initial Survey	Use Survey	Adoption Survey	Alternative Filter Survey	Ongoing Surveys
6. What is your household's primary source of water used for cooking? (Check one) ☐ Unfiltered faucet ☐ Bottled water ☐ Filtered - refrigerated water/ice dispenser ☐ Filtered - pitcher filter ☐ Filtered - under sink filter ☐ Filtered - faucet mounted filter ☐ Filtered - whole house filter ☐ Other (specify)	X				
7. What is your household's primary source of water used for infant formula preparation? (Check one) ☐ Unfiltered faucet ☐ Bottled water ☐ Filtered - refrigerated water/ice dispenser ☐ Filtered - pitcher filter ☐ Filtered - under sink filter ☐ Filtered - faucet mounted filter ☐ Filtered - whole house filter ☐ Not Applicable ☐ Other (specify)	X				
8. If you have an existing water filter system, what is the make and model number for your filter? (Fill in)	X				
9. Do you currently or do you plan in the future to use filtered or bottled water for infant formula? Yes/No/NA	X	X		X	X
10. If you do not primarily use the water filter provided, what issues are you experiencing? (Check all that apply) ☐ Filter pitcher isn't large enough ☐ Filter pitcher doesn't fit in refrigerator ☐ The filter pitcher takes too much time to fill ☐ It's too much effort to use the filter pitcher ☐ I'm not interested in filtering my drinking water		X			

DENVER WATER

FLOW Program Survey Question Matrix

Questions	Initial Survey	Use Survey	Adoption Survey	Alternative Filter Survey	Ongoing Surveys
☐ Other, please specify: (fill in the blank) ☐ Not Applicable (no issues)					
11. If the water filter provided does not meet your needs, would you be more likely to use an alternative filter? (Check one) ☐ Faucet-mounted filter ☐ Refrigerator filter ☐ Larger pitcher filter ☐ Not Applicable (the water filter meets my needs)		X			X
12. Are you familiar with filter maintenance and cartridge replacement requirements? E.g. replacing the filter cartridge, cleaning the pitcher (if applicable)? Yes/No		X		X	X
13. What questions or comments do you have about the FLOW Program?	X	X		X	X
14. How could we improve the FLOW Program?	X	X		X	X
15. Want to stay informed about the FLOW Program? Provide your email or phone number.	X	X		X	X
16. What is your age? ☐ Under 18 ☐ 18-24 years old ☐ 25-34 years old ☐ 35-44 years old ☐ 45-54 years old ☐ Over 55 ☐ Prefer not to say	X	X		X	X
17. What is your gender? ☐ Male ☐ Female ☐ Other (specify) ☐ Prefer not to say	X	X		X	X
18. Are you Hispanic or Latino? ☐ Yes ☐ No ☐ I do not know					

DENVER WATER

FLOW Program Survey Question Matrix

Questions	Initial Survey	Use Survey	Adoption Survey	Alternative Filter Survey	Ongoing Surveys
☐ Prefer not to say					
19. What is your ethnicity? (Check all that apply) ☐ White (Non-Hispanic) ☐ Black or African American ☐ Native American or Alaska Native ☐ Asian ☐ Native Hawaiian and Other Pacific Islander ☐ Multiple ethnicities ☐ Other (specify) ☐ I do not know ☐ Prefer not to say	X	X		X	X
20. Are you married, widowed, divorced, separated, or never married? ☐ Married ☐ Widowed ☐ Divorced ☐ Separated ☐ Never married ☐ Prefer not to say	X	X		X	X
21. Are you pregnant, nursing, or an expecting family? ☐ Yes ☐ No ☐ Prefer not to say	X	X		X	X
22. What is the primary language you speak? (Check all that apply) ☐ English ☐ Spanish ☐ Other (specify)	X	X		X	X

DENVER WATER

FLOW Program Survey Question Matrix

Questions	Initial Survey	Use Survey	Adoption Survey	Alternative Filter Survey	Ongoing Surveys
23. What is the highest level of school you have completed, or the highest degree you have received? ☐ Less than high school degree ☐ High school degree or equivalent (e.g., GED) ☐ Some college but no degree ☐ Associate degree ☐ Bachelor's degree ☐ Graduate degree ☐ Prefer not to say	X	X		X	X
24. Which of the following categories best describes your employment status? ☐ Employed, working 1-39 hours per week ☐ Employed, working 40 or more hours per week ☐ Not employed, looking for work ☐ Not employed, NOT looking for work ☐ Retired ☐ Disabled, not able to work ☐ Prefer not to say	X	X		X	X
25. How much total combined money did all members of your household earn in 2018? ☐ $0 - $9,999 ☐ $10,000 - $19,999 ☐ $20,000 - 29,999 ☐ $30,000 - 39,999 ☐ $40,000 - 49,999 ☐ $50,000 - 59,999 ☐ $60,000 - 69,999 ☐ $70,000 - 79,999 ☐ $80,000 - 89,999 ☐ $90,000 - 99,999 ☐ $100,000 or more ☐ Prefer not to say	X	X		X	X

APPENDIX D - COE

DENVER WATER

Community Outreach and Education (COE)

The overarching Lead Reduction Program Communication's Strategy, process, procedures, and guidelines will apply to the FLOW Program. The success of the COE will be paramount to provide Denver Water with the necessary data and information to support the variance submittal.

All COE materials will be bilingual for ease of use. The filter kit will include the following COE materials:

Frequently Asked Questions (FAQ)

The FAQ document will provide additional information beyond the press release of the filter program. The FAQ developed specifically for the filter program will have duplicative information from the larger FLOW Program initiative FAQ approved by the EPA and CDPHE, with additional context as to why participants are receiving the filter kit, the length of the program, information about the surveys, and more.

Magnet Reminder Card

A refrigerator magnet will provide a reminder to encourage filter pitcher use for infant formula, drinking, and cooking. The magnet will also remind users to change their filter cartridge regularly. Program contact information will be included on the magnet.

Door-hanger

10% of FLOW Program participants will have door-to-door delivery of their filter kits. A door-hanger will be left on doors with the filter kit to notify Denver Water households of the FLOW Program, inform them of the contents of the filter kit, and provide contact information should the Denver Water household residents not be home during the initial door to door delivery attempt.

Survey Card

An initial survey will be included in the filter kit. FLOW Program participants will be encouraged to complete the initial survey and return their comments to Denver Water within two weeks of receiving their filter kit. Future surveys will be mailed to the FLOW Program participants with incentives such as Amazon gift cards or the chance to be entered into a drawing for a reward offered for the completion of each survey.

APPENDIX III.D.1 - ACCELERATED LEAD SERVICE LINE REPLACEMENT PLAN

September 2019

DENVER WATER

Memo

1600 S Quebec Street
Greenwood Village, CO 80111
aecom.com

Project name: Accelerated Lead Service Line Replacement Plan

Project ref: Denver Water Lead Reduction Plan

To: Denver Water

From: AECOM

CC:

Date:
August 16, 2019

Appendix III.D.1 Accelerated Lead Service Line Replacement Plan

Introduction

Background and Purpose

The Denver Water Lead Reduction Program (LRP) provides a path forward for Denver Water to replace all lead service lines (including galvanized downstream of lead) within its service area (including distributors) over the next 15-years. To support this effort, the enclosed Accelerated Lead Service Line Replacement (ALSLR) Plan describes the general steps and the estimated resources needed to replace approximately 63,955 lead service lines (LSLs) with a 7.0% cumulative program year average replacement rate (or approximately 4,477 lead service lines per program year).

The goal of the ALSLR Plan is to develop an approach that allows for the consistent and reliable replacement of services over the next 15-years. The ALSLR Plan was prepared to develop a contracting and procurement strategy for Denver Water based on lessons learned from other Lead Reduction Programs (LRPs) that have successfully replaced a comparable number of lead services, on the order of a few 1000s per year. The contracting and procurement strategy for the ALSLR Plan is presented in the three construction phases: Pre-Construction Phase, Construction Phase, and Post Construction Phase. The ALSLR Plan describes the close collaboration necessary with the other LRP elements including the Filter Program Plan, Communications, Outreach and Education (COE) Plan, and Lead Service Line Inventory (LSLI – Predicative Model). The reader is directed to Table III.D-1 below, for a list of pertinent Definitions and Acronyms used in this Technical Memorandum as a reference guide.

Table III.D-1. List of Definitions and Acronyms

Definition or Acronym	Descriptions
ALSLR	Accelerated Lead Service Line Replacement
AL	Action Level
CDPHE	Colorado Department of Public Health and Environment
CI	Construction Inspector
CM	Construction Manager
COE	Communications, Outreach, and Education
EJCDC	Engineers Joint Contract Documents Committee
EPA	Environmental Protection Agency
KPI	Key Performance Indicator
LSLI	Lead Service Line Inventory
LRP	Lead Reduction Program
LRP Plan	document submitted to EPA/CDPHE as the technical document that supports Denver Water's variance request.
LSL	Lead Service Line
LSLR	Lead Service Line Replacement
Non-copper	Refers to materials such as lead, galvanized, and polyethylene
Program	Refers to program staff from Denver Water and/or program management firm as appropriate for the task at hand.
POU	Point of Use (as in POU filter)
RFP	Request for Proposal
ROM	Rough Order of Magnitude
TBD	To Be Determined
TM	Technical Memorandum
YoY	Year-Over-Year

References

1. Denver Water Standards / Specifications
2. AWWA/ANSI Standard C810-17
3. Denver Water Procurement Process
4. Predictive Model and Prioritization (Appendix III.B.3)
5. LRP Plan Submissions
6. Filter Adoption (Appendix III.C.1)
7. Filter Pilot (Appendix III.C.2)
8. Filter Program Plan (Appendix III.C.3)
9. Communications, Outreach, and Education Plan (Appendix III.A)

LRP Variance Criteria

Overview

The ALSLR Plan has been developed to meet certain Key Performance Indicators (KPIs) established in the LRP. The success of the ALSLR Plan depends on the success of other LRP elements, namely

the COE Plan and Filter Program Plan, and will undergo continuous improvement through the Learning-by-Doing element. The ALSLR Plan will address the following key LRP variance criteria elements;

- Denver Water will replace all lead services, from the main to the first fitting inside the dwelling. Lead services include galvanized pipe downstream of lead.
- The target of 7.0% cumulative program year replacements is based on a total estimated number of known and suspected lead services of 63,955.
- A LSL replacement for compliance is counted as partially[1] or fully replacing the lead or lead/galvanized service line from the water main to the premise.
- The overall LRP objective of replacing the lead service is to remove the major source of lead from customer's drinking water supply. This implies that all portions of the lead or lead/galvanized service line will be replaced in full – no known lead service line remains. Where a portion was previously replaced - confirmed through LSL investigation activities, the remaining lead or lead/galvanized service line will be replaced. Conditions under which the lead would not be replaced are limited to earning consent from the property owner to replace the service line. If consent is not provided, additional actions are triggered, as discussed in this Plan.

The evaluation criteria and reporting needs are defined in the Terms and Conditions[2].

Annual LSLR Criteria and Resource Requirements

Based on the lessons learned from other LRPs as well as Denver Water's history of LSLRs, a LSLR Resource Summary table was prepared and presents the anticipated range of level of effort (expressed as number of crews) that will be required to meet the 7.0% target for annual replacements based on various assumptions (see Table III.D-2). Denver Water's water main replacement program as well as other similar programs has found that their LSLR crews have consistently replaced from two to four LSLs per day depending upon various circumstances. Based on the LSL inventory of 63,955, Denver Water will need approximately 6 to 11 LSLR external crews, (see Table III.D-2) to achieve an 7.0% cumulative average replacement rate (or approximately 22 LSLRs daily).

Denver Water planned a conservative approach to the Accelerated Lead Service Line Replacement Program by setting the target replacement quantity at 5,250 lead service lines per year. Targeting a higher replacement quantity is more of a safety factor than a number adjustment to achieve compliance of 7.0% cumulative program year average replacement rate. For the LRP and ALSLR Program to be successful, confirming the number of lead service lines and where the lead services are located is paramount. Starting the Program with a 15% safety factor (4,477 vs 5,250 LSLs) for the targeted program year LSLR will provide a compliance buffer of 773 LSLs. This buffer gives the ALSLR Program the ability to manage unforeseen situations that may occur in the first few years without missing the regulatory compliance goal. Additionally, the higher targeted replacement volume will help the Program not rely on other programs to provide support on LSLR and reduce potential effects of other elements (such as inclement weather and foreseen planning issues) to influence the annual replacement totals.

Table III.D-2. 15-Year LSL Replacement Resource Summary

			No. of Crews*

[1] Reference Figure III.D-D. Non-Copper Service Line Replacement Scenarios for examples of acceptable partial LSL replacements.
[2] Reference Appendix IV.A.

Estimated LSL Inventory	Annual Replacement	Total Daily LSLR	LSLR/day per Crew	LSLR/day per Crew	LSLR/day per Crew	LSLR/day per Crew
	7.0%	200 work days	2	2.5	3	4
80,000	5,600	28	14	11	9	7
75,000	5,250	26	13	11	9	7
65,000	4,550	23	11	9	8	6
63,955	4,477	22	11	9	7	6
55,000	3,850	19	10	8	6	5

*Based on experience from Denver Water as well as other jurisdictions, a single crew can replace between 2 and 4 LSLs per day.

In the following sections, the ALSLR Plan will use the annual replacement target of 5,250 as the basis of calculations and resources required to meet the 7.0% cumulative program year average.

Overview of Other LRPs from Other Jurisdictions

Introduction

Denver Water reviewed the experience of other jurisdictions who replaced lead services in their water systems and the associated lessons learned helped guide the development of the proposed ALSLR Plan's contracting and procurement strategy, including the anticipated LSLR rates, delivery delays, and risks.

The previous LRP's experience was gathered from the City of Flint, Pittsburgh Water and Sewerage Authority, and Detroit Water and Sewerage Department based on AECOM's experience working with these water systems as well as information that is publicly available. The City of Flint, under an Emergency Order, replaced approximately 18,000 LSLs from December 2017 to January 2019. The Pittsburgh Water and Sewerage Authority, under an Administrate Order due to multiple Action Level (AL) exceedances, is mandated to replace 7.0% of approximately 14,000 LSLs per year from June 2017 to December 2019. Per the July 2018 Michigan Department of Environment and Quality Lead and Copper Rule, the Detroit Water and Sewerage Department needs to replace more than 125,000 LSLs at a replacement rate of 5.0% per year. Key lessons learned in terms of procurement, describing the scope and responsibilities of all parties to the LRP, and defining the process and steps involved with replacing the LSLs (see Table III.D-3). A preliminary list of potential risks to delivery are summarized in Table III.D-4, based on experience gained from other jurisdictions when replacing lead services on the order of 1000s per year.

Table III.D-3: Lessons Learned from Other Jurisdictions – Procurement, Contracting, and Scoping the Work

Item No.	Description
1	Provide a standard process and expectation related to invoicing when working with multiple contractors (one form for all contracts, offset invoice submittal schedule, enough back up provided with invoice). *Why? This will expedite accurate budget status reporting*

2	Delineate the roles and responsibilities regarding the Contractor and Client Representative communicating any aspect of LSLR work to Residents and ultimately to the regulatory agencies, consistent with the COE Plan. *Why? This will improve the effectiveness of the COE Plan and the overall LRP.*
3	Determine who will perform restoration efforts and describe scope in the Contract Documents accordingly. Consider hiring a separate contractor to be responsible for the restoration work, such that the LSLR crew is not responsible for any external restoration activities such as curb and gutter, landscaping (including turf), hardscaping, or sidewalk modifications, including: (1) filling any excavations on private property with removed soils (2) placing sod, concrete sidewalks and any concrete hardscaping in the public right of way (ROW) (i.e., in small sections of driveway) (3) completing final street paving, sidewalk replacement, and sod after the work order is completed. *Why? This promotes more efficient restoration work process and delegates the task a Contractor more specialized in this type of work. Note that Denver Water's current policy is to provide external restoration only.*
4	Determine the timelines and means and methods to communicate with the Property Owner (and Residents, if not the same) all aspects of the LSLR process. For example, the Client Representative should mail agreement packages to the Property Owners at least 45-days ahead of replacement. Details to be finalized in coordination with the COE Plan. *Why? This will inform the Property Owner of work to come and how they can prepare the property for the work. This will also allow the work to be performed efficiently, avoiding delays to obtain consent on the day of work.*
5	Describe expectations of the Contractor and Client Representative with respect to conducting Property Owner coordination meetings. The purpose of this meeting is to review the work process and potential restoration needs. Details to be finalized in coordination with the COE Plan, *Why? Supports maintaining the customer's trust in Denver Water while allowing the work to proceed efficiently.*
6	Allow one construction inspector (CI) per crew to keep up with reviewing the scope of work being performed, collecting the data necessary, and completing the daily paperwork. Communicate this expectation to the contractors bidding the work. *Why? Having adequate CIs will ensure work is accurately documented and uploaded to the lead service inventory in a timely fashion.*
7	Delineate roles and responsibilities for the Contractor and Construction Manager (CM) in the Contract Documents for who does what with respect to obtaining consent, flushing the service line post LSLR, and distributing filters etc. *Why? This will provide more transparency of expectations and accuracy during the procurement process, while reducing costs, protecting public health, avoiding duplication of effort and improving efficiency and quality of the LRP during execution*
8	Make mandatory the pre-bid conference to prevent excess time spent on RFP questions and unrealistic bids. *Why? Manages effort involved to procure the construction contracts*
9	Define the scope of work to attract companies that have the capability to operate with multiple crews simultaneously *Why? To improve consistency of the work while reducing the level of effort to manage all the Contractors.*
10	Demonstrate that contractors are qualified to perform the work. Contractors should be required to provide examples of projects with similar scale and scope to qualify for bidding. Unqualified contractors have shown that the critical schedules cannot be met, and the quality of work performed is lacking. *Why? To improve the quality of the work, to deliver on KPI expectations particularly related to budget and schedule.*
11	Manage the number of LSLR sites included in a work order (i.e., 200 to 500 addresses). *Why? Optimizing the Contractor's amount of work will lead to better management of their work load and*

	quality of work. This also allows the Program to be responsive to changing field conditions. The range of sites included in a work order will be determined during the annual ALSLR planning exercise.
12	Establish the needs for master plumbers to a) connect the service line to the water main, b) install water meter boxes where needed, and/or c) inspect the meter box installation as part of developing the contract documents. Require bidders to carry to master plumbers. *Why? Inadequate staff of plumbers could delay meter installs and leave Property Owners without water.*
13	Ease the evaluation of contractor bids by assuming that at least two full LSL replacements are completed per day per contractor crew. This is an average used for bidding purposes. If a crew works a 10-hour day, an average value of four LSL replacements will be completed per day. *Why? This will aid in the evaluation of bid pricing, assess level of effort bid, and determine how many crews are needed to meet the targeted rate of annual LSL replacements.*
14	Have Contractors be responsible for documenting conditions at a property before the work commences, using photographs with notes. This will then provide the basis of any customer questions about the work. *Why? This puts the onus of documentation (or proof) on the Contractor and reduces risk to the Owner.*

Table III.D-4: Lessons Learned from Other Jurisdictions – Delivery Risk

Item No.	Description
1	Large programs need protocols for reporting and tracking data in a consistent and timely manner that allows for QA review. Although it is reasonable to expect changes to data handling will occur over the life of the Program, managing these changes to reduce the risk of delays and potential claims is recommended. *Why? To promote quality and timeliness in data handling while providing some degree of consistency to the contractors with respect to executing the scope of the work.*
2	Strategies to promote continuity over the life of the Program should be built into the ALSLR Plan and LRP in general. For example, having a mechanism that promotes for knowledge transfer as staff assigned may change over the 15-year life of the program. *Why? To realize program efficiencies year-over-year and supporting the Learning-by Doing element of the LRP. The intent is to reduce the impact of delays or inefficiencies when transitioning from one year to the next.*
3	Know the stakeholders involved and collaborate work with them to earn support for the LRP in general. Manage stakeholders through the COE Plan. *Why? The LRP will benefit from stakeholder input and proactively managing this will limit the potential for surprises.*
4	The success of the ALSLR Plan depends on participation of the property owner (and resident if not the same person) and as such the number of replacements that can be completed each year depends on earning consent from the property owner as well as the resident performing certain actions. Coordination with the COE Plan and clear protocols for multiple opportunities to communicate with the property owner and residents need to be developed. *Why? Poor participation rates could make it challenging to meet the annual target for LSL replacements.*
5	With multiple capital programs operating in the neighborhoods, coordinating schedules among the various programs for water main, road work, or other infrastructure improvements will reduce the potential inconvenience to residents in addition to realizing schedule and cost savings. Annual planning efforts for the ALSLR Plan would benefit from incorporating schedule considerations from these other infrastructure programs. W*hy? This will demonstrate project organization to the Property Owners and reduce potential Property Owner complaints for extra work being performed.*

The proposed procurement strategy, contract documents to support the ALSLR Plan and the associated procedures that the work will follow are being developed based on the lessons learned from other jurisdictions and feedback received from area contractors at Industry Day and Pre-Qualification meetings.

Finding Lead and the Predictive Model

Introduction and Overview

Planning the annual lead service replacement locations and achieving the annual replacement numbers depends on knowing where lead services are in the system, so that replacement can be planned based upon:

- Individual premises with historic lead levels above 15 ppb and/or demographic risk; and
- Geographic areas with cumulative opportunities to reduce lead exposure.

As Denver Water updates its Lead Service Line Inventory (see section III.B), probability models can be used to predict where lead is likely to be found before proceeding with LSLR at a particular property. As further described in the Appendix III.B.3 (Predictive Model and Prioritization) and briefly described herein, the probability of a service line being constructed of lead will be incorporated into ALSLR planning efforts using the current service line categories as shown in Table III.D-5. To implement the ALSLR Plan, a list of properties on which to act must be extracted from the inventory on a regular basis (annually or more frequently). Actions on properties will be determined based on service line category. The service line categories and action groups in Table III.D-5 are based on the current model predictions.

Under the LRP Phase I inventory model, properties identified to have suspected or possible lead service lines will be enrolled in the Filter Program and provided with filters that are NSF certified for lead removal. Properties within LSLI Groups A and B (known, suspected, or possible lead service line, see Table III.D-5) are the focus of the ALSLR Plan as further described below. The properties with a suspected or possible LSL (Group B) will be subject to additional investigation methods and LSL replacement, if confirmed to be lead. The investigation methods will consist of either water quality sampling and/or potholing as necessary (in that order) to confirm service line material. A desk-top review will be performed along with COE as necessary on select properties unlikely to have a lead service. Frequent reviews of properties in the Predictive Model will be conducted to identify changes in Property's service line assumption category. Desk-top and field methods will be applied to the Group A and Group B properties to determine whether or not a lead service exists, with the intention of either replacing the LSL (if lead is confirmed) or removing the property from the Filter Program (if no lead is confirmed). The phased investigation methods are summarized in Table III.D-6 and were designed to answer the question "does the predictive model make sense" when assigning service line categories to properties. Details will be refined as the predictive model is used with subsequent updates to the LSLI each year.

Table III.D-5. Service Line Category and Actions

Group	Service Line Category	ACTION AND RESPONSES		
		Filter Program	Lead Inventory	ALSLR Program
A	Known lead service line	Provide Filter	Add to lead inventory as confirmed lead	1. Add to list for replacement 2. Remove from inventory / Filter Program through replacement
B**	Suspected and Possible lead service line	Provide Filter	Confirm materials (per Table III.D-6)	1. Add to list for replacement 2. Remove from inventory / Filter Program through replacement
C	Unlikely lead service line	Desk-top review / COE as necessary / Review Predictive Model output regularly for change in service line material assumption		
D	Confirmed to be lead-free	COE		
E***	Other (fire lines, recycled water taps, consecutive system)	No Action / COE		

*Table was developed using information in Appendix III.B.2 (Preliminary Identification of Lead Service Lines) and Appendix III.B.3 (Predictive Model and Prioritization).

(**) Water Quality sampling will be used to confirm the service line material for properties found in Group B.

(***) Inclusion in Group E is based on an application process, not likelihood of lead. Service lines will be maintained in the inventory. Should the application change in the future, COE material will be provided that indicates the water supply is not a suitable source of drinking water.

Table III.D-6. Summary of Phased Investigation Process

Service Line Category (probability value of lead service line)	Sequence of Investigation Method	Comment
Known or Suspected lead service line (≥ 0.8)	Confirm lead as part of replacement planning	For a property with a probability value of 0.8 or higher, the property is treated as if there is a known lead service with an investigation as part of the replacement activities.
Possible lead service line (≥ 0.5 to < 0.8)	These properties will be provided with a filter that is NSF certified for lead removal in year one of the LRP. During year one, Denver Water will perform additional work to update the probability value determination and categorization of the property as having a known lead service line or non-lead service line. o For example, a property with a probability value of 0.7 or higher* will first be subjected to a visual inspection, following by potholing, and if necessary, excavation to confirm the service line material. o For example, a property with a probability value of 0.6 to 0.8*, the data used to determine the p-value will be reviewed, followed with water quality sampling and contact with the property owner to understand the history of upgrades to the property.	Denver Water will focus on investigations independent of lead service line replacements to build back-log for the ALSLR Program in subsequent years and confidence in the Predictive Model.
Unlikely to have a lead service line (< 0.5)	Review historical data used to determine the probability value: does the data make sense and can outliers be explained? o If not, follow-up with water quality sampling to assess likelihood for finding lead o If water quality sampling results are inconclusive, visit the property and conduct visual assessment and contact property owner to understand history of updates to the property, if any If still inconclusive, proceed to more invasive field inspections, starting with potholing.	Where a low probability value is determined for a property that appears to be an anomaly in a street or neighborhood with known lead services, Denver Water will review the factors that contributed to the probability value determination and escalate investigation as needed to confirm the presence of lead or non-lead.

(*) Indicates that the probability values are subject to change as the inventory is better detailed.

Preliminary 2020 ALSLR Plan for Discussion Purposes

The 2020 ALSLR Plan will focus on Groups A and B as outlined in Table III.D-7. Within each of these Groups, Denver Water has categorized three LSLR Groups by various types of LSL properties' conditions (Table III.D-7); Geographic LSLR Area, Individual LSLR, and Investigations of LSL types. The estimated number of LSLRs used in the 2020 ALSLR Plan is 5,250 LSL and is based on the August 2019 estimate of 63,955 LSLs with a 15% safety factor. The LSLR volumes in each category will be further developed as the LRP matures over the next 2 to 4 years and as the predictive model is

better calibrated using the Group B investigation results as well as information from Group A replacements.

Table III.D-7. 2020 ALSLR Plan Summary

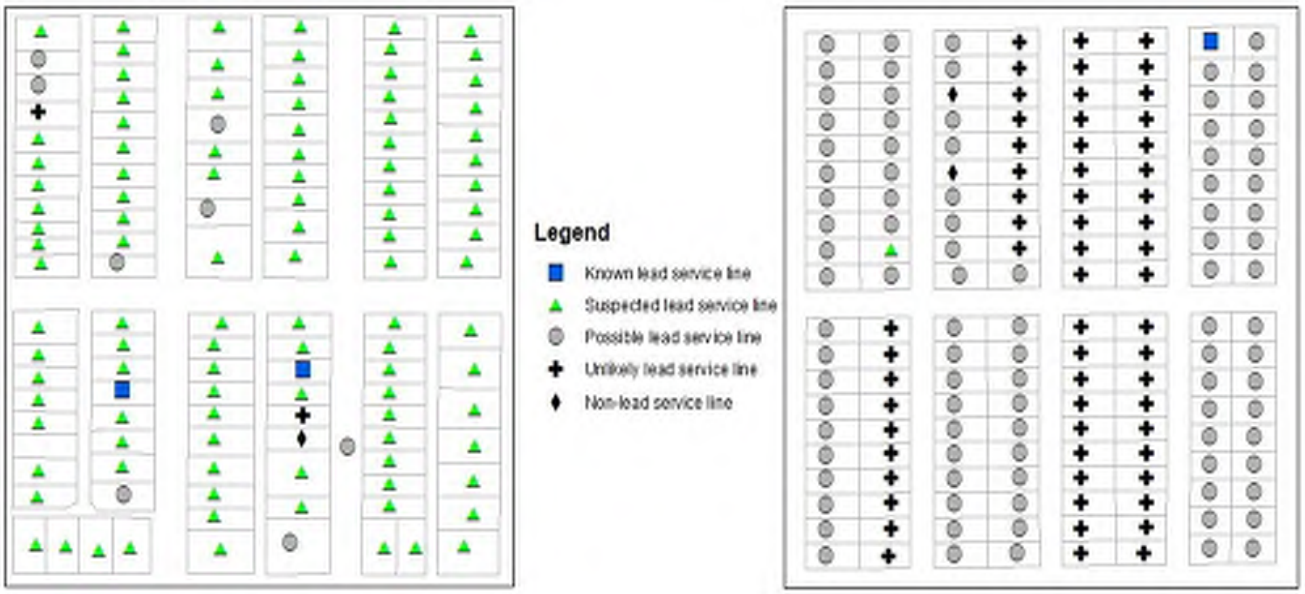
Group/Type		Est. Annual LSLR & LSL Investigation	Group Subtotals for Est. Annual LSLR and LSL Investigation
GROUP A – LSLR by GEOGRAPHIC AREA	Water main Replacement	400	
	Block by Block or Street by Street	3,000*	
	Municipal Pavement and Road Improvement Programs	450*	3,850*
GROUP A – LSLR by INDIVIDUAL	Leaks	300	
	Individual & High Priority LSLR	600*	
	Scrape Off and Redevelopment Properties	500	1,400*
GROUP B - INVESTIGATION	Investigations for areas with suspected and possible LSL	500*	
	Water Quality Testing of areas with expected or somewhat expected to have LSL	1,500*	2,000*

(*) asterisk indicates the values are subject to change.

A geographic depiction of an initial 2020 ALSLR Plan is presented below to provide an example of how the predictive model will be used to help plan the work. The example below incorporates the estimated ALSLR and LSL Investigations in Table III.D-7 (to be updated per the LSLI). In general, the Geographic Area defined by Group A (known lead) is expected to have higher per day of LSLR rates resulting from reduced effort for mobilization/demobilization while Individual LSLRs will have a lower LSL replacement rate as the result of greater efforts needed for mobilization/demobilization across an expanded geographic area. The ALSLR Plan will incorporate individual LSLRs within the Geographic Areas when located near each other and it is practical to do so.

The Geographic Area map of Figure III.D-A integrates various prioritization and risk parameters to allow the criticality of geographic areas to be ranked; this in turn is used to determine the highest priority areas to plan for a given program year's ALSLR inventory to be addressed.

Figure III.D-A. Geographic Area (left) and Individual (right) Map Visual Representation



An example of Geographic Area LSLRs (left-side) from Group A (known lead) are shown above in Figure III.D-A. As an example, the blue (square), green (triangle), and grey (circle)colors (symbols) reflect known lead, suspect lead, and possible lead service lines, respectively. The properties, shown on the right-side map, are individual LSL properties identified in a predominately non-lead area. The properties were recognized as a high risk based on prioritization parameters that use a consequence risk analysis. Individual properties may not be in highly concentrated areas like in the geographic areas. A separate ALSLR strategy is developed for Denver Water to mobilize LSL replacement crews to address these high-risk individual properties since the level of effort will not be comparable to LSLRs in the Geographic Area model. However, the impact of replacing these Individual LSLs is just as important in terms of public health.

Properties types targeted for Individual LSLRs include:

- multi-family units,
- daycare centers,
- private schools*, and
- health facilities.

These property types have a broader impact on Denver Water's customer base because their service lines provide clean drinking water to more than a single-family or customer.

*Service lines at all Denver public schools have been replaced.

A prioritization parameter, for both Groups A and B, is municipal (infrastructure) project data (i.e., planned project locations and times) which is used to aid in determining key areas to perform work, whether it's pavement restoration or water main replacement. Incorporating these municipal projects into the ALSLR work is key because of the ability to reduce disturbances to Property Owner's, reduce project costs, and facilitate service line material investigations.

Accelerated Lead Service Line Replacement Plan

Denver Water Lead Service Line Standards

Denver Water has years of experience executing LSLRs both as part of water main replacement projects as well as at individual properties. Denver Water plans to utilize their existing lead service line replacement design standards to act as a guideline for LSL replacement process completed under the ALSLR Plan. The Denver Water LSL standards state that lead service lines shall be replaced with copper service lines, provided that Denver Water is given consent by property owners. Denver Water's

goal under the ALSLR Plan is to replace all non-copper (lead or galvanized downstream of lead) service lines from the water main to the first fitting inside the residents dwelling. The ALSLR Plan goal is to replace LSLs at a cumulative program year average replacement rate of 7.0% throughout the 15-year program.

To achieve this goal, the ALSLR Plan will require close coordination among the Filter Program, Approvals/Permits, COE Plan activities, LSLI and predictive modeling tasks, and the various stakeholders during the full life-cycle of the LSLR process. Denver Water's continued proactive approach to LSLR will require activities to be closely coordinated during three phases of the LSLR: Pre-Construction Phase, Construction Phase, and Post-Construction Phase.

ALSLR Pre-Construction Phase

The Pre-Construction Phase uses the predictive model's biannual identification of Group A and B LSL replacements and investigation of properties (see Table III.D-8), based on the hierarchical approach described earlier. These properties classified in Group A and B categories will be the focus of the ALSLR. The properties included in Group A are to be replaced in the given year based on a geographic or individual approach. The Group B properties are scheduled for investigation of the service line material type in a given year. The investigation process will require potholing and/or water sampling to determine the expected material type of the service line. If any part of the service line material is verified as lead, the properties service line information will be updated in the LSLI. The properties will be allocated to the appropriate ALSLR Group for replacement in the future. If the service line material is verified as copper, then the service line information will be updated in the LSLI, and the properties will be removed from the LSLR list. The property information will be used by Denver Water to obtain the necessary permits and approvals from the respective agencies to conduct LSL replacements. The COE Plan describes how to inform property owner (and residents, if different) of the upcoming LSL replacement. Concurrently, the Filter Program will coordinate with the resident(s) to ensure the filter devices are made available and being used.

Denver Water's current LSLR program has a standard communication timeline. The Denver Water timeline illustrates the responsible parties and specific times before, during, and after construction when Denver Water staff must contact Property Owners. The Denver Water communications outline for LSL replacement (see Figure III.D-C) will act as the foundation with updates as necessary for the larger Denver Water ALSLR Pre-/Post-Construction Property Owner Communication Timeline.

Trained program staff will distribute and collect signed Resident Consent forms to perform LSL replacement, and conduct with consenting residents a detailed explanation of the work to be performed and address any questions residents may have. A LSLR Contractor will then proceed to verify the service line material prior to starting LSLR work. Pre-Construction activities are designed to enhance the LSLR rates through earlier identification of lead services at properties with unknown service materials. Furthermore, Denver Water will document pre-construction conditions (exterior and interior) for all properties consenting to LSL replacement.
In summary, this delivery process with the associated plans overview, objectives, and metrics being measured are described in Table III.D-9 and are intended to lay the ground work for successful LSL replacement through close collaborations with all LRP elements.

Table III.D-8. LSLR Contracting Groups Summary

LSLR Groups	Descriptions
Group A (Known Lead) - Geographic LSL Replacement Area	**Water main Replacement -** Confirm service line material and replace LSLs concurrently with water main replacement projects.
	Block by Block or Street by Street - Confirm service line material and replacement of LSLs on Blocks or Streets. These are LSL replacements that are confirmed to have a partial- or full-lead. High priority properties will be integrated via the prioritization model. For more details, see the Appendix III.B.3 *Predictive Model and Prioritization*.
	Municipal/Transportation/Pavement Improvements - Confirm service line material and replace LSLs in coordination with Municipal, Transportation, and/or Pavement improvement projects.
Group A (Known Lead) - Individual LSL Replacement	**Individual and High Priority** - Confirm service line material and replace LSLs for properties providing water to day-cares, schools, nursing, jails, dialysis and critical customer facilities. Properties are known to have high lead concentrations (> 15 ppb) and consequence (depending on risk factors).
	Redevelopment and Scrape Offs - Confirm service line material and remove existing LSLs. Developer to install new service line and tap.
	Leaks - Confirm service line material and replace LSLs jointly with Denver Water's service leak repair projects.
Group B (Suspected or Possible Lead) - LSL Investigation	**Investigation** – Potholing and/or water sampling LSL inventory with a relatively high probability of lead classification (possible or suspected, $p \geq 0.5$). Work is to be performed separately from LSL replacement contracts. Intent is to verify if service lines are lead or non-lead.
	Declined Consent Investigation – If Resident Consent is declined, the service line material to be verified will be listed in the LSLI as not verified and placed on a list of non-consenters and supplied to Denver Water legal department. (TBD per Approved Non-Consenter Policy)

Figure III.D-C. Denver Water's Communications Outline for LSL Replacement

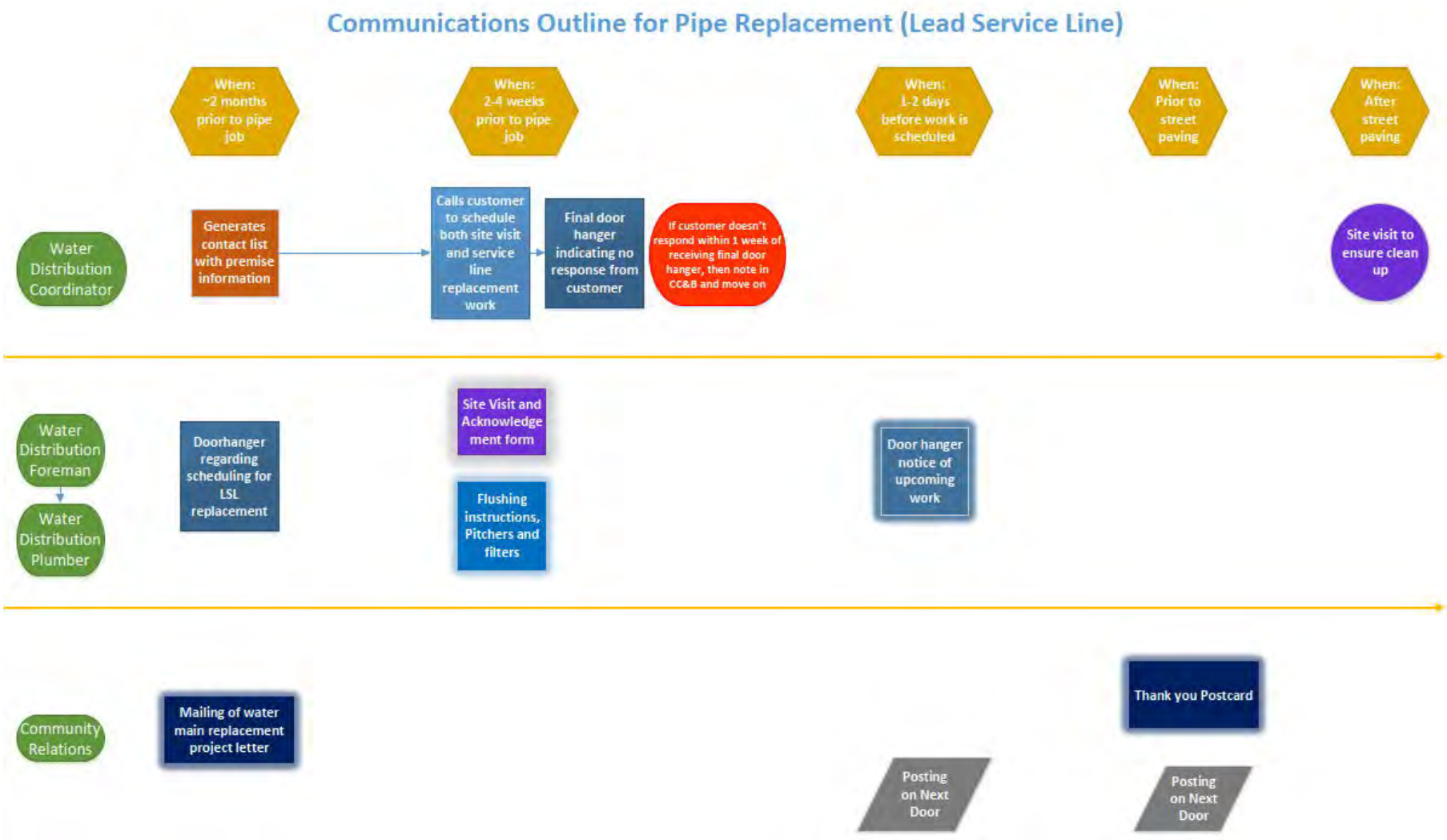


Table III.D-9. LSLR Pre-Construction Components

PREDICTIVE MODEL	APPROVALS / PERMITS	COE ALSLR PLAN
OVERVIEW		
The predictive model uses the lead service line inventory to annually plan the works schedule for Group A (Geographic and Individual LSLRs) and Group B (LSL Investigations) using a hierarchical approach as described above in Table III.D-8. The Group B properties will consider field investigation results.	Obtain the necessary approvals, permits, and documentation prior to ALSLR work, including local governments, property owners and residents with a known, suspected, or possible LSL. The Resident Consent Form is an important approval and the protocol to engage the property owner and resident is described in the COE Plan.	The COE ALSLR Plan will engage public stakeholders and residents in seeking customer/resident approvals to move forward with LSLR. Program representatives will work closely with all public stakeholders and residents/customers to perform the necessary COE activities. The COE Plan describes up to three touch points with residents to confirm and obtain Resident Consent Form Approval. Efforts will be coordinated with the COE team.
OBJECTIVES		
• Define annual ALSLR Plan. • Categorize replacements into ALSLR work groups: Investigation (green), Per Area (blue), and Individual (orange) • ALSLR work groups will act as the basis for Contracts o *Per Geographic Area* will be completed in a Block by Block or Street by Street manner. o *Individual* will include single LSLs in non-concentrated area and locations at properties determined to be of high lead potential and consequence. o *Investigation* will classify services based on likelihood (suspected or possible) that line is lead that requires confirmation. • Improve calibration of the predictive model as service line materials are confirmed; update predictive model twice a year. • Maintain independent LSL Investigation Contracts to support year-over-year planning by eliminating uncertainty of lead service line materials. o If service line is verified (potholed) to be lead, after Property Owner consent is received, it will be re-allocated to the appropriate ALSLR work group. o If Property Owner consent for investigation is declined, the service line material to be verified will be listed in the LSLI as not verified and placed on a list of non-consenters and supplied to Denver Water legal department. ((TBD per Approved Non-Consenter Policy)	• 8 Weeks Prior to Construction (timing to be confirmed): o Apply for necessary permits (CC&B, Municipality Traffic Control Plan, Tree Protection, Stormwater Permit, Stormwater Management Plan, Dewatering Permit, Sewer Discharge Permit, Street Restoration Plan, Street/Occupancy Permit, and Regional Building Permit). ***Note:*** *Estimate of the permits needed, will vary by geographic location of service line replacements.* • 6 Weeks Prior to Construction: o Program schedules a coordination meeting with property owners and answers any questions. • 4-5 Weeks Prior to Construction: o Program holds a coordination meeting with property owners, performs a pre-construction site inspection, and determines the tie-in location of service line. • 2-3 Weeks Prior to Construction: o Contractor will contact Denver Water Sales Administrators to schedule a water main tap and survey the property for utilities. o Contract must verify any conflicts noted during utility survey prior to LSLR. • 2 Weeks Prior to Construction: o Program will follow-up with any non-responsive property owners to obtain consent to perform the LSLR. o If consent is declined by property owner, Denver Water will follow non-consent procedure.	• 45-Days Prior to ALSLR Construction: o Mail LSL replacement project letters and consent form to the property owners (in their first language). • 4-5 Weeks Prior to Construction: o Program places signage in the geographic area for reminder of LSLR work to be performed. • 2-3 Weeks/Days Prior to Construction: o Program distributes informational door hangers. o Follow-up with property owners to address any uncertainty about the upcoming work and confirm they have signed the Resident Consent Form. • 1 Day Prior to Construction: o Provide 24-hour water outage notice in advance of LSL replacement.
METRICS		
The metric to assess performance is outlined in Appendix IV.A.	The metric is to obtain Approvals and Permits to achieve a confirmed ALSLR with a backlog of 4 Weeks of approved Resident Consent Forms.	The metric to assess performance is detailed further in Appendix IV.A.

TABLE III.D-9. LSLR Pre-Construction Components (Continued)

FILTER PROGRAM	ALSLR PLAN
OVERVIEW	
Customers with known, suspected, possible lead service lines will be automatically enrolled into the Filter Program and supplied with a filter kit and educational materials regarding use of the filter.	Activities will include confirmation that the Contractor has obtained the necessary approvals and permits, has all equipment and materials mobilized to the site, and is ready to commence with the ALSLR.
OBJECTIVES	
• 4-5 Weeks/Days Prior to Replacement: o Denver Water distributes additional NSF certified filters to remove lead, if required, during the property owner coordination meeting. • Denver Water to reinforce the message of continued use of the filters that are NSF certified to remove lead through six (6) months following LSLR.	• Contractor mobilization is complete and necessary plans, permits, and approvals are in place. • Safety Plans are in-place and Crews are briefed. • COE and Filter Plans have been reviewed. • Proactively obtain Resident Consent forms. • Contractor staff trained on how to engage with the public, who to contact for help, how to safely enter a property, etc. • For properties where consent for the LSLR is not earned, the property will be placed on a list for follow-up and CDPHE notified.
METRICS	
The metric to assess performance is detailed further in Appendix IV.A.	The metric to assess performance is detailed further in Appendix IV.A.

ALSLR Construction Phase

Once the Pre-Construction Phase activities have been addressed, the ALSLR Contractor will proceed to replace LSLs per the contracting model (see Table III.D-8). The Construction Phase focus is to replace lead service lines that are known or have gone through an investigation process that has confirmed the presence of lead service lines and/or galvanized downstream of lead. The investigation process is conducted using the progressively calibrated predicative model. Based on the determination, the Program will actively work with property owners to replace the lead service based on Property Owner/Customer approval of the Resident Consent Form. The different possible insitu lead service line configurations are shown in Figure III.D-D.

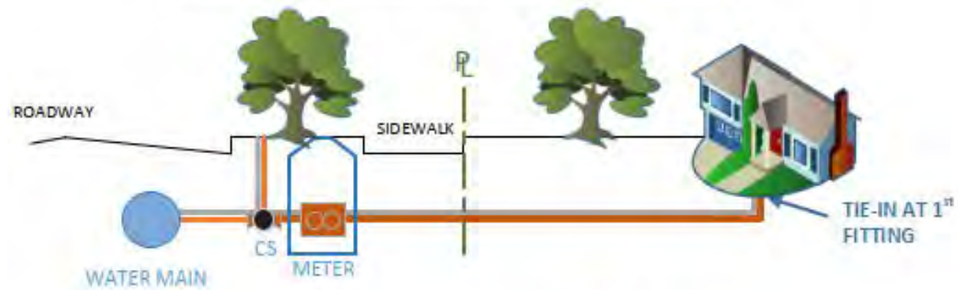
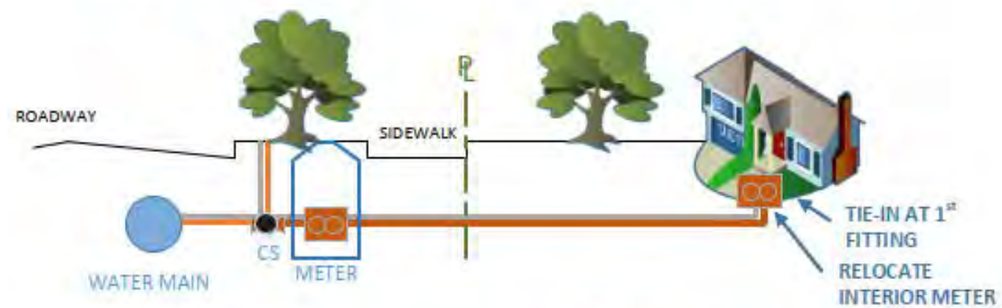
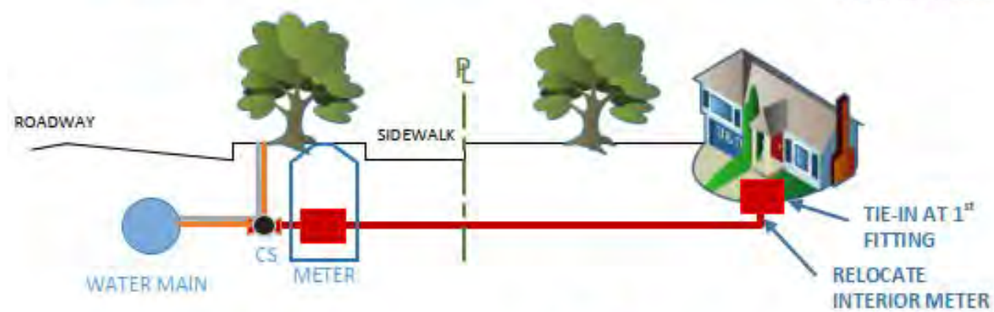
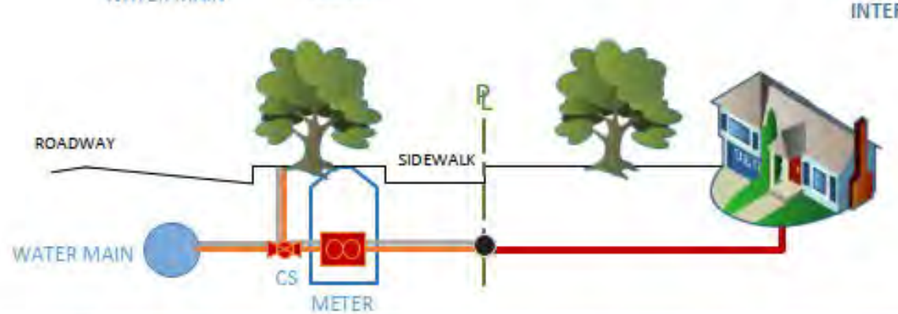
Denver Water will use the configurations of Figure III.D-D to document the level of LSLR and report the LSLR credit toward the total number of replacements completed each program year. In addition to the full replacements illustrated in Figure III.D-D, Denver Water may have a unique scenario that requires only partial LSLR. When Denver Water replaces water mains, the existing service line will need to be transferred from the old water main to the new water main. This LSLR activity provides Denver Water the opportunity to replace Property Owners service lines. If the existing service line at the water main is identified as lead, Denver Water will request resident consent to investigate the service line's material up to the first fitting inside the dwelling. However, if the property owner does not consent to having their lead service line replaced, Denver Water will only replace the LSL up to the meter regardless of the service line material from the meter to the first fitting inside the dwelling. This will not be considered a partial replacement, and it will not contribute to the cumulative program year average 7.0% LSLR.

During construction, Denver Water's Construction Inspectors (CIs) will provide field quality assurance and quality control (QA/QC) oversight for the work being performed by contractors to ensure compliance with the Contract Documents and Specifications. LSL replacement work will be overseen in the field by CIs; and the Project Engineers will review the LSL replacement data submitted, by the CI or Contractor, based on the work completed in the field. The Project Engineers will review the LSL replacement data or any reports, to ensure it is correct, before including it into the LSLI database for use by the Predictive Model.

ALSLR Post Construction Phase

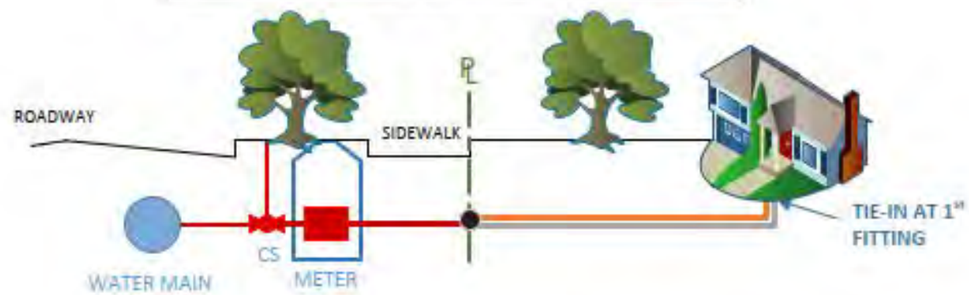
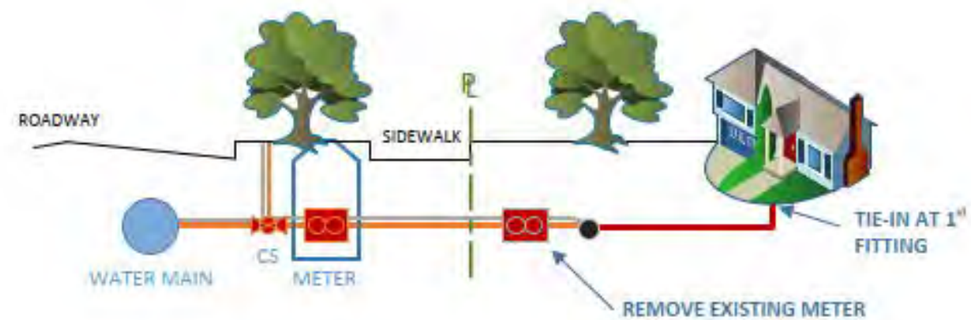
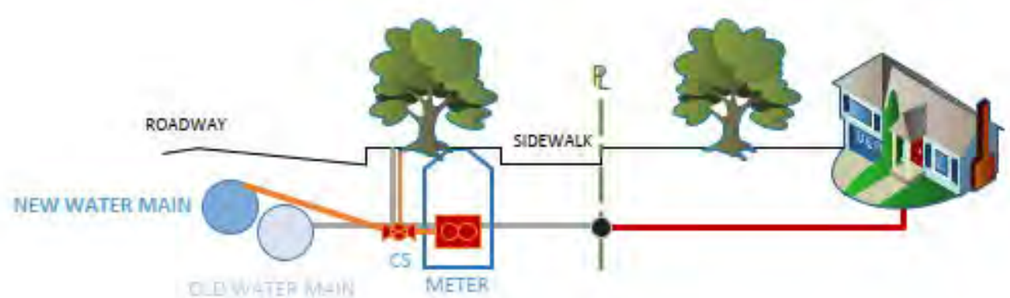
Once the LSLR has been completed through the Construction Phase, the ALSLR will move forward to the Post-Construction activities to ensure the new copper service line is ready for use per AWWA/ANSI Standard C810-17 (Standard C810-17) for Replacement and Flushing of Lead Service Lines. Upon completion of the flushing procedures and water quality testing, the property's results of LSL replacement will be recorded and stored in the appropriate data management system. The Post-Construction Phase activities are further highlighted in Table III.D-10 for each component of the LRP.

Figure III.D-D. Non-Copper Service Line Replacement Scenarios

SCENARIO TYPES	SCENARIO ILLUSTRATIONS	SCENARIO DESCRIPTIONS
Full LSLR with Exterior Meter		1. Replace lead service line (LSL) from the water main to the 1st fitting inside the building with copper. 2. Install new tap on water main. 3. Install a new meter and meter box in the Public Right Of Way (ROW). 4. Remove and install new curb stop (CS).
Full LSLR with Interior Meter		1. Replace lead service line (LSL) from the water main to the 1st fitting inside the building with copper. 2. Install new tap on water main. 3. Relocate the existing meter from inside the building. Install a new meter and meter box in the Public Right Of Way (ROW). 4. Remove and install new curb stop (CS).
LSLR at Curb Stop with Interior Meter Relocation		1. Replace lead service line (LSL) from the water main to the curb stop. 2. Install new tap on water main. 3. Relocate the existing meter from inside the building. Install a new meter and meter box in the Public Right Of Way (ROW). 4. Remove and install new curb stop (CS).
LSLR in Public ROW with Exterior Meter		1. Replace LSL from the water main to the property line with copper. 2. Install new tap on water main. 3. Remove and install a new meter and meter box in the Public ROW. 4. Remove and install new CS

LEGEND: EXTENT OF EXISTING LEAD OR GALVANIZED DOWNSTREAM OF LEAD — EXTENT OF EXISTING COPPER — EXTENT OF REPLACED COPPER — TIE-IN TO NON-COPPER EXISTING SERVICE

Figure III.D-D. Non-Copper Service Line Replacement Scenarios (Continued)

SCENARIO TYPES	SCENARIO ILLUSTRATIONS	SCENARIO DESCRIPTIONS
LSLR with Lead Service on Private Property		1. Remove LSL from the property line to the 1st fitting inside the building with copper. 2. Tie-in new copper service on private property to the copper service on the public property.
LSLR on Public and Private Property with Exterior Meter Relocation		1. Replace LSL from the water main to the 1st fitting inside the building with copper. 2. Install new tap on water main. 3. Remove and install a new meter and meter box in the Public ROW. 4. Remove and install new CS.
Water Main Replacement without Consent		**Consent not given by Property Owner to replace LSL during Water main Replacement Project:** 1. Replace LSL from old water main to the meter. 2. Install tap on new water main. 3. Remove meter and install new meter with copper service line. 4. Remove and install new CS. 5. Inform Property Owner that non-consent will result in a Lien on the Property's Title.

LEGEND: EXTENT OF EXISTING LEAD OR GALVANIZED DOWNSTREAM OF LEAD — EXTENT OF EXISTING COPPER — EXTENT OF REPLACED COPPER — TIE-IN TO NON-COPPER EXISTING SERVICE

Table III.D-10. ALSLR Post-Construction Components

PREDICTIVE MODEL	APPROVALS / PERMITS	COE PLAN	FILTER PROGRAM	ALSLR PLAN
OVERVIEW				
The LSLI will be updated with ALSLR information to reflect progress to refine the Predictive Model.	The approvals and permits must be closed out, once Group A - Geographic Area is complete.	Program team will notify the property owner of the water quality sample results and provide additional support as needed after the LSL replacement.	The Filter Program does not end with LSL replacement, Denver Water will deliver to the Property Owners the necessary information and materials to conduct a property plumbing flush and how to obtain a water quality sample.	Property Owners (Residents) will receive a new copper service line and restoration is completed.
OBJECTIVES				
• The LSLI database will be updated through ongoing reporting and provide the Predictive Model the necessary information to develop the annual LSLR program. • The LSLR crew rates will be documented to demonstrate the replacement rate of crews in the periodic LSLR progress reports. • Current year LSL replacements will be monitored to confirm Denver Water is meeting the cumulative program year average replacement rate 7.0% target.	• Once water service has been returned to the property owner, the Program will schedule restoration work to be completed on the property. • Provide list of properties where consent is denied to Denver Water legal department and CDPHE for follow-up. • Place/designate non-consent residents into Denver Water LSL inventory as noted for future follow-up.	• Program team to provide education materials to describe how and when to flush the home by the resident. • Program team to distribute water quality sampling kit, four (4) months after the LSL replacement. • Program team will inform the property owners of the water quality sample results for the four (4) month post replacement sample. • If water quality sample test result reveals lead level is high, the Program team will reach out to the property owner to provide additional education materials on how to identify potential sources of lead within the dwelling (plumbing), provide information on additional mitigation measures, and contact information for Community Organizations.	• Program team will communicate with the property owner with handouts to ensure the property owner understands the flushing and sampling programs that will be required post-construction. • Program team will continue to supply filter cartridges that are NSF certified to remove lead, as needed, up through six-months following the LSLR.	• Program team to perform 15-minute service line flush immediately after replacement. • Contractor commences restoration of the Resident's property to its pre-construction condition, which will be based on documentation obtained prior to construction. • Any non-salvageable materials generated from construction will be disposed of in accordance with the local regulations. • CI completes post-construction documentation (videos/photographs) of all areas restored.
METRICS				
The metric to assess performance is detailed further in Appendix IV.A.	• No outstanding Permits with municipalities. • Inspection approvals are received.	The metric to assess performance is detailed further in Appendix IV.A.	The metric to assess performance is detailed further in Appendix IV.A.	The metric to assess performance is detailed further in Appendix IV.A.

ALSLR Contracting Strategy

Introduction

Denver Water and other third parties have been replacing approximately 1,200 LSLs over the last few years. To meet the 7.0% program year ALSLR rate, Denver Water will contract with outside resources for the additional LSLR crews as discussed above. The proposed contracting strategy is to seek qualified local contractors to support Denver Water LSLR crews to meet the 7.0% program year ALSLR rate. The procurement strategy must consider approaches to the three LSLR groups discussed in Table III.D-8: geographic area, individual LSL, and LSL investigations. Denver Water will strive through planned Industry Day events to inform the Denver Metro contracting community of the LRP's goals, objectives, and resource needs. Through Industry Days and a qualification-based selection process, Denver Water will proactively identify a shortlist of qualified ALSLR Contractors and the number of LSLR crews needed to meet the planned replacement rate. Denver Water will use a pre-qualification approach to select qualifying contractors from the qualified contractors list, request price bids that will be used in selecting the most responsive and lowest cost contractors that can either individually or collectively provide the needed ALSLR crews to support in accomplishing the 7.0% ALSLR rate.

Overview LSLR Contract Types and Goals

The different LSLR groups and contract types from Tables III.D-7 and III.D-8 will be categorized through the Predictive Model to guide the Program in the ALSLR planning and contracting strategy. Based on these LSLR groups and contract types, a rough order of magnitude (ROM) estimate was developed for the annual LSLR volume for each of the main LSLR Groups supported by each sub-group category as shown in Table III.D-11. The estimated annual LSLR targets were defined using present Denver Water replacement rates and those from other jurisdictions. The 2 LSLR crew replacement rate selected ensures Denver Water will achieve the goal of 5,250 LSLRs per program year. Group A utilizes this replacement rate. Estimated annual LSLR volumes (with an asterisk) are determined from historical data, while LSLR volumes (with no asterisk) are estimated values assigned to each group type to meet the 7.0% cumulative average LSLR. The annual work days of 200 is used to determine the total number of annual LSLRs per group type. To maintain consistency with Table III.D-2, the estimated replacements per group type is set at 2 LSLRs per crew. The replacement rate used in the calculated volumes and rates consider production differences between LSLR crews per each group type due to the nature of the work. The difference in group type production efficiency is what attributes to the number of LSLRs per day minor differences. In summary, Denver Water will need approximately 13 ALSLR crews to achieve the 7.0% LSLR cumulative average. Scrape offs/Redevelopment Properties will be performed by their respective developers and hence, Denver Water will not be providing LSLR crews for this work. However, Denver Water through the collaboration with the City and County of Denver will define a SOP to work closely to monitor these activities and account for LSL being replaced.

Table III.D-11. ROM of Annual LSLR Volume Summary

LSLR Group Type		Est. Annual LSLR Completed	Est. LSLR/Day	Est. LSLR Crews	Pre-Const. Scope	Construction Scope	Post-Const. Scope
GROUP A - GEOGRAPHIC AREA	Water main Replacement	400	-	-	Coordinate, schedule w/ Denver Water, COE	Verify and Replace LSL	Filter, Flushing and Restoration Work
	Block by Block or Street by Street	3,000*	15.0	5	Permitting, COE	Verify and replace LSL	Flushing, Restoration Work
	Municipal Pavement and Road Improvement Programs	450*	2.25	1	Permitting, COE	Verify and Replace LSL	Filter, Flushing and Sampling, Restoration Work
	Subtotal	3,850*	17.25	6			
GROUP A - INDIVIDUAL	Service Line Leaks	300	-	-	Permitting, Notifications	Leak Repair Verify and Replace LSL	Flushing, Restoration Work
	Individual & High Priority LSLR	600*	3.0	2	Permitting, Notifications	Verify and Replace LSL	Flushing, Restoration Work
	Scrape Offs and Redevelopment Properties	500	-	-	Permitting, Coordinate with Property	Replace or Remove LSL Based on New Use	Filter, Flushing and Sampling, Restoration Work
	Subtotal	1,400*	3.0	2			
	Combined Total	5,250*	20.75	8			
GROUP B -INVESTIGATION	Field Investigations for areas expected or somewhat expected to have LSL	500*	5.0	1	Permitting, Notifications	Field Verify LSL	Restoration Work and Report Findings
	Water Quality Testing of areas expected or somewhat expected to have LSL	1,500*	-	-	Notifications	Obtain Water Quality of Property	Report Findings
	Total	2,000*	5.0	1 - 2			

(*) asterisk indicates the values are provisional and subject to change.
(-) hyphen indicates that these group types will be completed by internal Denver Water crews.

As shown above, Denver Water's Preliminary 2020 ALSLR Plan estimates approximately 5,250 planned LSLRs and does not include the Group B investigation category since no LSLR will be conducted as part of these investigations. Denver Water will use external contracted crews to staff up

to 13 ALSLR crews to meet the 7.0% cumulative program year average replacement goal. The Group B, Investigation category has not been included in the total due to the difficulty determining the number of non-lead service lines that will be encountered. However, the investigation category has been established to assist Denver Water in better understanding the LSL inventory that has been identified, via water quality testing or investigation activities, in areas of their system that are defined in Group B – suspected and possible to contain LSL. As discussed in the LRP, where contractors are conducting investigations only, if copper service lines are found, the lead service line inventory will be updated to reflect the copper service and be incorporated into the 7.0% compliance count. Residents in the Filter Program, found to have a non-lead service line, will be removed from the Filter Program.

Contractor Performance

In late 2019, Denver Water plans to solicit and shortlist qualified Contractors to support the ALSLR Plan. Denver Water will be seeking to identify a minimum of 16 LSLR crews or more as needed to conduct the ALSLR work in 2020. Denver Water reviewed two types of ALSLR contracting strategies;

- **Option 1 - On a single-year basis** - request price bids from the shortlist of qualified contractors to obtain the necessary qualified crews prior to the following program year (2020) ALSLR work. By awarding a finite quantity for each work type over a defined period, contractor performance can be monitored and if necessary, determine paths for improvement. This will allow Denver Water to reward the outperforming contractors with additional work during the contract period based on adjustments to their bid quantities and if necessary, unit price adjustments. The annual single year contract award will keep bid quantities and associated prices to a defined and manageable amount and scope. This will allow Denver Water the ability to manage the various aspects of the LSLRs and ensure the specific areas and needs are completed in a timely manner prior to moving to another location. This contracting process would repeat each program year by soliciting price bids from the qualified shortlist. Under the multi-year contract, task orders would be issued to the selected contracts for approximately 200 properties to help in managing the annual ALSLR program and if needed, to make adjustment during the program year.

- **Option 2 - On a multi-year basis** - request bids from the shortlist of qualified contractors to obtain the necessary qualified crews prior to the following program year (2020) ALSLR work. Denver Water will award the first-year (2020) contract to the most responsive and low-price contractor(s). The multi-year contract would have a two or three-year extension clause that would allow for annual unit quantities and price adjustments. The option for the subsequent program year's ALSLR work will be based on contractor performance: If ALSLR targets are not being met, the Contractor will be removed from the LRP. if it is determined that ALSLR targets are met, Contractors will be given the option to extend their contract for the next program years' work after successful negotiations on their unit prices. The multi-year contracts will continue with maintaining/updating bid quantities and associated prices to a defined and manageable amount and scope. This will allow Denver Water the ability to manage the various aspects of the ALSLRs and ensure the geographic and individual LSLR areas and needs are being addressed in a timely manner prior to moving to another location. Under the multi-year contract, task orders would be issued to the selected contracts for approximately 200 properties to help in managing the annual ALSLR program and if needed, to make adjustment during the year.

Denver Water favors Option 2 because of the flexibility in contracting and reduction in administrative costs to repeat the annual contracting and bidding process if not warranted. In addition, this will allow Denver Water the opportunity to adjust bid schedule unit prices (increasing or decreasing) which reflect competitively priced field tasks. In addition, this option will incentivize Contractors to perform at a higher-level of production and quality while meeting the overall LSLR goals. The incentive clause will consider three primary objectives; safety, quality, and replacement rates. Furthermore, within the first 90 days, Denver Water will use lessons learned for improvement and adjustment to the overall ALSLR

process. This multi-year approach will allow Denver Water the opportunity to make Contract Document adjusts prior to subsequent program years' work extensions or during the recomplete of new contracts.

Learning by Doing

Denver Water's business practice is founded on the philosophy of continual improvement and development as an organization. To that end, Denver Water will instill this philosophy through the Learning by Doing element of the LRP into the ALSLR Plan and the associated construction contracts. Bi-annually, the Learning by Doing approach will include Roundtable Partnership Meetings that will be conducted with ALSLR contractors to discuss and articulate lessons learned to promote greater safety, quality, LSLR crew efficiencies, and opportunities for improvement in all areas of the ALSLR Plan including being good neighbors in the community. The Learning by Doing approach will provide a sounding board for contractors to discuss opportunities for improvements that will help meet ALSLR objectives and provide a better understanding of issues that have arose during the program year (see Table III.D-12 for proposed discussion topics).

Table III.D-12. Learning by Doing Meeting Schedule and Proposed Topics

Meeting Type (Month)	Key Topics Discussion Items
2nd Quarter Review	Safety Review, Communications (between Contractor-Denver Water and Contractor-Property Owner), Delays (Field Issues), Risks, Data Management (Submittal of information), LSLR Process (Best Practices), Other
4th Quarter Annual Review	Safety Review, Communication, approvals/permits, filter, Contracting (Resources), Procurement (Unit Pricing), Replacement Rates vs. Target, Improvements to Contract & Specifications, Restoration, Data Management, Risks Review, Other Risks and Items not previously identified, Other

ALSLR Regulatory Performance Criteria

The LRP Plan is required to meet the basis of regulatory compliance by meeting the 7.0% cumulative program year average rate of replacement such that all known lead service lines are replaced within 15 years, For details please refer to Appendix IV.A, Proposed Terms and Conditions.

To evaluate the sensitivity of the calculation used to determine the cumulative rate of replacement for each program year, sample calculations were prepared Several scenarios were developed and analyzed to understand how different assumptions affect compliance and the performance of the 15 year Program, including:

- Maintaining baseline compliance replacement rates of 7.0% (baseline condition).
- Starting the Program above 7.0% replacement rates over the first half of the Program and decreasing the rate of replacement in later years of the Program (fast start, slow end).
- Completing the Program early by maintaining high replacement rates through a majority of the Programs life (early completion).
- Recovering the (cumulative program year average after with one year of poor performance (baseline plus one year poor performance).

- Starting the Program slowly with a 6.0% replacement rate in program year 1 and 6.5% replacement rate in program year 2, then maintaining the 7.0% replacement rate from program year 3 until the end of the Program (slow start).
- Poor performance (below 7.0% replacement rate) on multiple occasions in the first half of the Program to determine if it is possible to recover the cumulative program year average (failure condition).

It is evident from the results (shown in Table III.D-13) of the six scenarios that it is paramount that the Program maintain or exceed the 7.0% replacement rate. It is possible to recover from one poor performing year by exceeding the 7.0% goal for several years thereafter, but recovery after more than one year of poor performance is unlikely. Therefore, Denver Water will closely monitor ALSLR crews' performance throughout the life of the LRP and if necessary, make adjustments to address factors that hinder performance. It is anticipated that the Group A targeted rough order of magnitude LSLR volume for each type of group (Geographic and Individual) and number of crew estimates will evolve over the life of the LRP such that all known LSLs are replaced within 15 years.

Table III.D-13. Sensitivity Analysis ALSLR Performance Scenarios

Program Year	BASELINE CONDITION			FAST START/SLOW END			EARLY COMPLETION			BASELINE CONDITON + 1 YEAR POOR PERFORMANCE			SLOW START (YEAR 1 AND 2 MINIMUM) + BASELINE CONDITION			FAILURE SCENARIO		
	LSLR per Year	Average	Cumulative Average	LSLR per Year	Average	Cumulative Average	LSLR per Year	Average	Cumulative Average	LSLR per Year	Average	Cumulative Average	LSLR per Year	Average	Cumulative Average	LSLR per Year	Average	Cumulative Average
1	4477	7.0%	7.0%	5250	8.2%	8.2%	5600	8.8%	8.8%	4477	7.0%	7.0%	3837	6.0%	6.0%	3200	5.0%	5.0%
2	4477	7.0%	7.0%	5000	7.8%	8.0%	5600	8.8%	8.8%	4477	7.0%	7.0%	4157	6.5%	6.2%	3400	5.3%	5.2%
3	4477	7.0%	7.0%	5000	7.8%	7.9%	5600	8.8%	8.8%	4477	7.0%	7.0%	4477	7.0%	6.5%	4477	7.0%	5.8%
4	4477	7.0%	7.0%	4800	7.5%	7.8%	5600	8.8%	8.8%	4477	7.0%	7.0%	4477	7.0%	6.6%	3200	5.0%	5.6%
5	4477	7.0%	7.0%	4800	7.5%	7.8%	5600	8.8%	8.8%	4477	7.0%	7.0%	4477	7.0%	6.7%	4477	7.0%	5.9%
6	4477	7.0%	7.0%	4700	7.3%	7.7%	5250	8.2%	8.7%	4477	7.0%	7.0%	4477	7.0%	6.8%	4477	7.0%	6.1%
7	4477	7.0%	7.0%	4500	7.0%	7.6%	5250	8.2%	8.6%	1000	1.6%	6.2%	4477	7.0%	6.8%	4750	7.4%	6.3%
8	4477	7.0%	7.0%	4500	7.0%	7.5%	5250	8.2%	8.6%	6000	9.4%	6.6%	4477	7.0%	6.8%	4750	7.4%	6.4%
9	4477	7.0%	7.0%	4500	7.0%	7.4%	5250	8.2%	8.4%	5250	8.2%	6.9%	4477	7.0%	6.9%	500	0.8%	6.2%
10	4477	7.0%	7.0%	4400	6.9%	7.4%	5250	8.2%	8.5%	5250	8.2%	6.9%	4477	7.0%	6.9%	5724	9.0%	6.1%
11	4477	7.0%	7.0%	4300	6.7%	7.4%	5000	7.8%	8.4%	4477	7.0%	6.9%	4477	7.0%	6.9%	5000	7.8%	6.2%
12	4477	7.0%	7.0%	4250	6.6%	7.3%	4705	7.4%	8.3%	4477	7.0%	6.9%	4477	7.0%	6.9%	5000	7.8%	6.4%
13	4477	7.0%	7.0%	3300	5.2%	7.1%	-	-	-	4477	7.0%	7.0%	4477	7.0%	6.9%	5000	7.8%	6.5%
14	4477	7.0%	7.0%	3255	5.1%	7.0%	-	-	-	4477	7.0%	7.0%	4477	7.0%	6.9%	5000	7.8%	6.6%
15	1277	2.0%	6.7%	1400	2.2%	6.7%	-	-	-	4477	7.0%	7.0%	2237	3.5%	6.7%	5000	7.8%	6.7%

(-) Dash denotes no further work to be performed.

Average – Means the program year replacement rate.

Procurement Strategy

Introduction

The ALSLR Plan contracting strategy will use Denver Water's procurement office to establish a standardized procurement process to notify and solicit qualifications and bids from outside contractors. To support this procurement process, Denver Water will provide an ALSLR Contract Document that includes standard front-end contract documents supported by technical specifications, supplemental specifications, and standard drawings for all components of the ALSLR work. The LSLR Contract Manual will contain the necessary bid forms that will govern the work to be conducted and payment for this work on a unit price basis. Denver Water will use three bid schedules based on the type of Groups identified above; Geographic, Individual, and Investigation.

Denver Water Purchasing utilizes the Rocky Mountain E-Purchasing System that helps to provide greater visibility to the contracting industry. The Rocky Mountain E-Purchasing System will be utilized as well as other notifications process for Industry Day, the subsequent Request for Qualifications (RFQ).

Denver Water promotes inclusiveness in their procurement process based on setting goals for Minority, Women, and Veterans owned businesses or Special Business Enterprise (SBE) and Minority Business Enterprises (MBE). To continue with best practices in the community and construction industry and to foster inclusion of qualified SBE's/MBE's, Denver Water will establish minimum goals for participation as a percent of construction dollars for construction contracts under the LRP.

ALSLR Contractor Procurement

Qualified Contractors who have been determined as most responsive and lowest price will be selected based on a task order format to focus on three LSLR Group areas: Geographic Area, Individual, and Investigations as further described below. The Plan may adjust the contracting and procurement strategy for this work as the ALSLR work evolves and specific or specialty work items are better identified that would warrant individualizing a specific scope of work outside of those already planned.

Lead Service Line Replacement Contractors will have a task order that defines scope of work (upwards of 200 properties) to replace lead service lines from the main to the first fitting within the dwelling and conduct restoration of disturbed areas. The LSL replacements scope will include from connection to the water main, meter box replacement (if not already located outside the property), curb stop replacement, and plumbing connections inside the resident home. ALSLR contractors will be expected to have excavation, boring, and plumbing capabilities to complete the replacements. Contractors will mobilize to one geographic area to replace multiple services in a given block, while others will replace individual lead service lines in high priority locations. Construction Liaisons will be present during construction to manage communications with Property Owners and Contractors. The Contractor will not be expected to interface or coordinate with the Property Owners.

Investigation Contractors will have a task order scope of work to verify whether a lead service line exists ahead of the replacement crews. These contractors will be expected to use different methods of excavation, hand digging, potholing, meter box viewing, and interior dwelling investigation. Their productivity and ability to verify the presence of a LSL will help in better updating the LSLI and calibration of the predictive model. By improving the LSLI database, the predictive model will help in

assuring task orders for various LSLR groups will assist in keeping the replacement contractors on schedule and achieve the annual ALSLR target. Construction Inspectors will report their findings to the Program team so that the LSLI can be updated, the prioritization model can be adjusted, and planning for replacement can be performed. Construction Liaisons will be present during construction to manage communications with Property Owners and Contractors. The Contractor will not be expected to interface or coordinate with the Property Owners.

Scheduling and Coordination

To promote the LRP, ready the contracting community for ALSLR work, and gauge the interest of the contracting community, an open house (referred to as an Industry Day) will be planned for early August 2019. During the Industry Day, contractors will learn more about the LRP goals and expectations and Denver Water can also use this event as a forum to receive Construction Industry feedback. This will benefit not only potential bidders, but also the Program team in finalizing the contracting and procurement strategies. The dialogue from the Industry Day will be used to discuss unit price bidding options, clarify specifications, and aid in assigning risks within the construction contract document. The event will be advertised through the Rocky Mountain System BidNet, the Colorado Contractors Association, Denver Water's Public Information, and other appropriate channels. This event will be in advance of the formal qualification process so that the information gathered and shared can be used by Denver Water to develop the qualification package and contract documents.

A Request for Qualifications Process will follow the Industry Day to solicit specific information on relevant work experience, bonding, insurance, key staff, and overall capacity and approach. The qualifications packages will be evaluated, and a short list of contractors will be developed. If needed, interviews can be conducted during this stage. Once the short list of contractors is developed, these contractors will be invited to a price bid on three bid forms; Group A – geographic, Group A – individual, and Group B - Investigations.

All Contractor Procurement Contract Documents are expected to be finalized by October 15, 2019 and to allow the bid process to move forward once the LRP variance is approved. The current timeline and milestones for the Procurement and Contracting of the ALSLR Plan are illustrated below in Table III.D-14.

Table III.D-14. Timeline and Milestones for Procurement and Contracting, Example

Description	Estimated Timeframe
Request for Qualifications (RFQ) Notification	August 2019
Receive RFQ	Mid-September 2019
Shortlist Qualified Contractors	Early October 2019
Finalize Accelerated Lead Service Line Contractor Contract Documents	October 15, 2019
Finalize ALSLR 2020 Work Plan	Mid October
Request for Unit Bid Price Proposals (RFP)	Mid October
Pre-Bid Meeting	TBD
Bid Opening	Early November
Bid Awards	Mid November
Notification of Selected ALSLR Contractors (Multiple)	TBD
Issue Task Orders	TBD
ALSLR Notice to Proceed	January 2020

Summary

Denver Water through a proven process will procure the needed qualified contractors for successful implementation and completion of the annual ALSLR Program. Denver Water is committed to providing the necessary resources to meet the ALSLR cumulative program year replacement rate goal of 7.0%.

APPENDIX III.E.1 - LEAD SEQUENTIAL SAMPLING STUDY

September 2019

DENVER WATER

Appendix III.E.1

Lead Sequential Sampling Study

Background

The purpose of this study is to gain a better understanding of the comparative influence of existing lead service lines (LSLs) and copper with lead solder (Cu w/ Pb) in addition to galvanized (GAL) plumbing downstream of an existing or replaced lead service line on lead levels at customers' taps.

Sequential sampling of individual homes was used to capture water quality samples representing various plumbing material types within a single premise to understand the amount of lead released from those materials.

Sequential sampling entails taking multiple water quality samples from a customer's tap, one after another, to discern how water quality changes throughout the premise plumbing and service line. Three categories of homes were sought to take part in the study: 1) homes a with lead service lines (LSL), 2) homes with copper with lead solder (Cu w/ Pb) and 3) homes with galvanized (GAL) plumbing downstream of an existing or replaced lead service line. To date, thirty-two Denver Water customers' homes have been potholed in search of homes that meet the criteria of the study. This report highlights the results of the three rounds of quarterly sampling that took place in Q4 of 2018 as well as Q1 and Q2 of 2019.

Study Design

- The sampling methods used for this study were informed by the work of Michael Schock et. al as outlined in the presentation, "Lead Tap Sampling Approached: What Do They Tell You".
- Lead concentration were measured via the EPA method 200.8 and are presented as dissolved lead in this report.
- The sequential sample volumes outlined below were collected after a minimum 6-hour stagnation time from the cold-water kitchen or bathroom faucet.
    - 125mL, 125mL, 250mL, 250mL, 250mL, 500mL (as many 500mL samples as necessary to capture service line volume back to the main based on a calculated volume of the plumbing system).
    - Five additional 1000mL samples were collected at the end of the sequence after the 1st round of sampling to ensure that final sample represented water originating from the main and not sitting in the service line during stagnation.
- A volume weighted lead concentration of the first 5 samples (1000mL cumulative) was calculated to determine the "Calculated 1st Draw" lead concentration. This concentration represents the expected concentration of an LCR compliant first draw sample.

First Round Sampling Results

- Lead Service Line Homes
    - Seven of the identified homes were confirmed by potholing to have lead service lines.
        - All results for the first-round sampling of LSL homes are shown in Figure 1 below.
        - The average "Calculated 1st Draw" lead concentration was 6.1 ppb.

        - The average of the highest measured lead concentration from all LSL homes was 13.9 ppb. The maximum lead concentration for any LSL home was 23.4 ppb.

- Copper with Lead Solder Homes
    - Seven of the identified homes were confirmed by potholing and internal plumbing inspection to have copper with lead solder.
        - All results for the first-round sampling of Cu w/ Pb homes are shown in Figure 2 below.
        - The "Calculated 1st Draw" lead concentration for all Cu w/ Pb homes except one was below the minimum reporting limit (MRL) of 1 ppb.
            - The one exception (Garrison St.) had a "Calculated 1st Draw" lead concentration of 4.9 ppb and a maximum lead concentration of 8.6 ppb. It was hypothesized that the results from this home were artificially high due to particulate that was observed in the samples and believed to be caused by closing the hot water shut off valve for the "first time in 20 years", according to the customer.
            - Re-sampling was performed at this home the following month and lead concentrations of all samples were below 1.7 ppb with a "Calculated 1st Draw" lead concentration of 1.2ppb. The re-sampling results are labeled "S Garrison RS" in the Figure 2 below.
        - None of the Cu w/ Pb homes had a single sample with a lead concentration of 1.8 ppb or greater (initial Garrison results excluded).
        - The average of the highest measured lead concentration from all copper with lead solder homes was 1.1 ppb (2.2 ppb when including the initial Garrison results).

- Galvanized Plumbing Downstream of a Replaced Lead Service Line
    - During the first round of sampling, no homes were identified to have galvanized plumbing downstream of an existing or previously replaced lead service line.

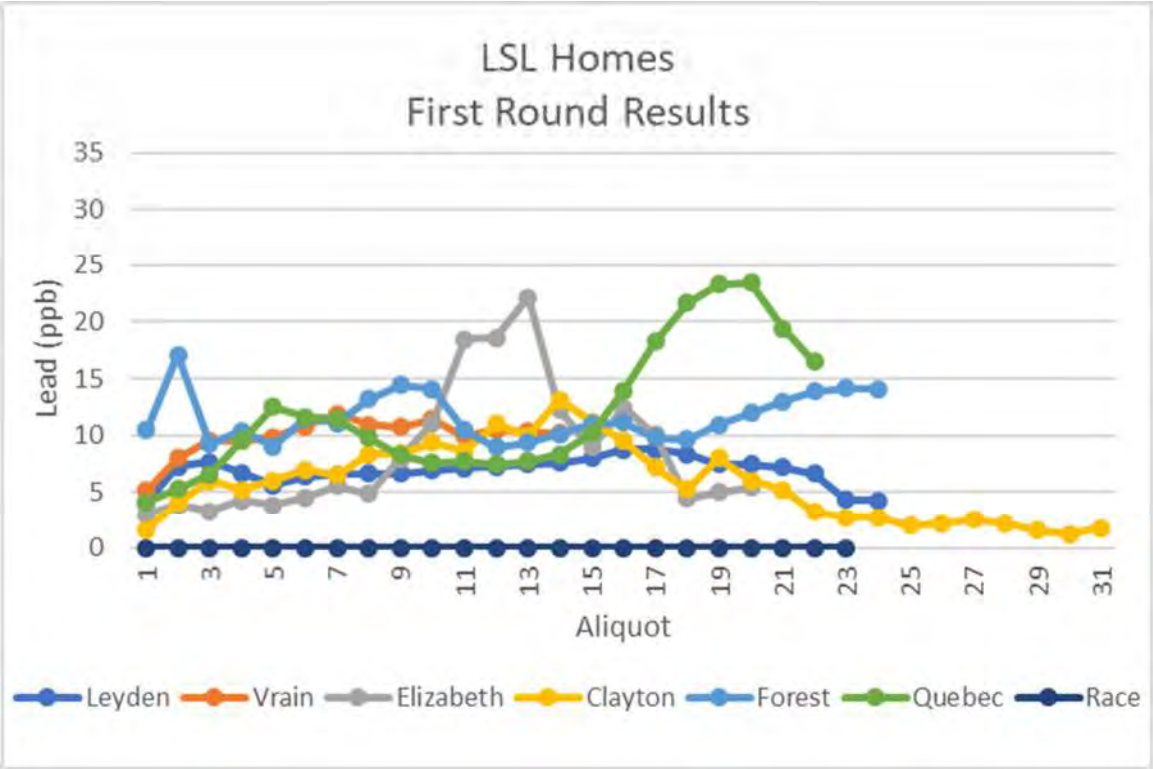


Figure 1 – First Round LSL Homes Results

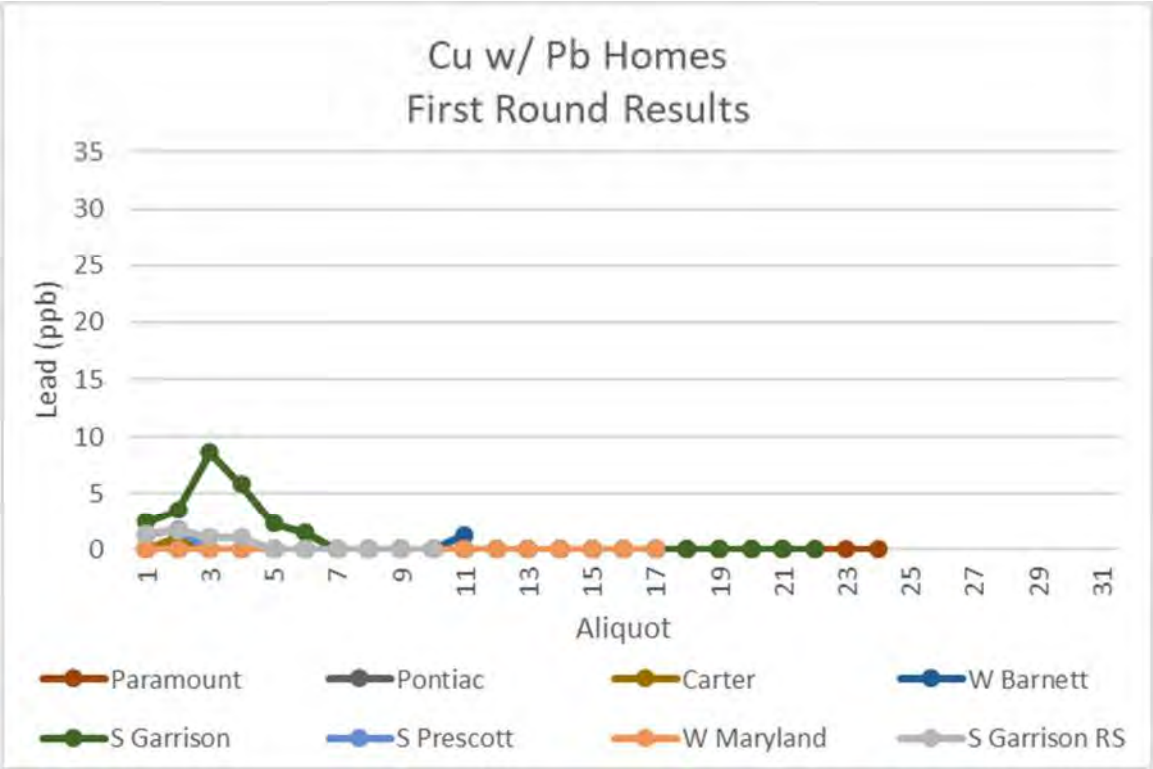


Figure 2 – First Round Cu w/ Pb Homes Results

Second Round Sampling Results

- Lead Service Line Homes
    - The same seven lead service lines homes from the first round of sampling were sampled again 2-3 months later. Two additional lead service line homes were identified to represent portions of the distribution system not captured in the initial round of sampling for a total of 9 homes sampled.
        - All results for the second-round sampling of LSL and GAL homes are shown in Figure 3 below.
        - The Race St. home was confirmed to have a lead service line despite all samples measuring below the MRL.
        - The average "Calculated 1st Draw" lead concentration for LSL homes was 4.6 ppb.
        - The average of the highest measured lead concentration from all LSL homes was 15.9 ppb. The maximum lead concentration for any LSL home was 33.6 ppb.

- Copper with Lead Solder Homes
    - Six of the copper with lead solder homes sampled in the first round of sampling were sampled again 2-3 months later. One of the homes dropped out of the study.
        - All results for the second-round sampling of Cu w/ Pb homes are shown in Figure 4 below.
        - The average "Calculated 1st Draw" lead concentration for Cu w/ Pb homes was below the MRL.
        - The average of the highest measured lead concentration from all copper with lead solder homes was 1.5 ppb.
        - No sample from any of the Cu w/ Pb homes in the second round of sampling had a lead concentration greater than 4.3 ppb.

- Galvanized Plumbing Downstream of a Replaced Lead Service Line
    - All results for the second-round sampling of GAL home are shown in Figure 3 below.
    - Only one home with galvanized plumbing downstream of a replaced lead service line was identified for the second round of sampling. This home is identified as Mariposa in Figure 3.
    - Of all the 15 homes sampled, the galvanized home had the 3rd highest "Calculated 1st Draw" lead concentration at 8.6 ppb. The galvanized home also had the 3rd highest maximum lead concentration at 25.8 ppb.
    - The lead levels released from the galvanized home were similar to the lead service line homes.
    - It is of interest to note that lead levels spike earlier in the sampling sequence for the GAL line compared to LSLs. This is indicative of galvanized internal plumbing acting as a source of lead.

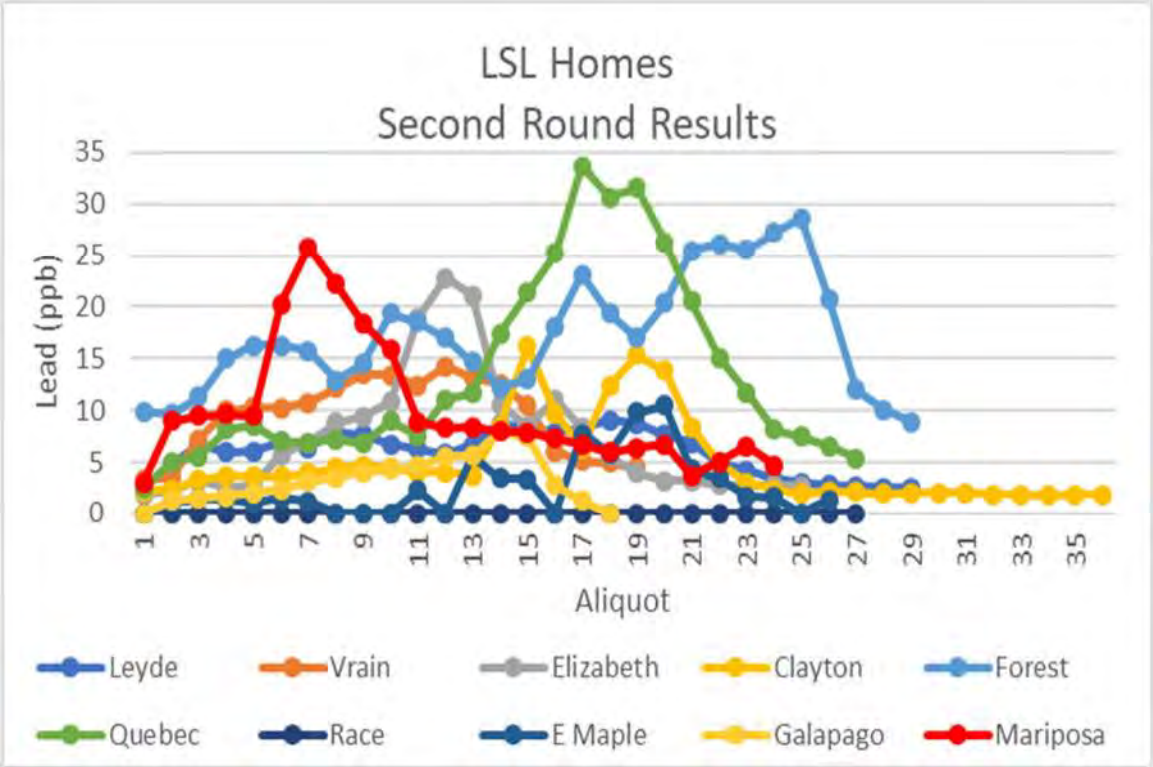


Figure 3 – Second Round LSL and GAL Homes Results

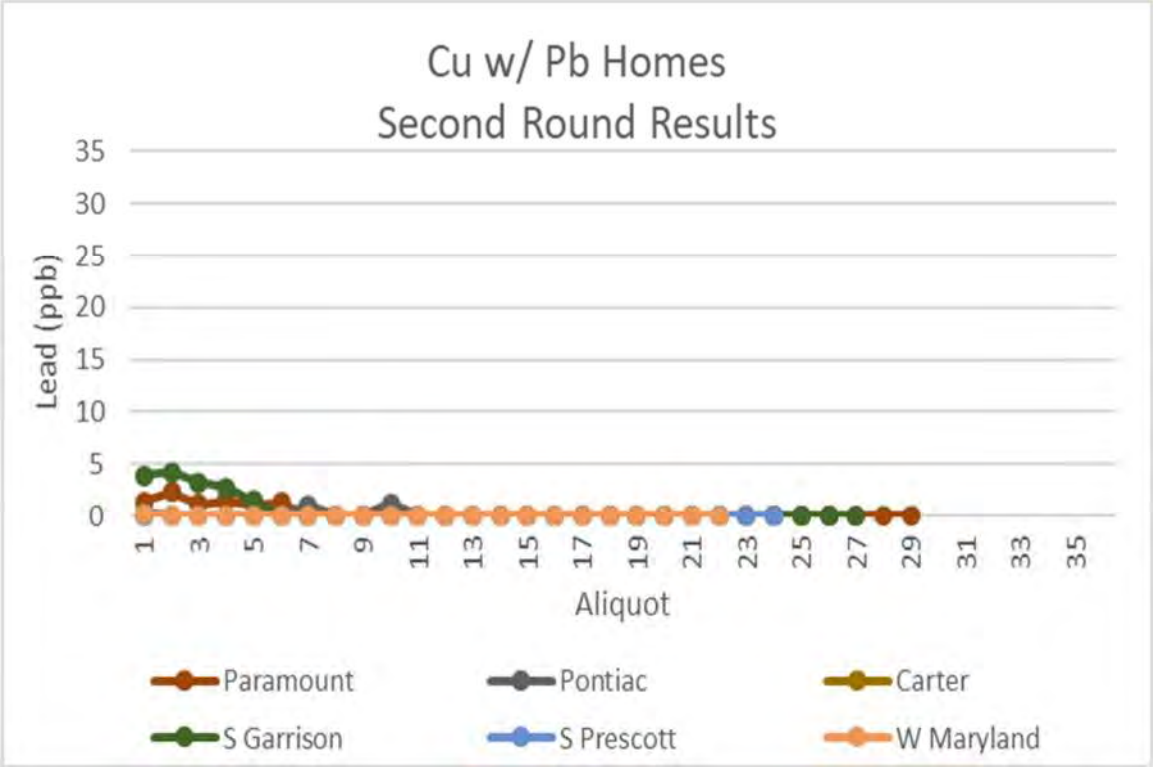


Figure 4 – Second Round Cu w/ Pb Homes Results

Third Round Sampling Results

- Lead Service Line Homes
    - For the third round of sequential sampling, one of the original homes (Forest St) dropped out of the program. Eight LSL homes remained in the study for the 3rd round.
        - All results for the second-round sampling of LSL and GAL homes are shown in Figure 5 below.
        - Overall, lead levels in all samples were significantly lower for the 3rd round of sampling. The highest measured lead value from any LSL home sample was only 10.4 ppb.
        - The average "Calculated 1st Draw" lead concentration for LSL homes was 1.8 ppb.
        - The average of the highest measured lead concentration from all LSL homes was 7.2 ppb.

- Copper with Lead Solder Homes
    - The six homes from the second round of sampling were sampled again for round three.
        - All results for the second-round sampling of Cu w/ Pb homes are shown in Figure 6 below.
        - Lead levels from Cu w/ Pb homes were significantly lower for the 3rd round of sampling. Only two samples from any of the Cu w/ Pb homes in the third round had a lead concentration above the MRL, both of which came from the Garrison St. home.
        - The average "Calculated 1st Draw" lead concentration for Cu w/ Pb homes was below the MRL.

- Galvanized Plumbing Downstream of a Replaced Lead Service Line
    - Despite multiple attempts to contact the owner of the GAL home, samples were not collected for the third round.
    - One other home has been identified that potentially meets the requirements of the study. At the time of writing this report, sample collection is being scheduled with the homeowner.

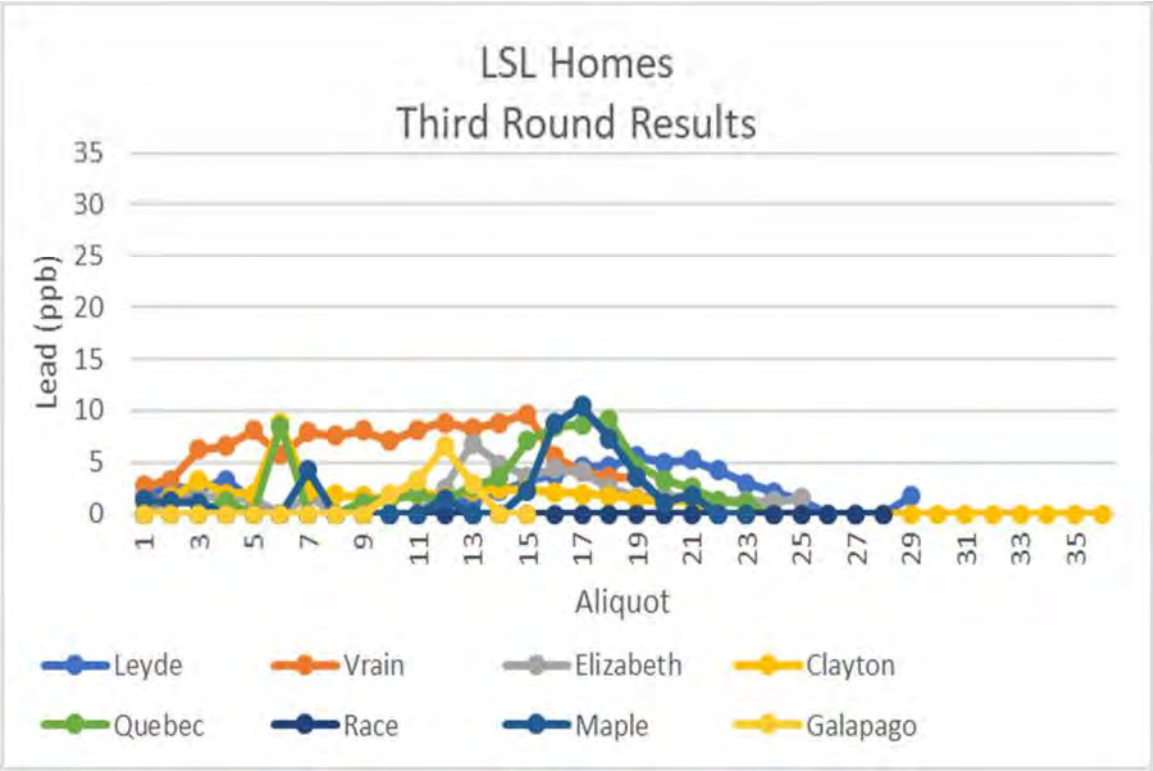


Figure 5 – Third Round LSL Homes Results

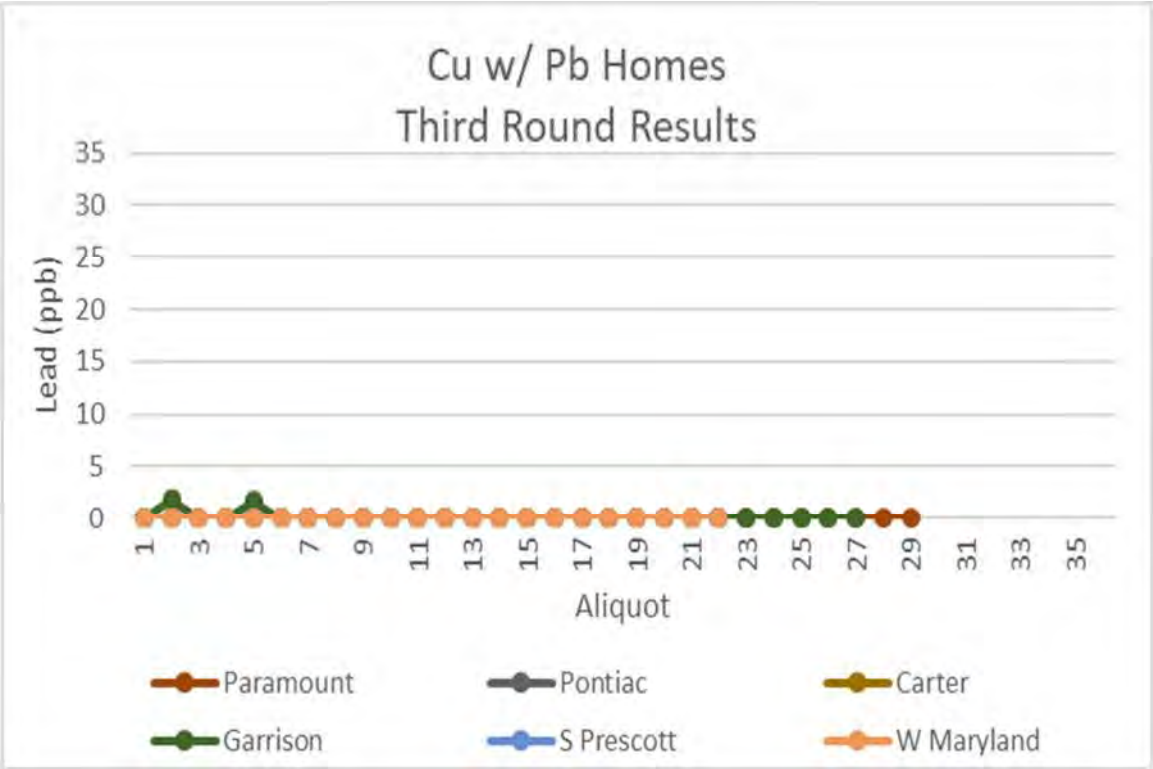


Figure 6 – Third Round Cu w/ Pb Homes Results

Conclusions

- Of the homes sampled in sequential sampling study, lead service lines overwhelmingly represented the greatest source of lead when compared to copper with lead solder.
    - Not including the first-round initial sampling at S Garrison as explained above, all samples events at copper with lead solder (Cu w/ Pb) homes yielded maximum lead concentrations below 5 ppb.
    - Conversely, all sampling events at lead service line (LSL) homes yielded maximum lead concentration greater than 5 ppb. The maximum Pb concentration measured from any LSL home was 33.6 ppb.
- The first liter of water from the tap, represented by the first 5 sample aliquots in this study and used to derive the "Calculated 1st Draw" lead concentration, contained nearly all the lead released from a copper with lead solder home in this study.
    - Only 3 samples from Cu w/ Pb homes had a lead concentration greater than the MRL after the 5th aliquot (representing a 1-liter first draw). These three samples were all less than 1.4 ppb.
    - These results are consistent with those found in the customer requested sampling program.
        - Table 1 below highlights the similarity of results from the customer requested sampling program (1196 sampling events over 3 years) compared to the sequential sampling study (20 sampling events over 9 months) for Cu w/ Pb homes.
        - First, second, and third draw equivalent samples were calculated based on the sampling procedure described below to make the comparison between the two different data sets.
- The "Calculated 1st Draw" concentrations for lead service lines are lower than subsequent aliquots and therefore under-represents the amount of lead released from a lead service line home.
    - Only one LSL home during one sampling round had a maximum lead concentration occur in the first five aliquots.
- The single galvanized home participating in the study yielded lead levels similar to LSL homes. However, the peak lead level in the GAL home occurred in an earlier sample in the sampling sequence compared to LSL homes.
    - Caution must be used when viewing the results from the GAL home. The results from the single GAL home sampled in this study may not be representative of other galvanized homes within the distribution system.
    - The lead results from GAL home are consistent with the hypothesis that galvanized pipe acts as a lead sink while downstream of a lead source (i.e. lead service line) and then acts as a lead source once the original source of lead has been removed.

Figures 6-10 summarize the lead results from the three rounds of sequential sampling. Lead concentrations below the reporting limit of 1 ppb are reported as 0 ppb.

Table 1 – Comparison Between Customer Requested Sampling and Sequential Sampling Results

	Decade of Home Construction	Average Lead (ppb)			50th Percentile Lead (ppb)			90th Percentile Lead (ppb)		
		1st Draw	2nd Draw	3rd Draw	1st Draw	2nd Draw	3rd Draw	1st Draw	2nd Draw	3rd Draw
Customer Requested Sampling Results	1952-1959	1.13	0.62	0.7	0.5	0.5	0.5	2	0.5	0.5
	1960-1969	1.18	0.85	0.72	0.5	0.5	0.5	3	0.5	0.5
	1970-1979	2	0.69	1.14	0.5	0.5	0.5	3	1.5	0.5
	1980-1982	1.19	0.67	0.5	0.5	0.5	0.5	2	1.16	0.5
	1983-1987	1.01	0.48	0.48	0.5	0.5	0.5	2	0.5	0.5
Sequential Sampling Study Results	Copper with Lead Solder Homes	0.8	0.1	0.1	0.0	0.0	0.0	2.9	0.0	0.0

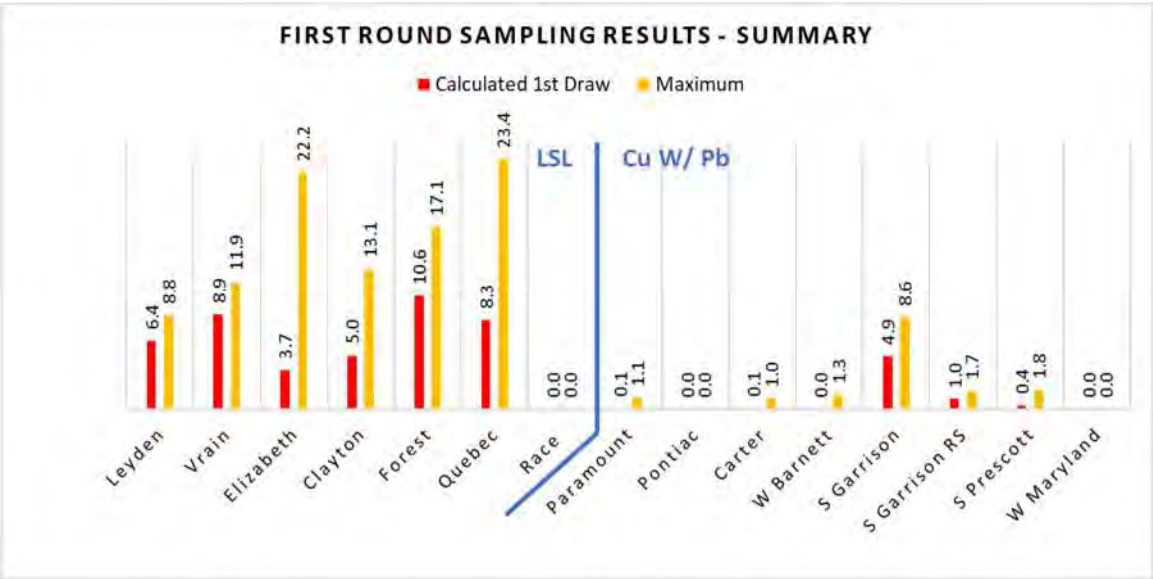


Figure 7 – First Round Sampling Lead Results as ppb

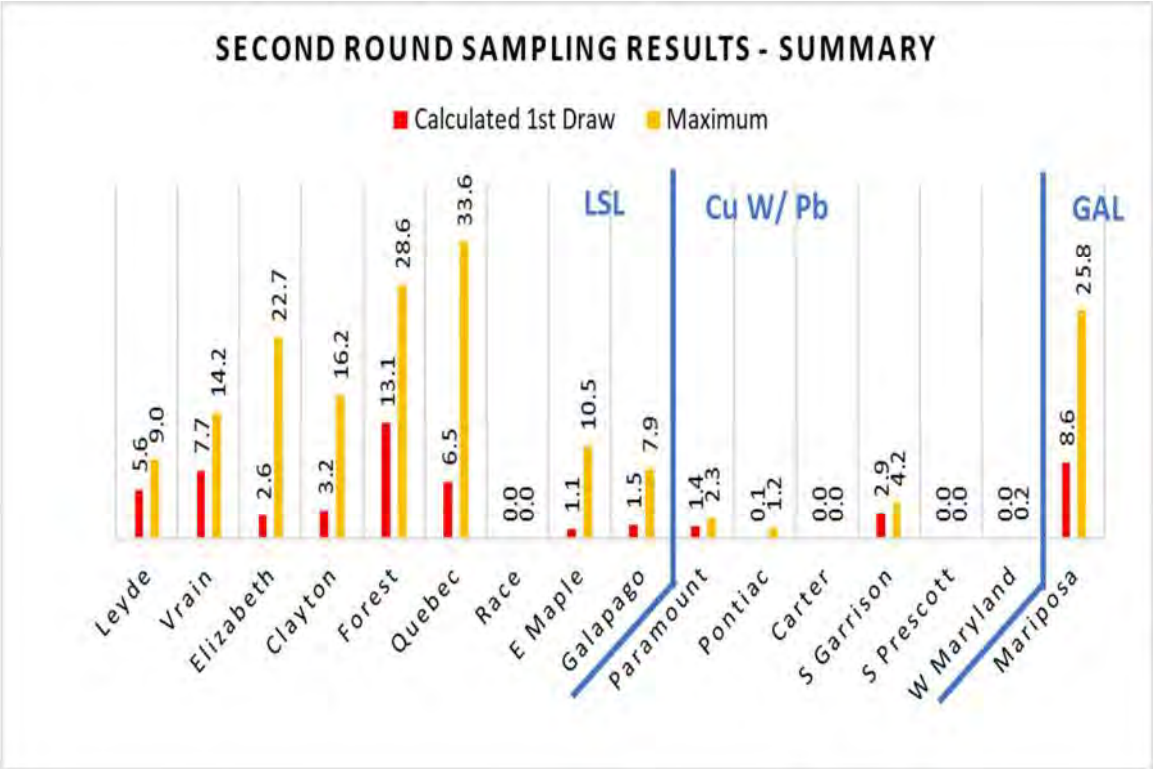


Figure 8 – Second Round Sampling Lead Results as ppb

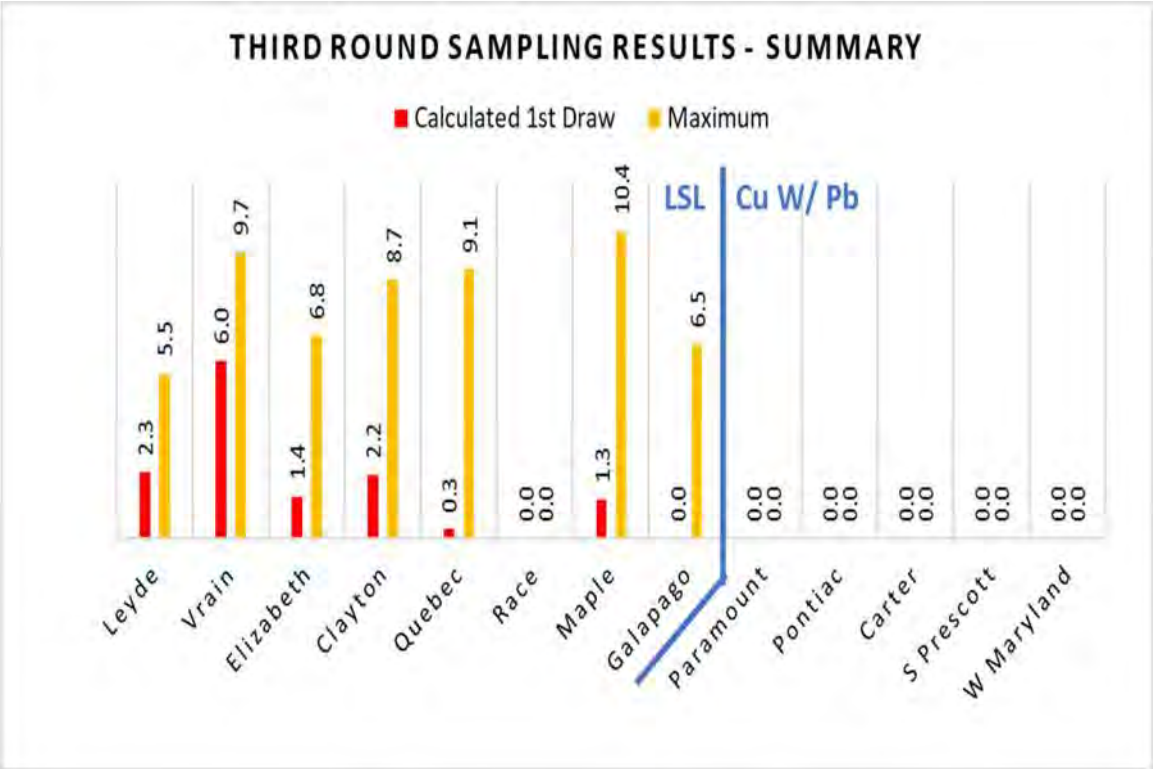


Figure 9 – Third Round Sampling Lead Results as ppb

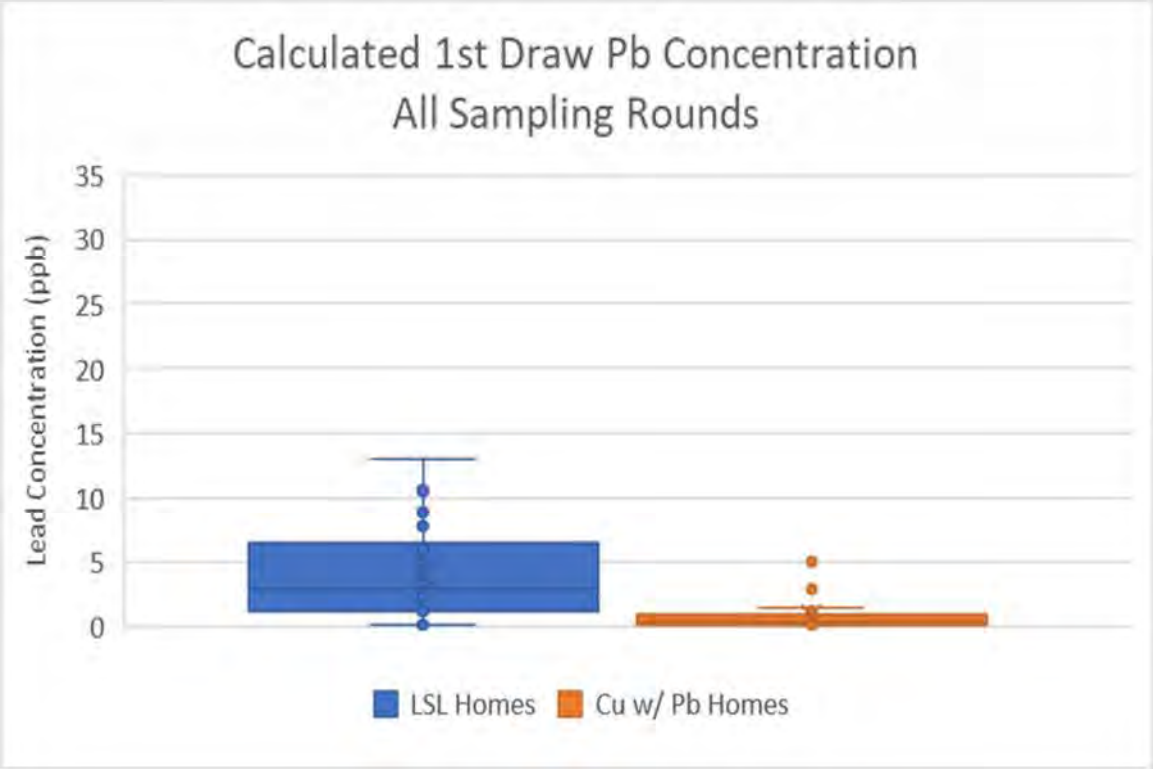


Figure 10 – All Results for Calculated 1st Draw Lead Concentration from Each Home Sampled

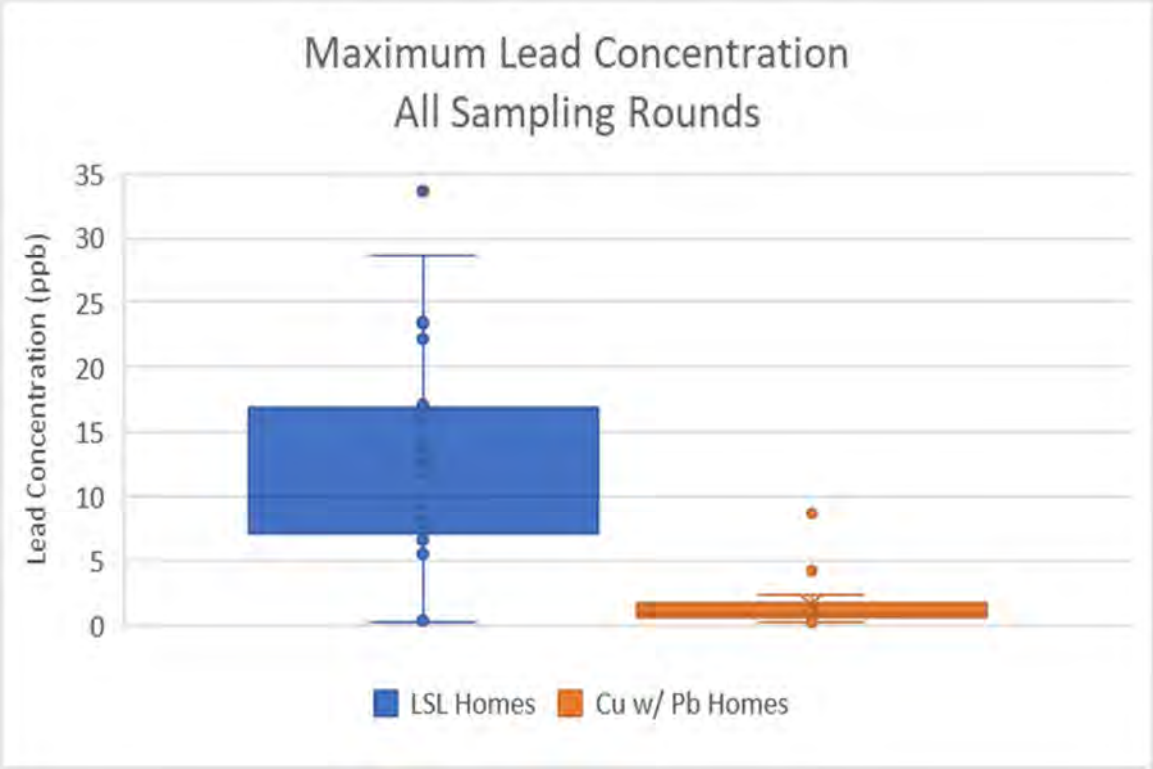


Figure 11 – All Results for Maximum Lead Concentration from Each Home Sampled

Sampling Method Comparison

Denver Water's Customer Requested Lead Sampling program asks customers to collect three 1-liter samples following at least 6 hours of stagnation. The first 1-liter sample is collected immediately following stagnation before any water has passed through the premise. After the first sample is collected, customers are asked to flush for 25 seconds without shutting off the faucet. A second 1-liter sample is then collected. After the second sample is collected, the customer is asked to flush for an additional 25 seconds before collecting the third and final 1-liter sample. Denver Water has measured sampling flow rates when collecting lead samples and has found that flows typically range between 2-4 liters per minute. It is assumed that the flushing rate during the 3-Draw sampling is within this range.

The first 1-liter sample represents the same volume of water that is collected during LCR compliance sampling. This sample is thought to be most influenced by the sampling fixture and internal plumbing nearest to the fixture. The second sample is collected with the intent to capture the lead from internal plumbing without significant influence from the sampling fixture or the service line. The third sample is intended to represent the water stagnating in the service line.

Figure 11 and 12 show the lead concentrations from three homes sampled during the 2nd round of sequential sampling. The three homes include a lead service line home (Quebec), a copper with lead solder home (Paramount) and a home with galvanized plumbing downstream of a replaced lead service line (Mariposa). Overlaid on these figures are the theorical sample and flushing volumes corresponding to the 3-Draw sampling protocol described above. Note that the horizontal axis represents the aliquot or sample bottle with volumes detailed in the Study Design section above.

The homes selected are not intended to represent all homes of certain plumbing type. They were merely selected as an example. It is impossible to select a "representative home" because of the innumerable variables associated with lead sampling. For example, when looking at the aliquot in which the maximum lead concentration occurred in LSL homes, it varies from aliquot 13-27. This means that for lead service line homes, the maximum lead concentration could occur between the fifth and twelfth liter when sampling.

Given the number of variables that impact lead concentration captured during a sampling event (faucet flow, internal plumbing and service line length, stagnation time, flushing prior to stagnation, etc) and the resources required to process and analyze samples, Denver Water has concluded that the existing 3-draw sampling protocol is the most appropriate method to obtain consistent and reliable data on lead concentrations from homes when sampling lead is requested by customers.

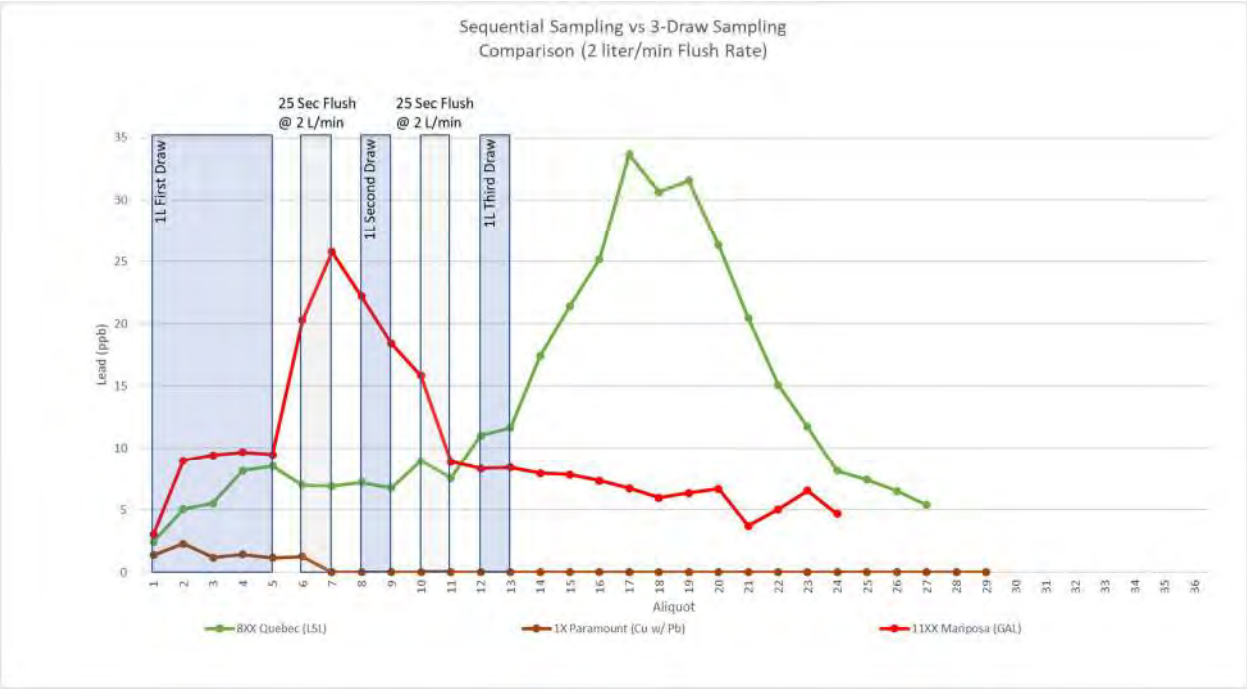


Figure 11 – 3-Draw Sample Volumes at 2 L/min Flushing Compared to Sequential Sampling Results

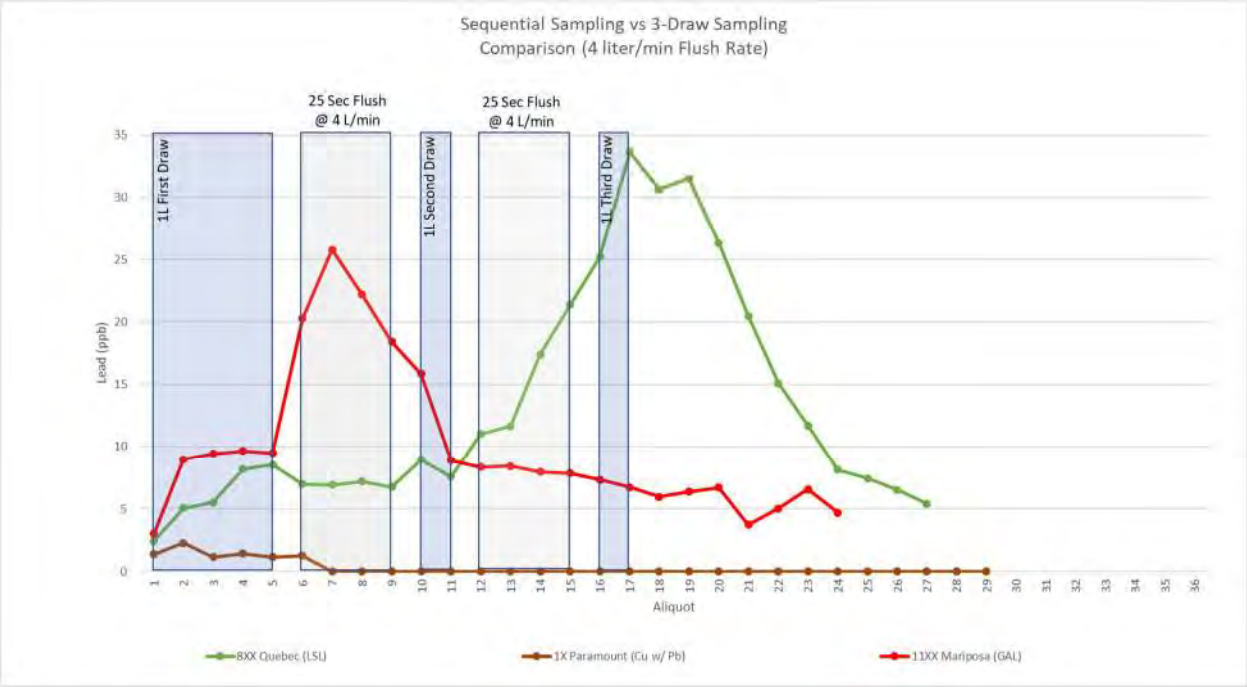


Figure 12 – 3-Draw Sample Volumes at 4 L/min Flushing Compared to Sequential Sampling Results

APPENDIX III.E.2 - LEAD FROM SOLDER

September 2019

DENVER WATER

Appendix III.E.2

Immersion Study Comparing 2 mg/L of Orthophosphate and pH 8.8 for Controlling Lead Release from Solder

Date: August 16, 2019

To: Denver Water

From: Corona Environmental Consulting, LLC

Research Question

Does 2 mg/L of orthophosphate as PO_4 and pH 8.8 result in equivalent lead reduction from copper with lead solder coupons?

Introduction

Copper service lines joined by leaded solder are known to exist in many homes in the United States, including homes within Denver Water's service area. Copper lines with lead solder will become a dominant source of lead once the lead service lines are removed. The purpose of this Appendix is to summarize the findings of a 17-week immersion study comparing the performance between high pH with alkalinity adjustment and orthophosphate for control lead release from copper with lead solder.

In developed countries the solder used to join copper pipes has historically been lead-tin solder. In the United States, 50/50 lead/tin solder was common (MWH, 2005). Lead bearing solder has been banned from use in drinking water plumbing and 95 percent tin and 5 percent antimony is now more commonly used in the US. As part of the LCR materials survey Denver Water found copper joined by lead solder to be common in homes constructed between 1983 and 1988. The 90th percentile lead levels from Tier 1 homes with copper with lead solder has been consistently below 10 ppb, as shown in Figure 1.

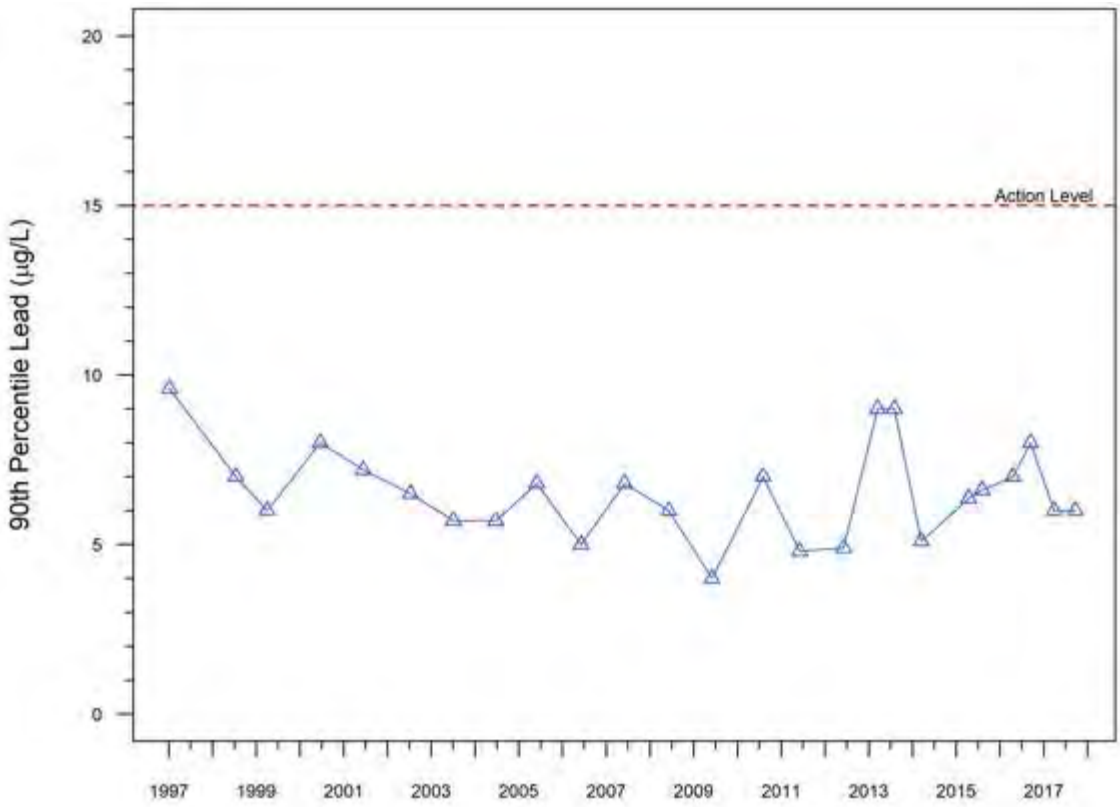


Figure 1. Denver Water's 90th percentile lead levels for Tier 1 homes with copper with lead solder

Similar to lead service lines, the corrosion of copper with lead solder can be reduced by pH/alkalinity adjustment or the addition of a corrosion inhibitor (e.g., orthophosphate). However, the corrosion of lead solder is different from lead pipe because the corrosion of solder is driven by the galvanic cell. Lead release from solder is variable over time and across different sites in a distribution system with similar age and construction (Schock and Lytle, 2011). This is partly due to random particulate lead release (Lytle et al., 1993). Lead release from solder is significantly influenced by the joint's geometry and the workmanship (Lyon and Lenihan, 1977).

In general, only a small amount of solder is exposed to the water and since lead/tin solders are anodic to copper the small anode-large cathode surface area effects apply. In this circumstance the larger the cathode compared to the anode results in greater galvanic current and solder corrosion.

Water parameters found to increase the corrosion of solder are lower pH and higher chloride and nitrate concentrations (Oliphant, 1983). Sulfate in sufficient concentration can mitigate the effect of chloride and the ratio of these predictors (i.e., chloride to sulfate mass ratio or CSMR) have been used as a measure of the potential for galvanic corrosion of copper with lead solder (Oliphant, 1983; Gregory, 1990; Nguyen et al., 2011). Sulfate works by changing the corrosion product to crystalline plates that are more protective. If a utility has a CSMR increase above 0.5 and an alkalinity less than 50 mg/L as $CaCO_3$ then the utility could potentially have serious lead problems following treatment changes that increase the CSMR (Nguyen et al., 2010). Low pH occurs at the solder metal surface due to corrosion reactions, but alkalinity provides buffering to mitigate the pH decrease and dissolution of lead into the water. For example, in bench scale studies with copper with lead solder Nguyen et al. (2010) found that lead release at an alkalinity of 25 mg/L as $CaCO_3$ was ~ 2.5 times higher than lead release at 100 mg/L as $CaCO_3$. The finished water CSMR

at the Marston and Moffat water treatment plants is shown in Figure 2. In general, the CSMR at Marston tends to be higher than at Moffat. Most times the CSMR is below the 0.5 threshold; however, there are several occasions where this is exceeded. The fluctuation in CSMR is likely due to changes in the ionic composition of the source water. Neither addition of caustic soda (NaOH) or orthophosphate as phosphoric acid (H_3PO_4) for corrosion control will affect the CSMR.

Denver Water is converting their ammonia source from aqueous ammonia to liquid ammonia sulfate (LAS) at Marston (~early 2020) and Foothills (late 2020 or early 2021). Longer term, Denver Water is also converting from chlorine gas to bulk hypochlorite at Marston (~2025) and Foothills (~2028). Both of these changes will have a small positive impact on CSMR as detailed in the 2017 OCCT Study (Denver Water, 2017). Specifically, conversion from aqueous ammonia to LAS will result in a net increase in sulfate ions in the finished water, and thus a reduction in CSMR. On average, the three drinking water plants dose 0.63 mg/L as N to form total chlorine for residual maintenance. Converting to LAS, this dose is 2.97 mg/L as LAS and 2.16 mg/L as sulfate. Converting to LAS would result in an average net increase of 2.16 mg/L of sulfate in finished water. Conversion to bulk hypochlorite will reduce the chloride concentration by 0.5 mg/L per mg/L as Cl_2. This will reduce the chloride in the water by about 1.5 mg/L. Taken together, these long-term changes will reduce the CSMR in the Marston water from an average of 0.5 to about 0.4 (-20%). In the Moffat water the predicted change is from an average of 0.3 to 0.2 (-33%).

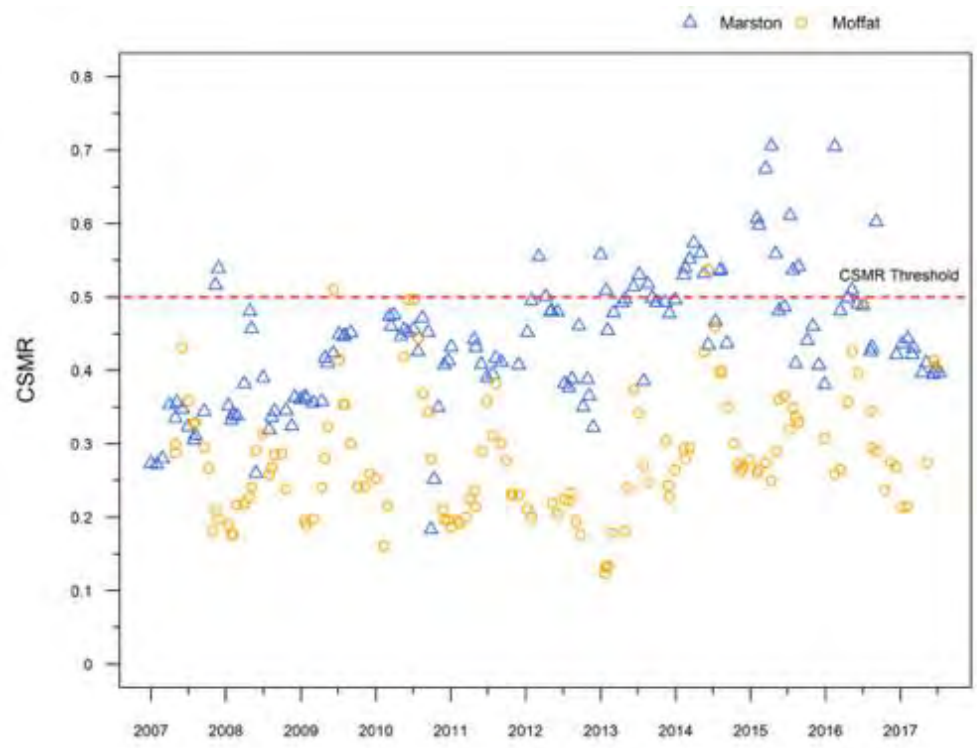


Figure 2. CSMR in the Marston and Moffat finished water

Immersion Study

Past and recent studies of systems similar to Denver Water suggest that it is possible that pH/alkalinity can reduce lead level from solder similar or better than orthophosphate treatment (Boffardi and Sherbondy, 1991; MacQuarrie et al., 1997; Confluence Engineering Group, 2018). Denver Water conducted testing on copper with lead solder coupons in both source waters at bench-scale. The immersion study tested 2 mg/L of orthophosphate and pH adjustment to 8.8 for controlling lead release

from new copper with lead solder. The experimental matrix is presented in Table 1 below. The experiment was designed following the CDPHE document "Lead and Copper Corrosion Bench-Scale Testing Guidance Manual" prepared by Hazen and Sawyer (2019). Each condition was tested in triplicate. Glass jars (250 mL) were cleaned by filling them with 0.1 M hydrochloric acid and allowing to sit for 24 hours. Each test jar was labeled with a unique identifier including the test water ID, test material, and replicate number. Copper with lead-tin solder coupons were prepared by melting a 1-inch long piece of lead solder into a 1-inch long ½'' diameter new copper coupling. All coupons were cleaned by immersing them in 0.1 M hydrochloric acid for 30 seconds, rinsing them with deionized water and the allowing them to air dry. Each coupon was suspended in a glass jar using a zip tie attached to the cap and the cap was epoxied to reduce reactions with the atmosphere outside the jars (Figure 3).

Table 1. Testing Matrix for Lead Release from Copper with Lead Solder.

Test Water	**pH**	**Orthophosphate Dose (mg/L as PO_4)**	**Number of Cu/Pb Solder Coupons**
Marston/Moffat	7.8	0 (Control)	3/3
Marston/Moffat	7.8	2.0	3/3
Marston/Moffat	8.8	0	3/3

55-gallon samples of combined filter effluent were collected from Marston and Moffat treatment plants. A six-week conditioning phase was followed by a nine-week treatment phase. The jars were filled so that they were headspace free. Chloramination and corrosion control (pH adjustment or orthophosphate addition) were performed just before filling. Sample water is collected three times per week with a composite sample being analyzed at the end of each week. The vessels were stored in the dark on a temperature-controlled orbital shaker. Water characterization of the influent waters is presented in Table 2.

Figure 3. Sample immersion vessel

Table 2. Collected combined filter effluent water characterization for immersion testing.

Parameter	Marston Influent	Moffat Influent
pH	7.8	7.8
Alkalinity (mg/L as $CaCO_3$)	61.2	39.9
Calcium (mg/L)	34.5	17.8
Magnesium (mg/L)	8.6	2.0
Chloride (mg/L)	26.4	3.7
Sulfate (mg/L)	65.0	17.9
Sodium (mg/L)	17.0	2.8
Conductivity (µS/cm)	362	139
CSMR	0.41	0.21

Lead, pH, and Orthophosphate Data for Immersion Study Conditions

The descriptive statistics and illustrations included below compare lead release data from copper with lead solder immersion studies using Marston and Moffat Plant influent water under conditions of an orthophosphate dose of 2 mg/L (as PO_4), pH adjustment to 8.8 and a control (no treatment). Only data from the last 7 weeks of the treatment are used in the calculations to avoid conditioning effects.

Lead Summary Statistics

Lead concentration data for the three treatment conditions are summarized in Table 3 which shows that the median lead concentrations were lower for both pH adjustment and orthophosphate compared to the control regardless of the source water. However, for the Marston coupons the mean lead concentration for orthophosphate was more than three times higher than the control and eight time higher than the pH condition. This was due to lead spikes that occurred in the last three weeks of the study in one of the Marston orthophosphate replicates. For this reason, we rely on the median and percentile statistics for comparison. For Moffat coupons, the mean followed the same pattern as the median lead release where both orthophosphate and pH adjustment resulted in lower lead levels compared to the control. However, orthophosphate resulted in slightly lower lead release.

Table 3 Summary of lead concentration data for immersion study (Week 11-17)

	Marston			Moffat		
Condition	Control	pH	Orthophosphate	Control	pH	Orthophosphate
Mean (ppb)	45.7	22.4	134.2	19.3	8.7	4.7
Variance (ppb^2)	1759.6	56.1	130579.4	138.8	9.0	1.4
Standard Deviation (ppb)	41.9	7.5	361.4	11.8	3.0	1.2
Minimum (ppb)	21.1	14.0	7.4	7.3	5.1	2.9
1st Quartile (ppb)	28.7	17.0	8.8	10.2	7.1	4.0
Median (ppb)	32.7	19.4	9.8	13.6	7.8	4.4
3rd Quartile (ppb)	46.0	29.2	37.9	33.1	9.9	5.4
Maximum (ppb)	221.9	39.5	1590.0	42.0	17.7	7.9
Count	21	21	21	21	21	21

pH Summary Statistics

Between weeks 11-17 the pH before and after the water change was monitored. The time series pH results are shown in Figure 15 in the Appendix. The target mean pH for the control and orthophosphate conditions was 7.8 ± 0.2 and 8.8 ± 0.2 for the pH adjustment condition. Table 4 and Table 5 show that mean pH before and after the water change was within the target pH range for both the Marston and Moffat coupons.

Table 4 Summary of pH data for Marston coupons before and after water change (Week 11-17)

	Control		**pH**		**Orthophosphate**	
	Before	**After**	**Before**	**After**	**Before**	**After**
Mean	7.78	7.79	8.72	8.56	7.69	7.62
Variance	0.01	0.01	0.00	0.01	0.00	0.02
Standard Deviation	0.11	0.15	0.05	0.10	0.06	0.15
Minimum	7.62	7.57	8.62	8.34	7.60	7.41
1st Quartile	7.68	7.73	8.69	8.50	7.65	7.52
Median	7.82	7.81	8.71	8.58	7.68	7.59
3rd Quartile	7.86	7.85	8.75	8.62	7.73	7.68
Maximum	7.95	7.99	8.82	8.72	7.80	8.21

Table 5 Summary of pH data for Moffat coupons before and after water change (Week 11-17)

	Control (pH 7.8)		**pH (pH 8.8)**		**Orthophosphate (pH 7.8)**	
	Before	**After**	**Before**	**After**	**Before**	**After**
Mean	7.85	7.80	8.84	8.68	7.75	7.65
Variance	0.01	0.01	0.00	0.01	0.00	0.02
Standard Deviation	0.11	0.15	0.05	0.10	0.06	0.15
Minimum	7.63	7.49	8.67	8.40	7.60	7.44
1st Quartile	7.72	7.72	8.71	8.51	7.64	7.56
Median	7.90	7.81	8.87	8.71	7.71	7.65
3rd Quartile	7.94	7.87	8.96	8.82	7.87	7.76
Maximum	8.00	8.19	8.99	8.96	7.98	7.87

Orthophosphate Summary Statistics

For the orthophosphate conditions the target was a mean concentration of 2 ± 0.3 mg/L as PO_4. Table 6 shows that the means for the Marston and Moffat coupons were within the target mean. While these results were on the low side, this can be explained from the consumption of orthophosphate by the coupons during the testing period.

Table 6 Summary of 2 mg/L target orthophosphate data after treatment addition (Week 11-17)

	Marston	**Moffat**
Mean (mg/L)	1.8	1.7
Variance ($(mg/L)^2$)	0.0	0.0
Standard Deviation (mg/L)	0.2	0.1
Minimum (mg/L)	1.2	1.6
1st Quartile (mg/L)	1.7	1.7
Median (mg/L)	1.8	1.7
3rd Quartile (mg/L)	1.9	1.8
Maximum (mg/L)	2.2	1.8

Lead Illustrations

Lead concentration data for the Marston coupons and the Moffat coupons over time are shown in Figure 4 and Figure 5, respectively. Data above 500 ppb are not shown in Figure 4 and Figure 5 and all the data during the study are shown in Figure 16 and Figure 17 in the Appendix. Control charting for the lead data are discussed in the Appendix. Figure 4 and Figure 5 identify the pre-treatment before pH adjustment or orthophosphate addition. The respective target pH or orthophosphate level over time is also shown. These time series figures provide visual information on how lead release from each coupon behaved over time and show that in general the experiment did not exhibit a high level of variability except for a few occasions. It is of note that during the conditioning phase, all the vessels experienced exactly the same conditions except source water. It can be observed that lead concentrations stabilize over time and essentially are unchanged between weeks 5 and 6 meaning conditioning is complete. While there is some replicate-to-replicate variability, most of the lead release has stabilized to about 50 ppb prior to the beginning of treatment.

The lead concentration data for the Marston and Moffat coupons are also shown as boxplots grouped based on the condition for the last 7 weeks of the study (Figure 6 and Figure 7). The boxplot figures allow for comparing lead release under the different treatment conditions, and similar to the time series figures, they also illustrate the variability in lead release. The boxplots have been prepared with the box ranging from the 25th to the 75th percentile with the median shown as a line through the box. The diamond indicates the average value. The whiskers extend from the 5th the 95th percentile. Values outside the 5th and 95th percentiles are shown as dots and the number below the box indicates the number of data points use in the construction of the boxplot.

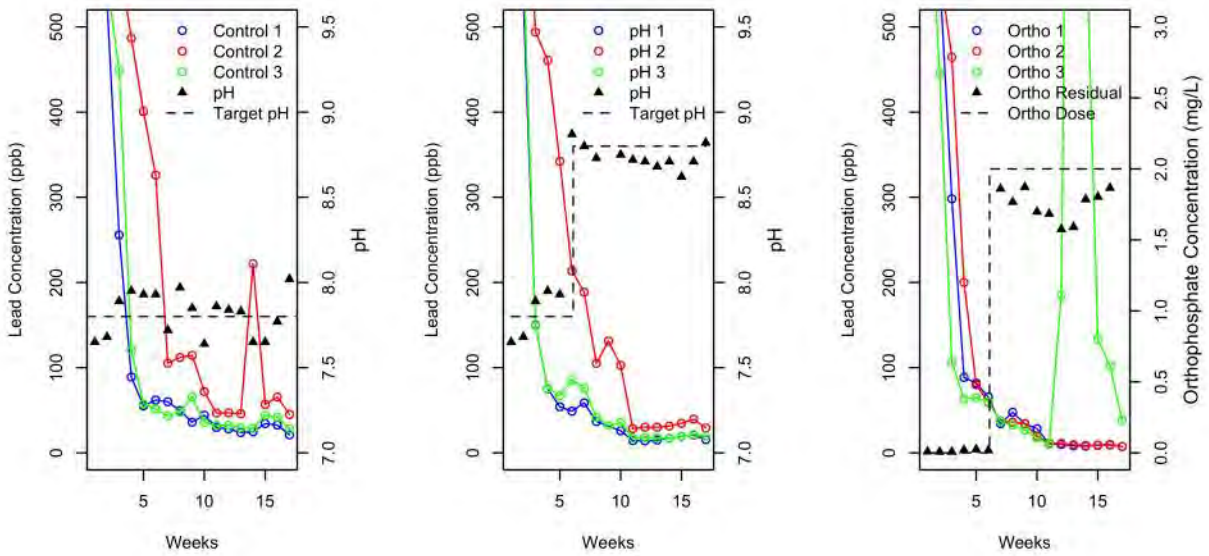


Figure 4. Time series of lead concentration data from lead solder coupons in Marston Water

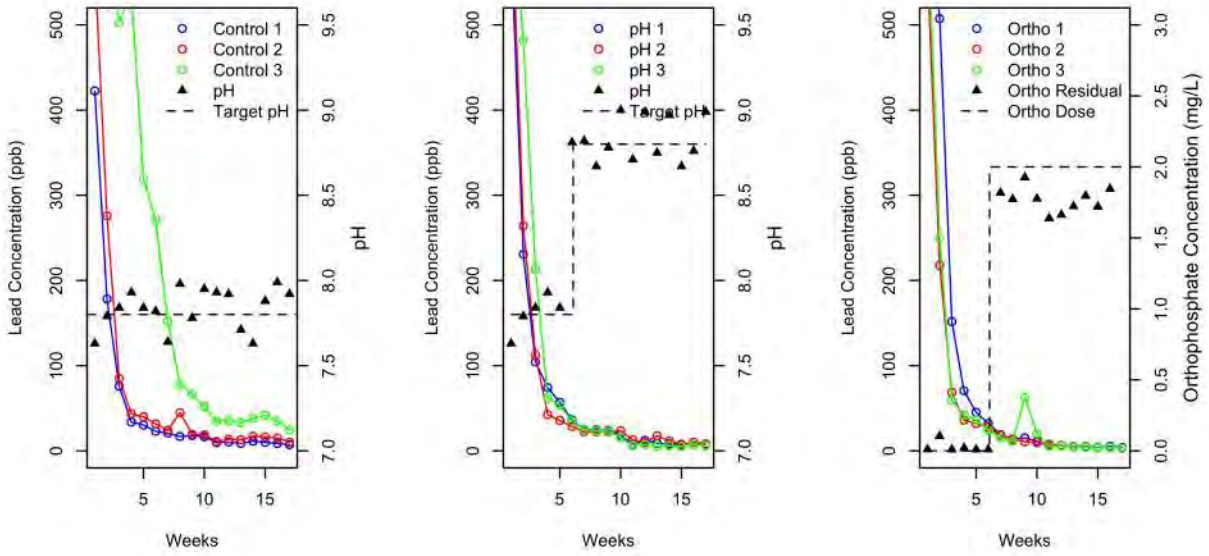


Figure 5. Time series of lead concentration data from lead solder coupons in Moffat Water

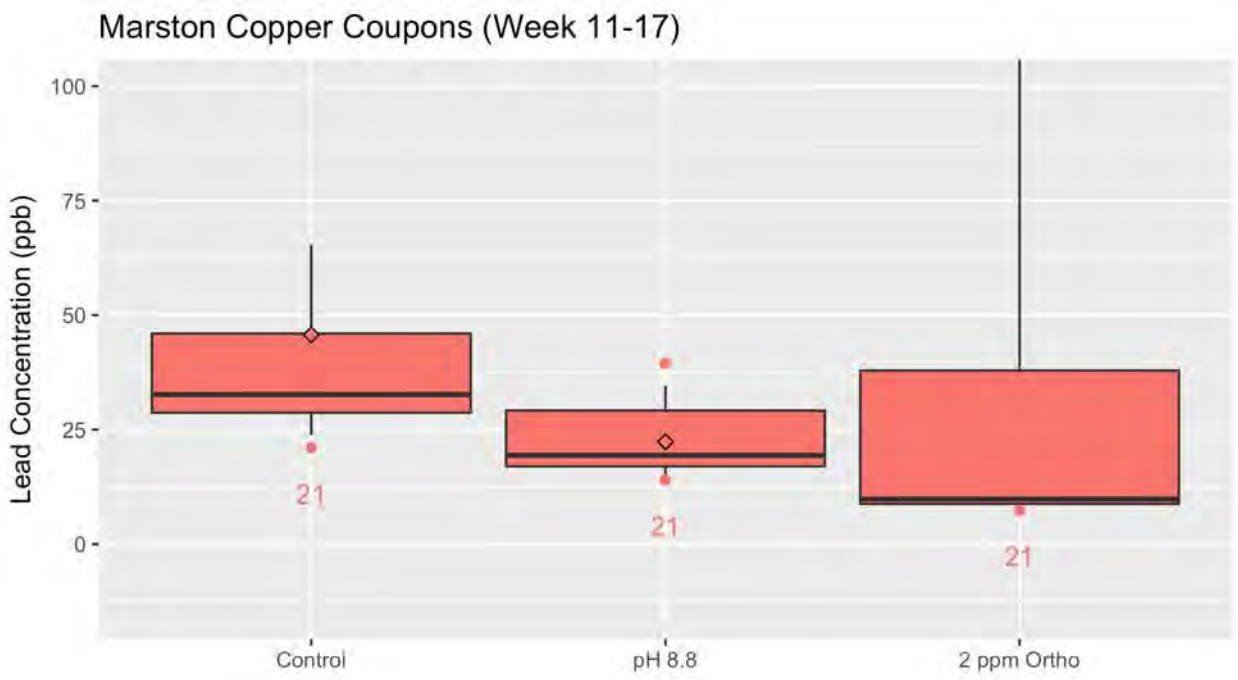


Figure 6 Boxplots of lead concentration data from lead solder coupons in Marston Water

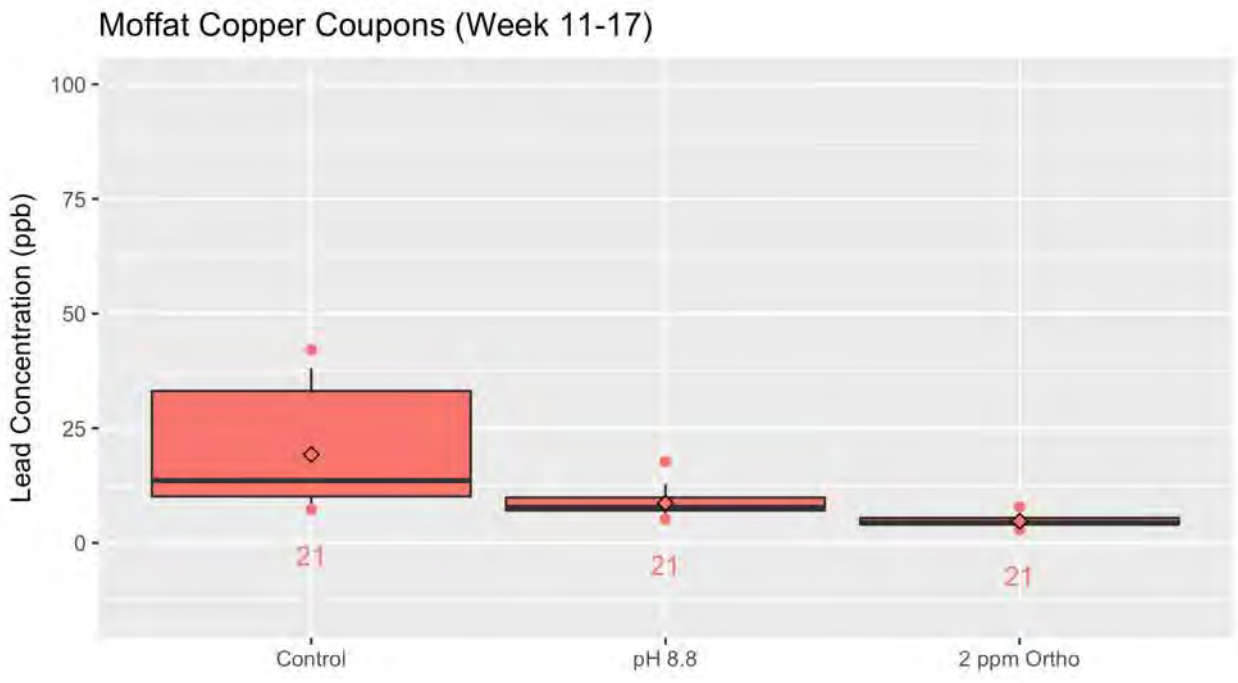


Figure 7 Boxplots of lead concentration data from lead solder coupons in Moffat Water.

The distribution of lead reductions between the control and the treatments was calculated using all the possible combinations of the data without duplication for Marston and Moffat coupons. The distributions of lead reductions are also shown as histograms in Figure 10. The results of the reduction calculations are summarized in Table 7. For both Marston and Moffat, the median lead reduction is greater for the orthophosphate treatment compared to the pH treatment. In other words, the orthophosphate treatment results in greater lead reduction compared to the pH adjustment.

Because negative removals are not expected as a result of the treatment conditions (but instead of variability that is independent of the treatment condition), we recalculated the statistics with all reductions below zero excluded from the analysis (Table 8). Box plots of these data are presented in Figure 8 and Figure 9. Distributions of lead reductions are also shown as histograms in Figure 10 after a 5,000 sample bootstrap.

Table 7 Summary of lead reduction data comparing to control to the treatment conditions

	Marston		**Moffat**	
	pH 8.8	2 ppm Ortho	pH 8.8	2 ppm Ortho
Mean (%)	37	-280	38	66
Variance ($\%^2$)	960	11387	1425	350
Standard Deviation (%)	31	1067	38	19
Minimum (%)	-88	-7449	-142	-8
1st Quartile (%)	22	-17	18	53
Median (%)	40	68	44	68
3rd Quartile (%)	58	78	70	84
Maximum (%)	94	97	88	93

Table 8 Summary of lead reduction data comparing to control to the treatment conditions

	Marston		**Moffat**	
	pH 8.8	2 ppm Ortho	pH 8.8	2 ppm Ortho
Mean (%)	46	72	49	67
Variance ($\%^2$)	434	183	593	342
Standard Deviation (%)	21	14	24	19
Minimum (%)	0	10	1	9
1st Quartile (%)	32	66	29	54
Median (%)	46	74	50	68
3rd Quartile (%)	61	80	71	84
Maximum (%)	94	97	88	93

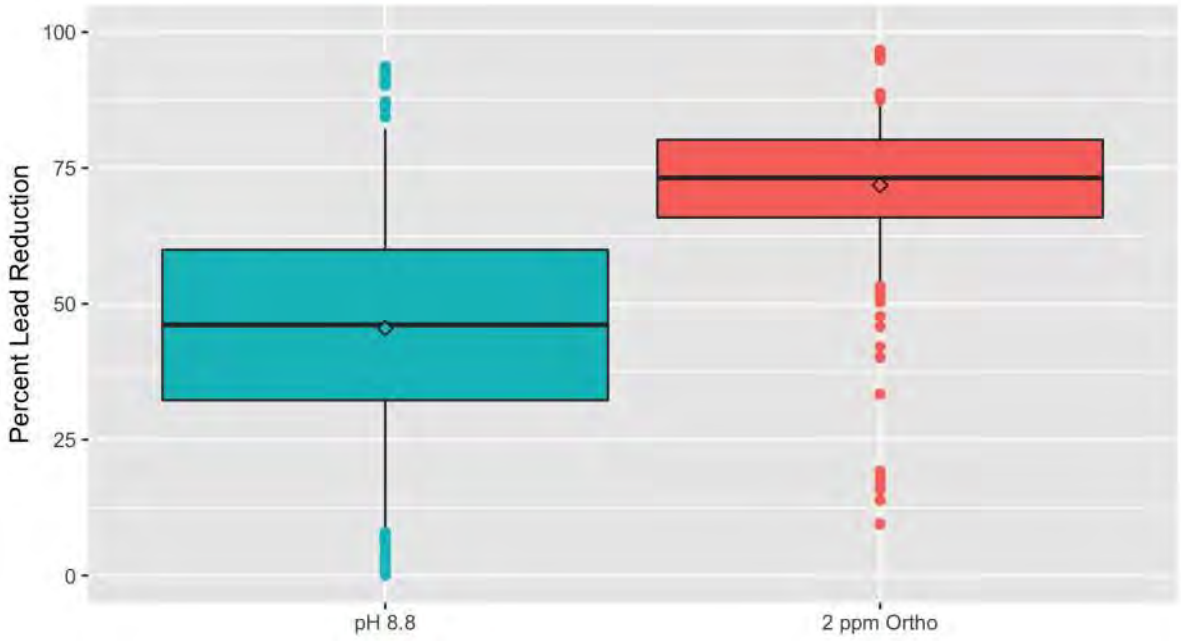


Figure 8 Distribution of percent reduction comparing the control condition to the treatment conditions at Marston

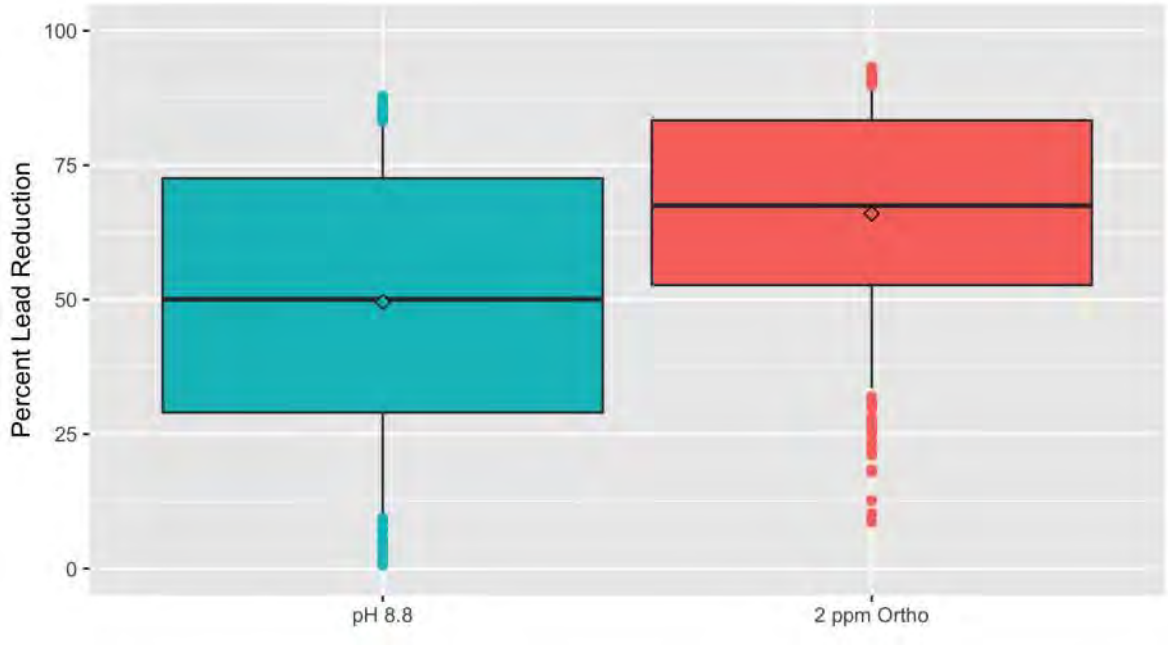


Figure 9 Distribution of percent reduction comparing the control condition to the treatment conditions at Moffat

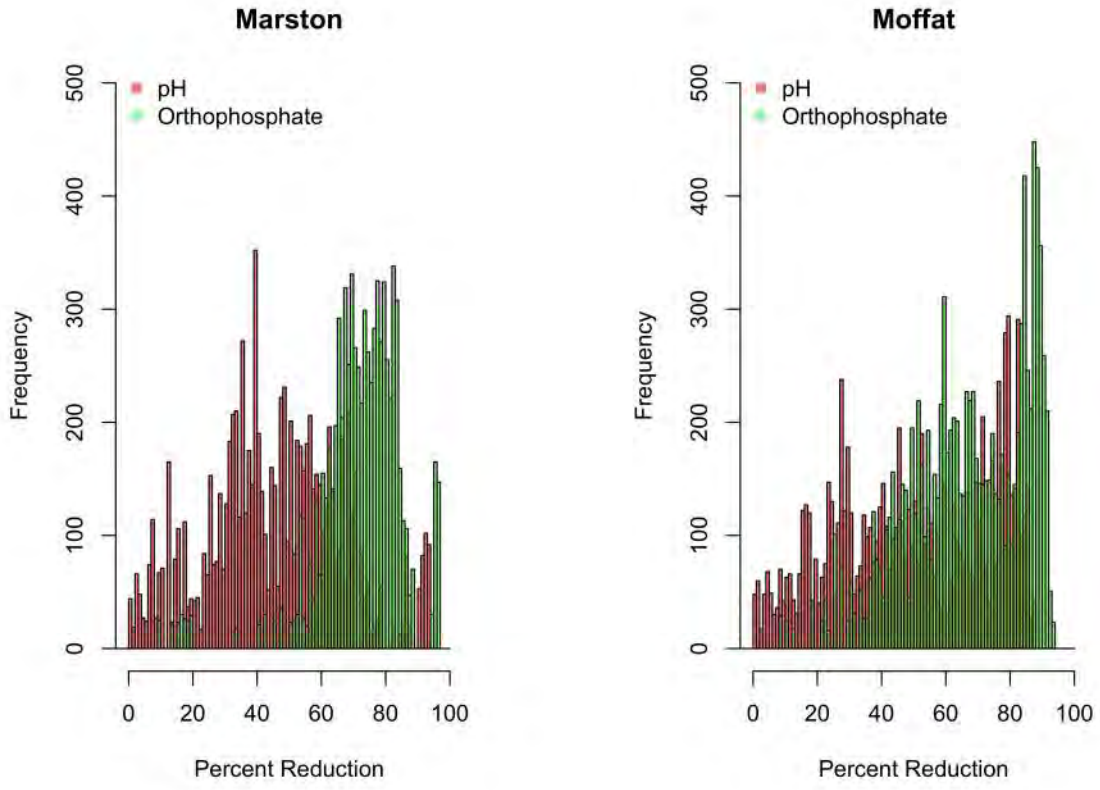


Figure 10 Distributions of lead reduction comparing the control to the treatments in Marston and Moffat coupons

Copper Data for Immersion Study Conditions

The descriptive statistics and illustrations included below compare copper release data from copper with lead solder immersion studies using Marston and Moffat Plant influent water under conditions of an orthophosphate dose of 2 mg/L, pH adjustment to 8.8 and a control. Only data from the last 7 weeks of the treatment are used in the calculations. Copper concentration data for the three treatment conditions are summarized in Table 9.

Table 9 shows that the median and median copper concentrations were lower for both pH adjustment and orthophosphate compared to the control regardless of the source water. For the Marston coupons the mean and median copper concentration for orthophosphate slightly lower than the pH treatment. For the Moffat coupons, the mean and median copper concentration was slightly lower for pH treatment compared to orthophosphate addition.

Table 9 Summary of copper concentration data for immersion study (Week 11-17)

	Marston			Moffat		
Condition	Control	pH	Orthophosphate	Control	pH	Orthophosphate
Mean (ppb)	406.7	185.4	154.5	371.8	134.9	142.1
Variance (ppb ^{2})	1758.5	550.8	10.74.1	4053.4	357.5	219.3
Standard Deviation (ppb)	41.9	23.5	32.8	63.7	18.9	14.8
Minimum (ppb)	344.9	154.1	50.3	250.7	101.9	118.8
1st Quartile (ppb)	380.6	167.1	146.0	323.4	121.5	133.3
Median (ppb)	394.6	180.7	165.4	360.9	136.5	138.9
3rd Quartile (ppb)	447.3	201.2	171.8	416.8	142.8	145.0
Maximum (ppb)	514.6	239.4	201.1	481.6	173.1	187.0

Copper Illustrations

Copper concentration data for the Marston coupons and the Moffat coupons over time are shown in Figure 11 and Figure 12, respectively. For the Marston and Moffat coupons copper release increased during the conditioning phase. After the treatment changes were made copper continued to increase in the control condition but decreased in the two conditions where treatment was added.

The copper concentration data for the Marston and Moffat coupons are also shown as boxplots grouped based on the condition for the last 7 weeks of the study (Figure 13 and Figure 14). The boxplots show that copper release in the control conditions was more variability compared to the treatment conditions. Similar to the lead data, control charts were developed for the copper release data for the three conditions tested in Marston and Moffat Water Racks (Figure 24 and Figure 29) in Appendix.

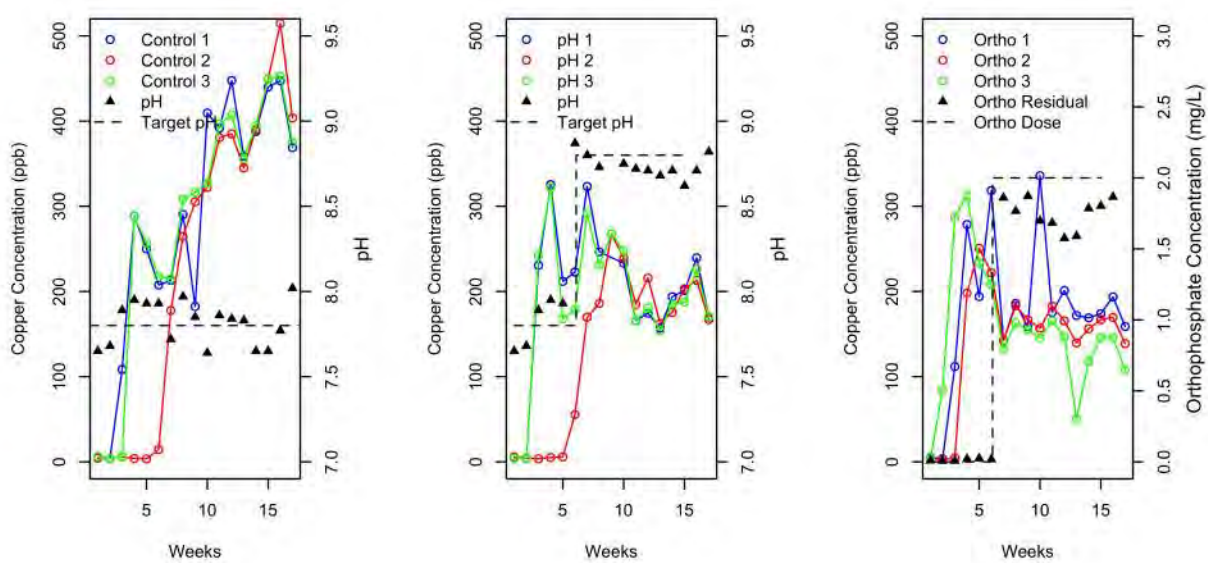


Figure 11. Time series of copper concentration data from lead solder coupons in Marston Water.

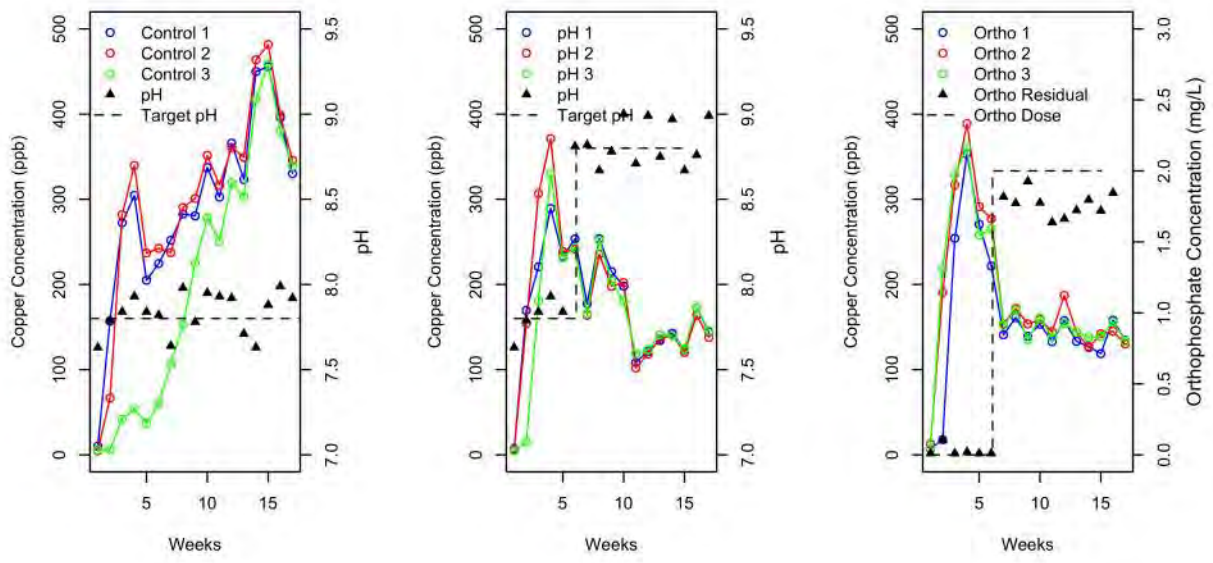


Figure 12. Time series of copper concentration data from lead solder coupons in Moffat Water.

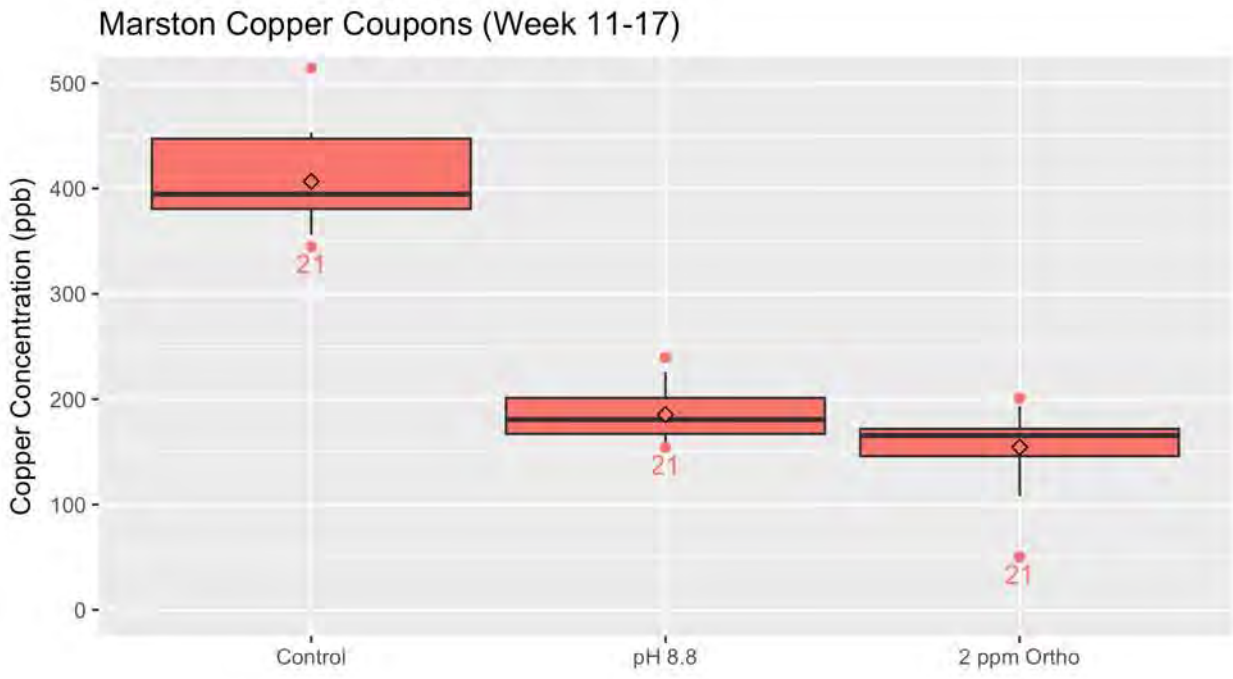


Figure 13 Boxplots of copper concentration data from lead solder coupons in Marston Water

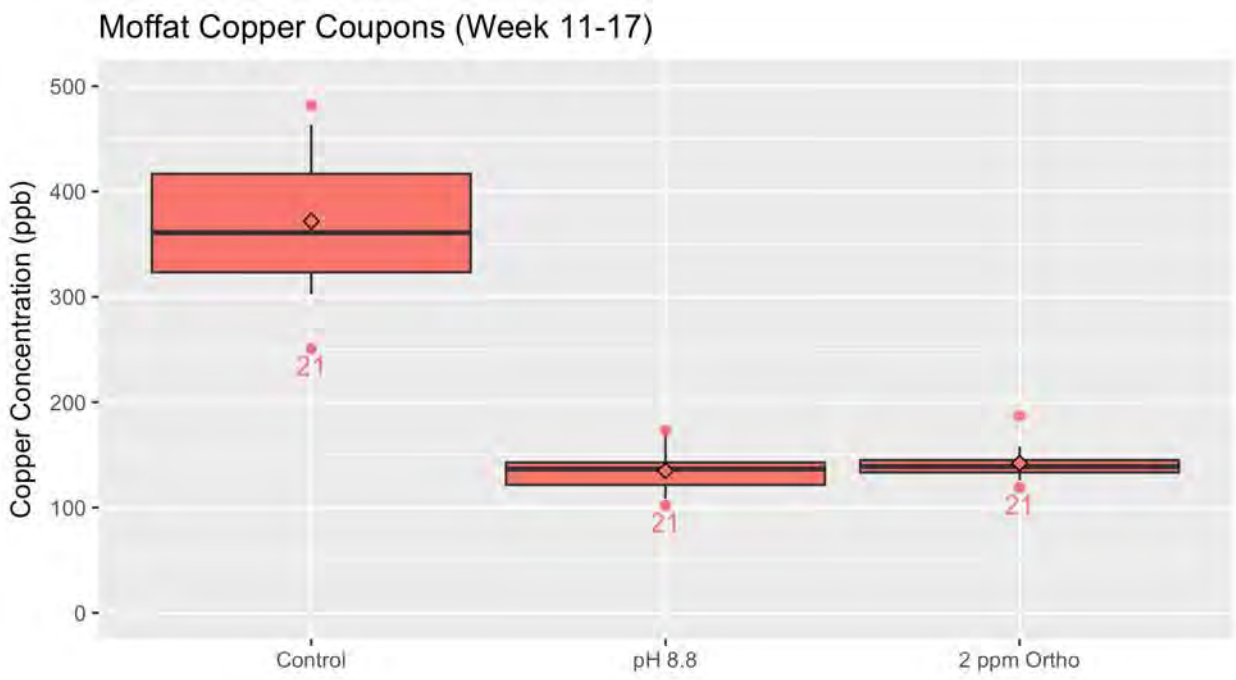
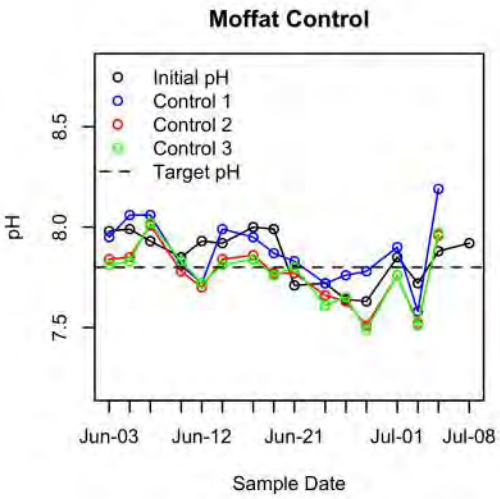


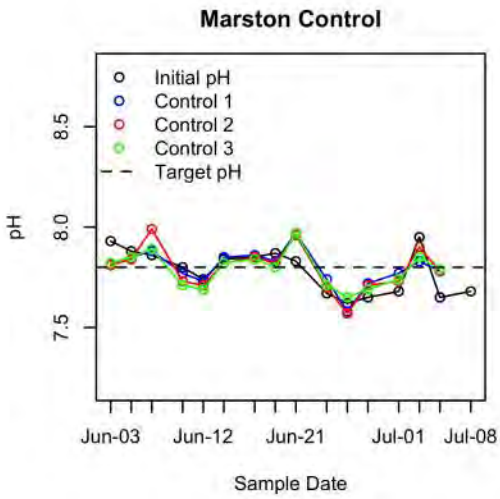
Figure 14 Boxplots of copper concentration data from lead solder coupons in Moffat Water

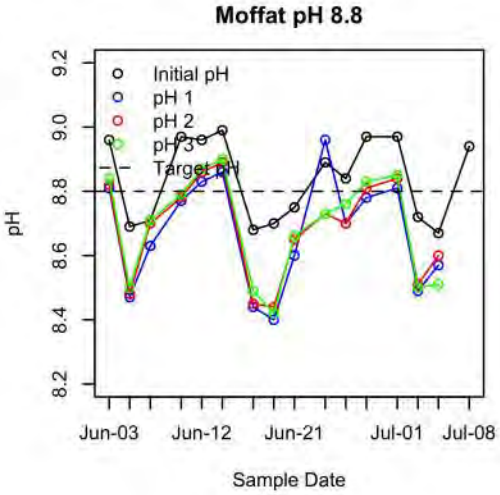
Summary & Conclusions

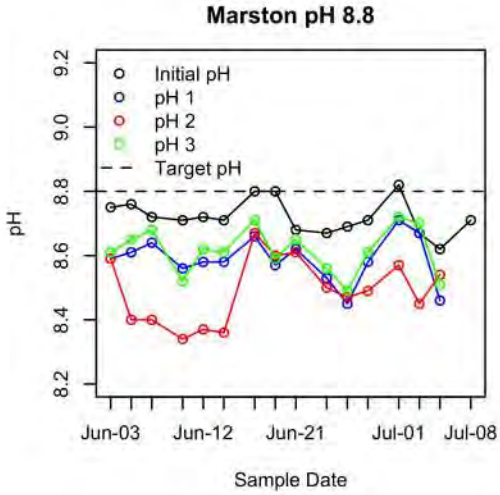
We conclude that the median lead release from copper with lead solder was lower for orthophosphate treatment compared to pH adjustment for both Moffat and Marston waters. The median lead reductions from 2 mg/L as PO_4 were 74% and 68% from Marston and Moffat, respectively. For pH control at pH of 8.8, the median lead reductions were 46% and 50% from Marston and Moffat, respectively.

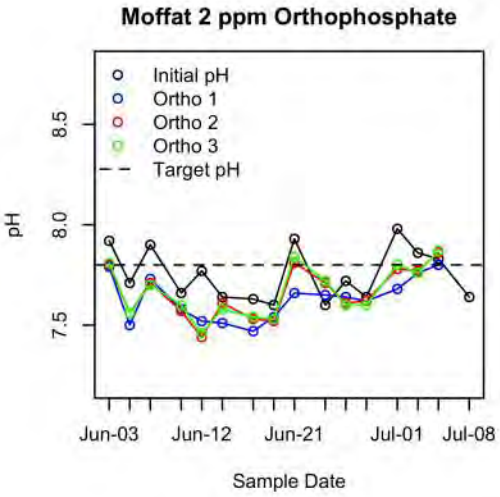
Appendix


Moffat Control
Initial pH
Control 1
Control 2
Control 3
Target pH
pH
7.5
8.0
8.5
Jun-03
Jun-12
Jun-21
Jul-01
Jul-08
Sample Date


Marston Control
Initial pH
Control 1
Control 2
Control 3
Target pH
pH
7.5
8.0
8.5
Jun-03
Jun-12
Jun-21
Jul-01
Jul-08
Sample Date


Moffat pH 8.8
Initial pH
pH 1
pH 2
pH 3
Target pH
pH
8.2
8.4
8.6
8.8
9.0
9.2
Jun-03
Jun-12
Jun-21
Jul-01
Jul-08
Sample Date


Marston pH 8.8
Initial pH
pH 1
pH 2
pH 3
Target pH
pH
8.2
8.4
8.6
8.8
9.0
9.2
Jun-03
Jun-12
Jun-21
Jul-01
Jul-08
Sample Date


Moffat 2 ppm Orthophosphate
Initial pH
Ortho 1
Ortho 2
Ortho 3
Target pH
pH
7.5
8.0
8.5
Jun-03
Jun-12
Jun-21
Jul-01
Jul-08
Sample Date

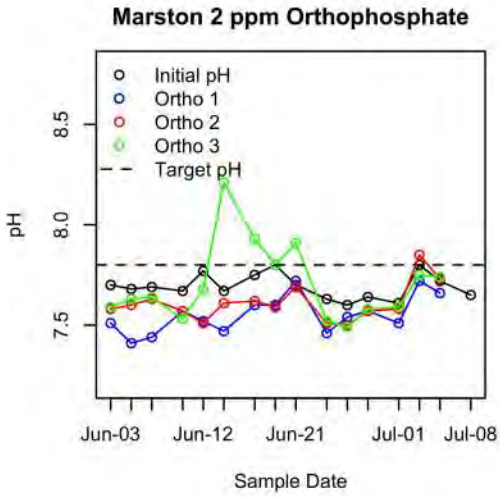

Marston 2 ppm Orthophosphate
Initial pH
Ortho 1
Ortho 2
Ortho 3
Target pH
pH
7.5
8.0
8.5
Jun-03
Jun-12
Jun-21
Jul-01
Jul-08
Sample Date

Figure 15. pH in the glass reactors before and after water change

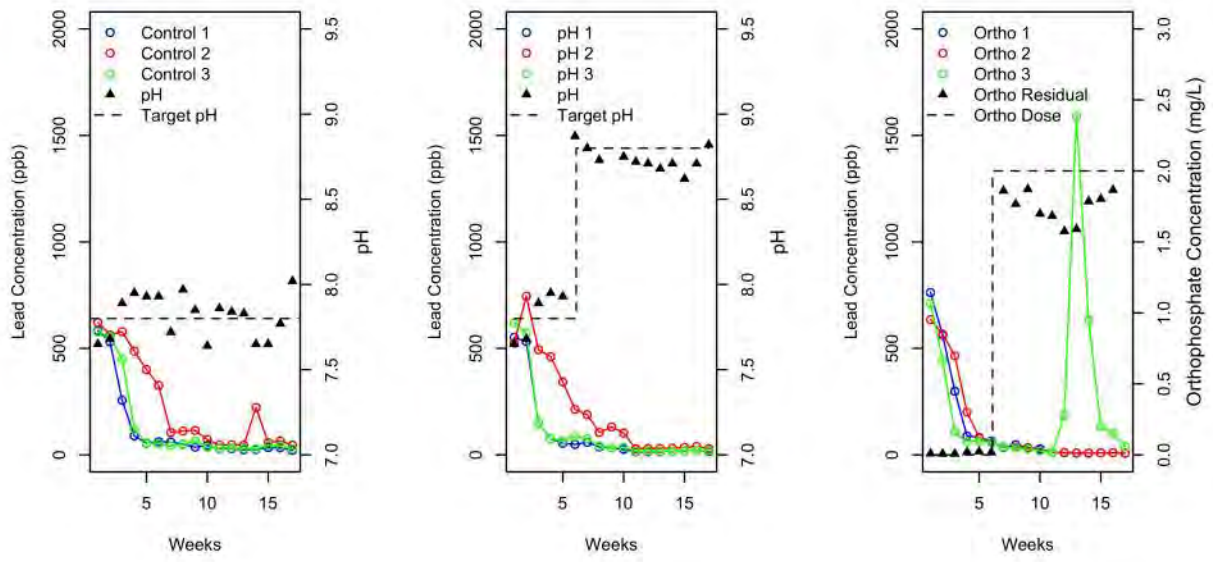


Figure 16. Time series of lead concentration data from lead solder coupons in Marston Water

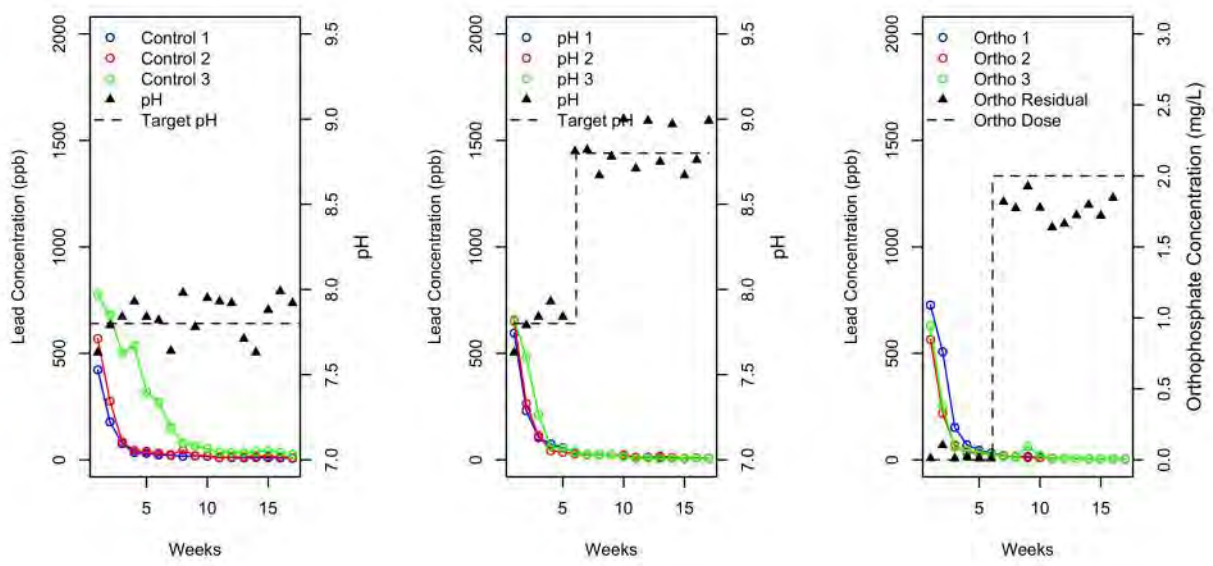


Figure 17. Time series of lead concentration data from lead solder coupons in Moffat Water

Lead Control Charts

Control charts were developed for the lead release data for the three conditions tested in Marston and Moffat Water Racks for data used in the analysis. The control charts display a series of mean day lead

concentrations throughout the experimental period. The center line is equal to the mean of all samples collected and the upper and lower control limits indicate the threshold at which the process output is considered statistically out of control and are drawn at three standard deviations from the center line. The data identified in red indicate data out of control while data identified in yellow indicate when the mean lead concentration for at least seven consecutive weeks with data available fall on one side of the center line. The control chart refers to these points as "violating runs."

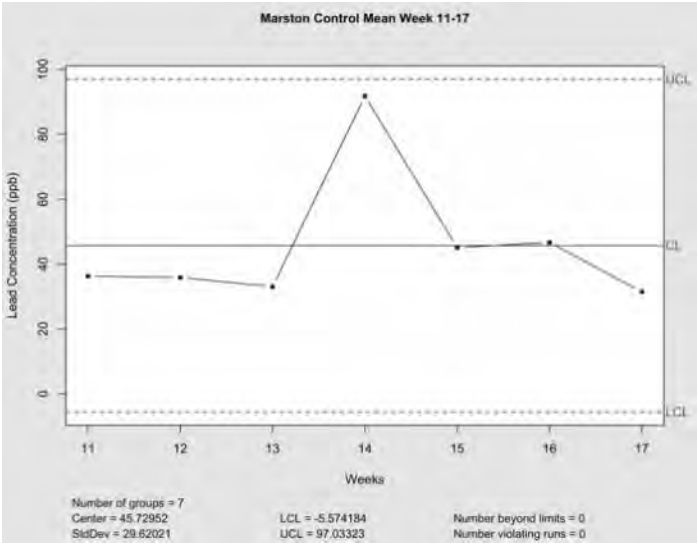


Figure 18 Control charts for pooled lead concentration data from the Marston control coupons

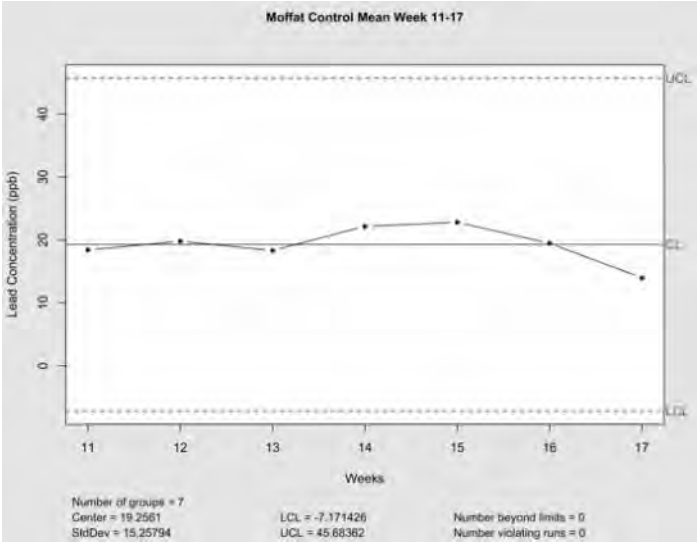


Figure 19 Control charts for pooled lead concentration data from the Moffat control coupons

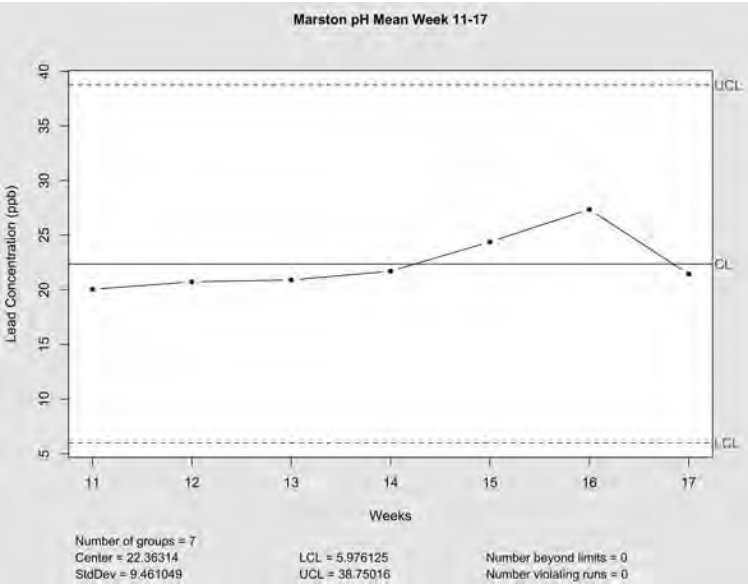


Figure 20 Control charts for pooled lead concentration data from the Marston pH coupons

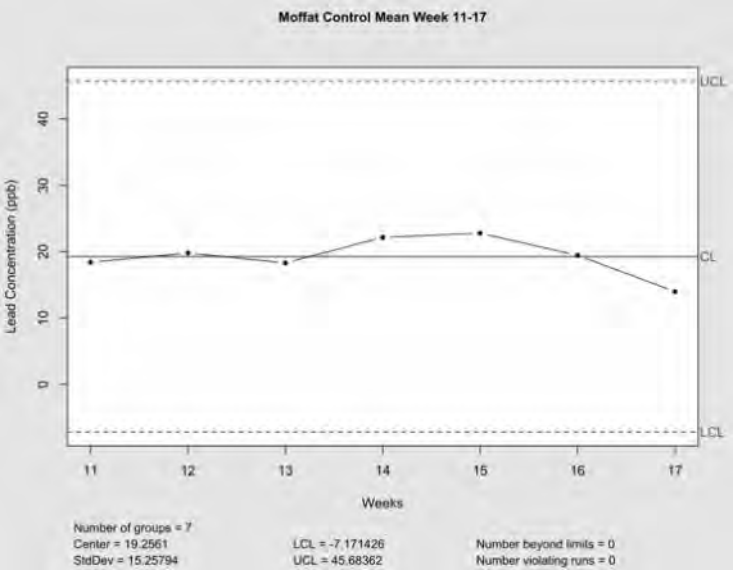


Figure 21 Control charts for pooled lead concentration data from the Moffat pH coupons

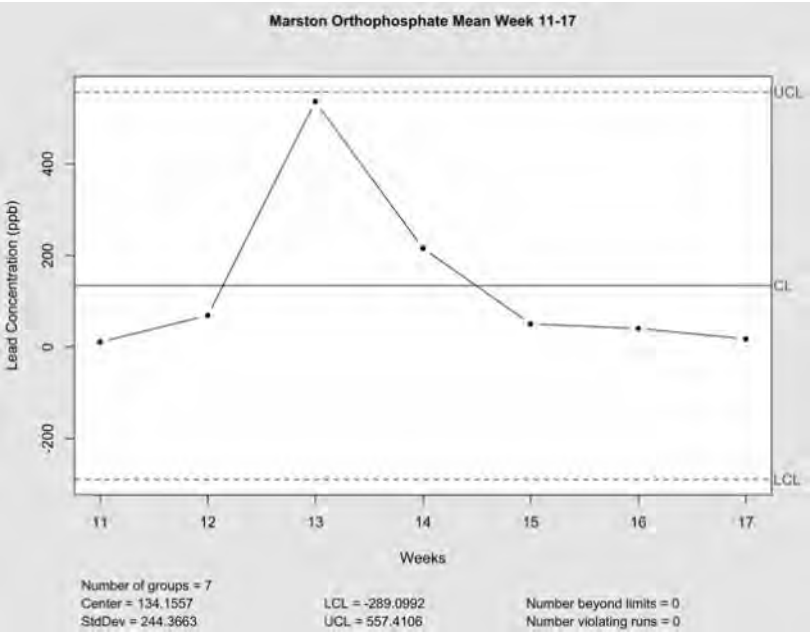


Figure 22 Control charts for pooled lead concentration data from the Marston orthophosphate coupons

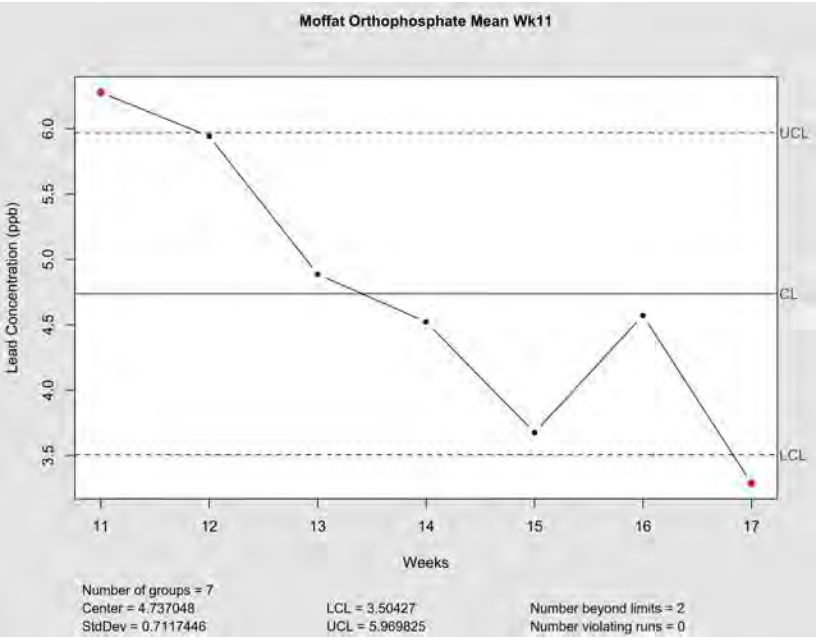


Figure 23 Control charts for pooled lead concentration data from the Moffat orthophosphate coupons

Copper Control Charts

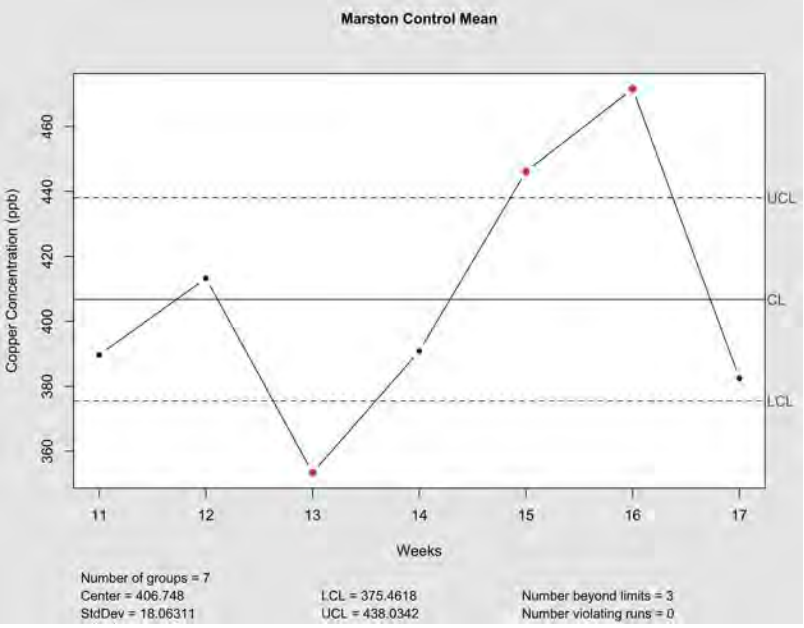


Figure 24 Control charts for pooled copper concentration data from the Marston control coupons

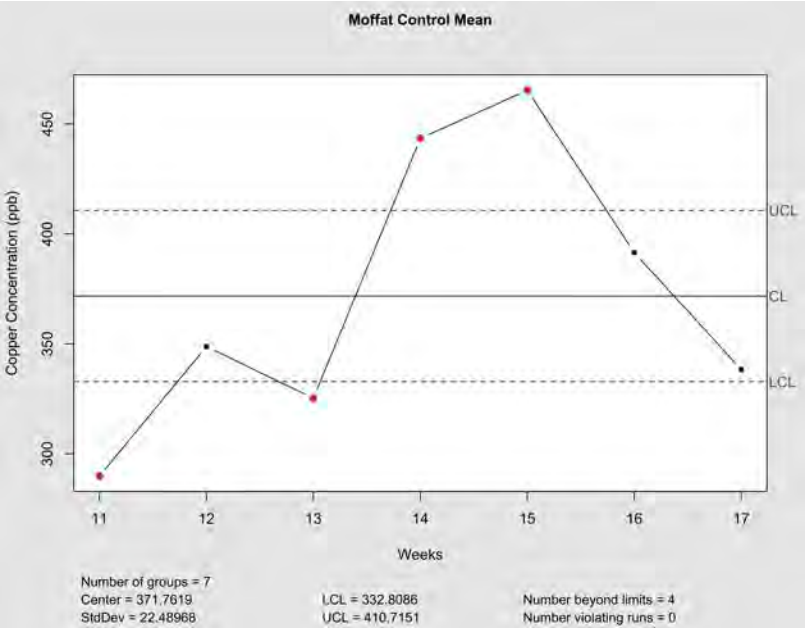


Figure 25 Control charts for pooled copper concentration data from the Moffat control coupons

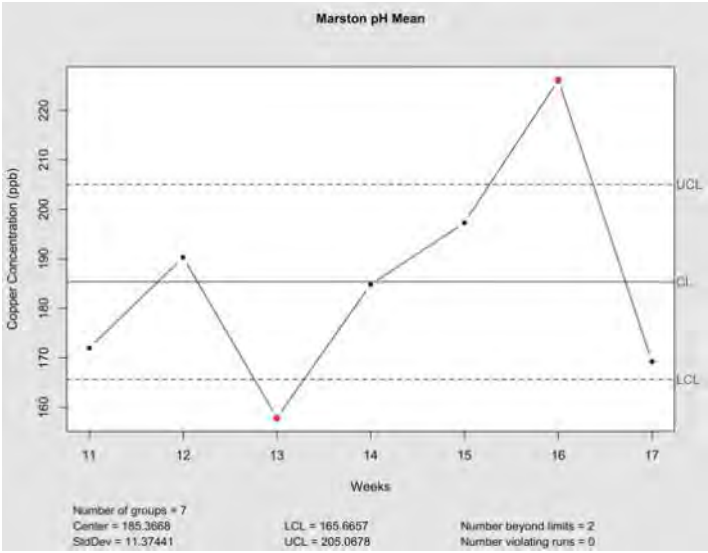


Figure 26 Control charts for pooled copper concentration data from the Marston pH coupons

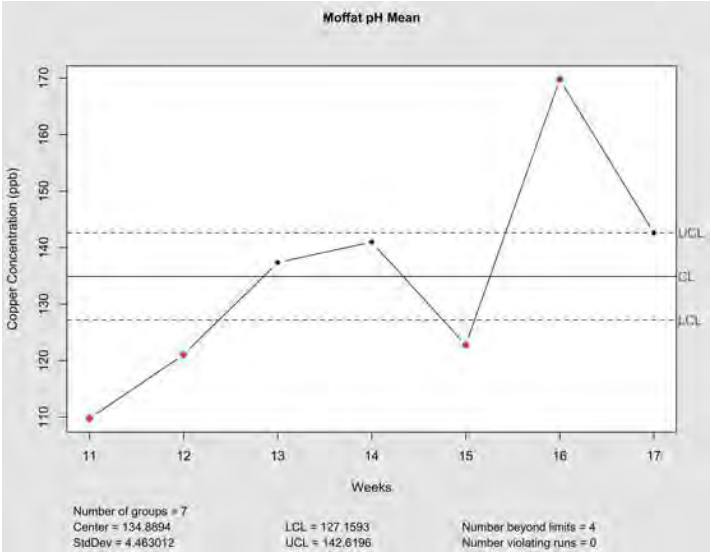


Figure 27 Control charts for pooled copper concentration data from the Moffat pH coupons

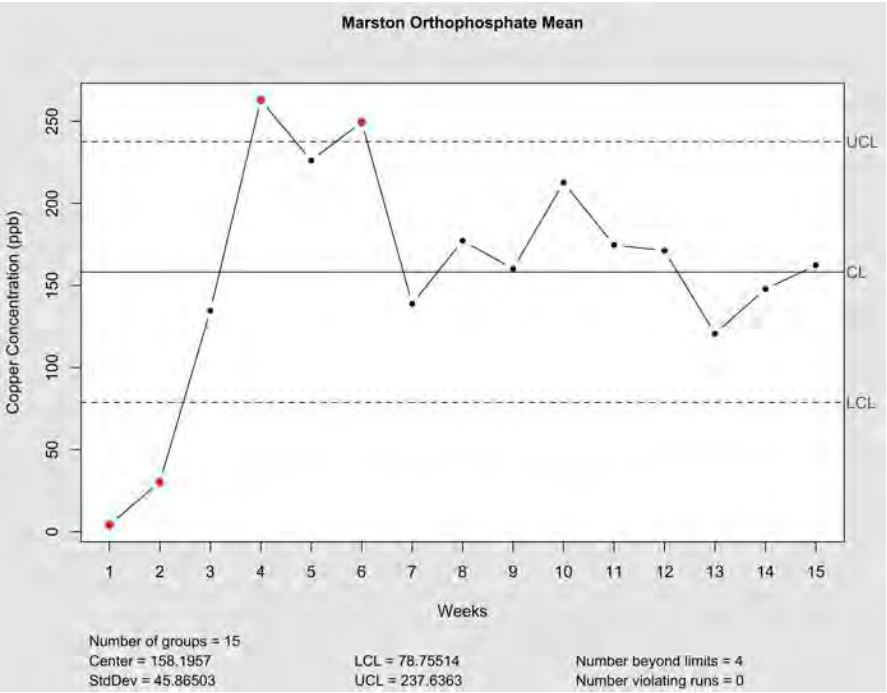


Figure 28 Control charts for pooled copper concentration data from the Marston orthophosphate coupons

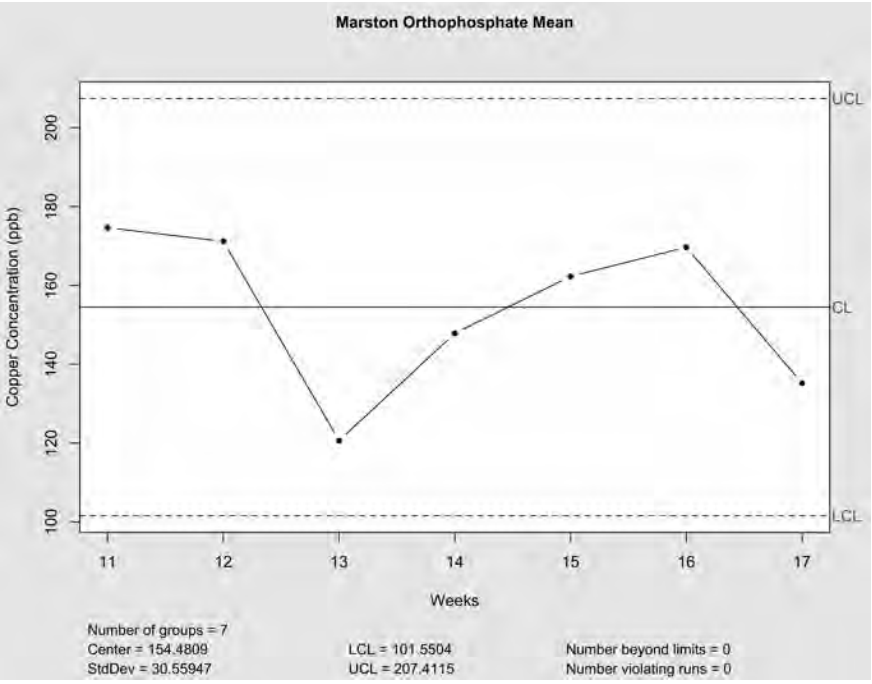


Figure 29 Control charts for pooled copper concentration data from the Moffat orthophosphate coupons

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APPENDIX III.E.3 – NITRIFICATION POTENTIAL OF ORTHOPHOSPHATE ADDITION AND INCREASED pH

September 2019

DENVER WATER

Appendix III.E.3:

Nitrification Potential of Orthophosphate Addition and Increased pH

Date: September 5, 2019

To: Denver Water

From: Corona Environmental Consulting, LLC

Introduction

The purpose of this appendix is to investigate the potential impacts of the two corrosion control strategies on nitrification occurrence in Denver Water's distribution system. Both corrosion control alternatives, orthophosphate addition and pH adjustment, have the potential to alter microbial communities within the distribution system by altering the C-N-P balance with the addition of phosphate, or by inhibiting microbial growth by increasing the pH.

Nitrification in chloraminated water systems is a common occurrence (AWWA 2013) and has been known to occur within Denver Water's distribution system. Nitrification was investigated in a 2016 Water Quality Model and Study completed by Bohannan Huston (2016), which concluded that episodic nitrification was observed in certain areas of the distribution system generally from September through November. These episodes coincided with decreases in production, and therefore, longer residence times (Bohannan Huston, 2016).

Nitrification is a two-step process that consists of a chemical reaction followed by a biological reaction. The chemical reaction is the auto decomposition of monochloramine which liberates free ammonia to the water. The biological reaction occurs when nitrifying bacteria use the free ammonia as a substrate, consuming the residual disinfectant. Nitrification is typified by the loss of the chloramine residual, increased microbial activity, depressed pH in poorly buffered waters, and the presence of nitrite and nitrate. Waters undergoing nitrification have also been shown to increase the concentrations of N-nitrosamines, such as N-nitrosodimethylamine (NDMA) and total N-nitrosamines (TONO), as well as disinfection by-products (DBPs) in chloraminated drinking water distribution systems depending on water quality conditions (Zeng & Mitch, 2016).

Data Review and Findings

The biological nitrification process requires specific water quality conditions to proceed, such as the bioavailability of nutrients (carbon, nitrogen, and phosphorus) and favorable pH and temperatures to promote nitrifying bacteria growth.

Nitrifying bacteria are mostly autotrophic, using inorganic carbon as their carbon source. In Denver Water's system this carbon source is carbonate. If an abundance of organic carbon exists in a system from the background organic matter, heterotrophic bacteria will outcompete nitrifiers and inhibit nitrification. Thus, nitrification is expected to proceed when there is high nitrogen concentration relative to

bioavailable carbon. Nitrification conditions are favorable in Denver Water's system as nitrogen is added during treatment as ammonia for chloramine formation.

The Marston and Moffat Treatment Plants' treated water nutrient conditions in terms of ammonia and bioavailable carbon are presented by a box and whisker plot in Figure 1. The box represents the range from the first to the third quartile with the whiskers extending to the 5th and 95th percentiles. Data outside these ranges are shown as individual dots. Assimilable organic carbon was estimated based on 10% of total organic carbon (TOC) being bioavailable (Camper et al., 2000; Terry & Summers, 2018). Ammonia nitrogen was calculated from the total chlorine residual in the lead pilot, assuming Denver Water's target chlorine-to-ammonia-as-nitrogen ratio of 4.5:1 (by mass). Denver Water's carbon and ammonia conditions lie within the region of heterotrophic and nitrifying bacteria colonization and is close to the region in which nitrifying bacteria dominate (Verhagen & Laanbroek, 1991). This indicates a high potential for nitrification and suggests the biological reaction is limited elsewhere.

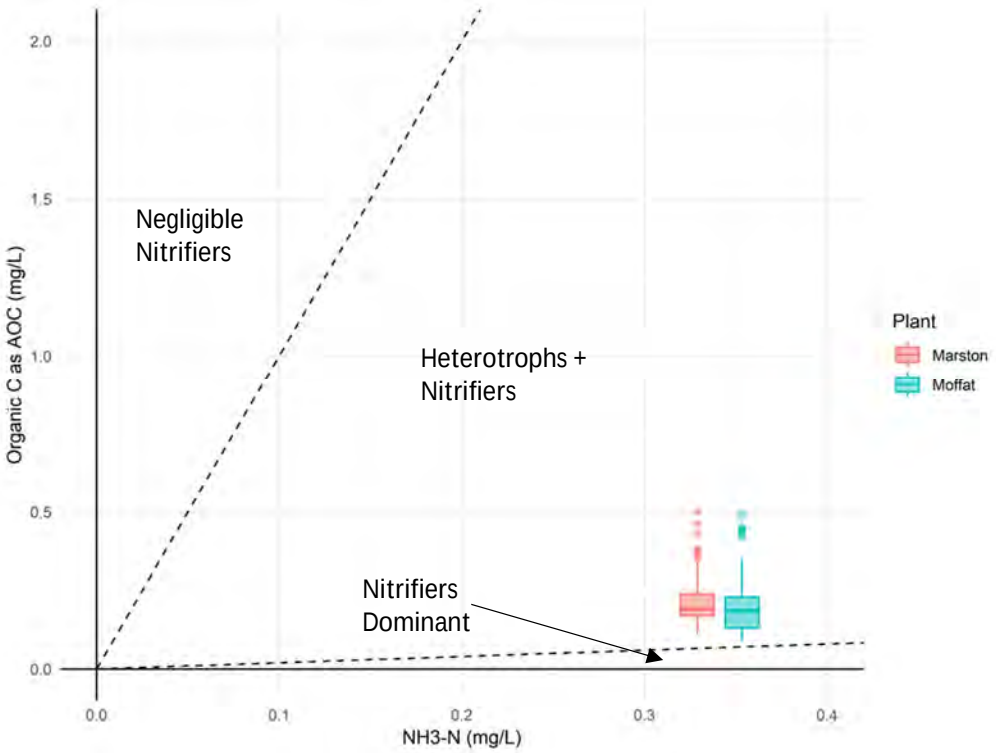

Figure 1 Effluent organic carbon and nitrogen concentrations at the Marson and Moffat Treatment Plants

Limited phosphorus concentrations in drinking water may inhibit the growth of nitrifiers in drinking water systems (AWWA, 2013). Specifically, phosphorus concentrations below 10 µg/L-P are considered limiting and concentrations below 25 µg/L-P are considered potentially limiting (AWWA, 2013). Furthermore, a study conducted by van der Aa et al. (2000) observed that in order to maintain sufficient nitrification, phosphorus concentrations of at least 10 µg/L-P are required. They also observed that concentrations of 30 µg/L-P are required to re-establish ammonia removal by nitrifiers at low temperatures. Phosphorus results obtained from the lead pilot are presented as a box and whiskers plot in Figure 2. Phosphorus in these systems originates from the source water, as phosphorus is not added as part of existing operations. These results indicate that nitrification in Denver Water's distribution system may be phosphorus limited. While phosphorus limitation in drinking waters is uncommon, it is not unexpected at Denver Water as the

water sources are first-use mountain runoff with few anthropogenic sources of phosphorus. Furthermore, any influent phosphorus is subject to coagulation with alum which tends to bind a fraction of the phosphorus for removal within the treatment plant.

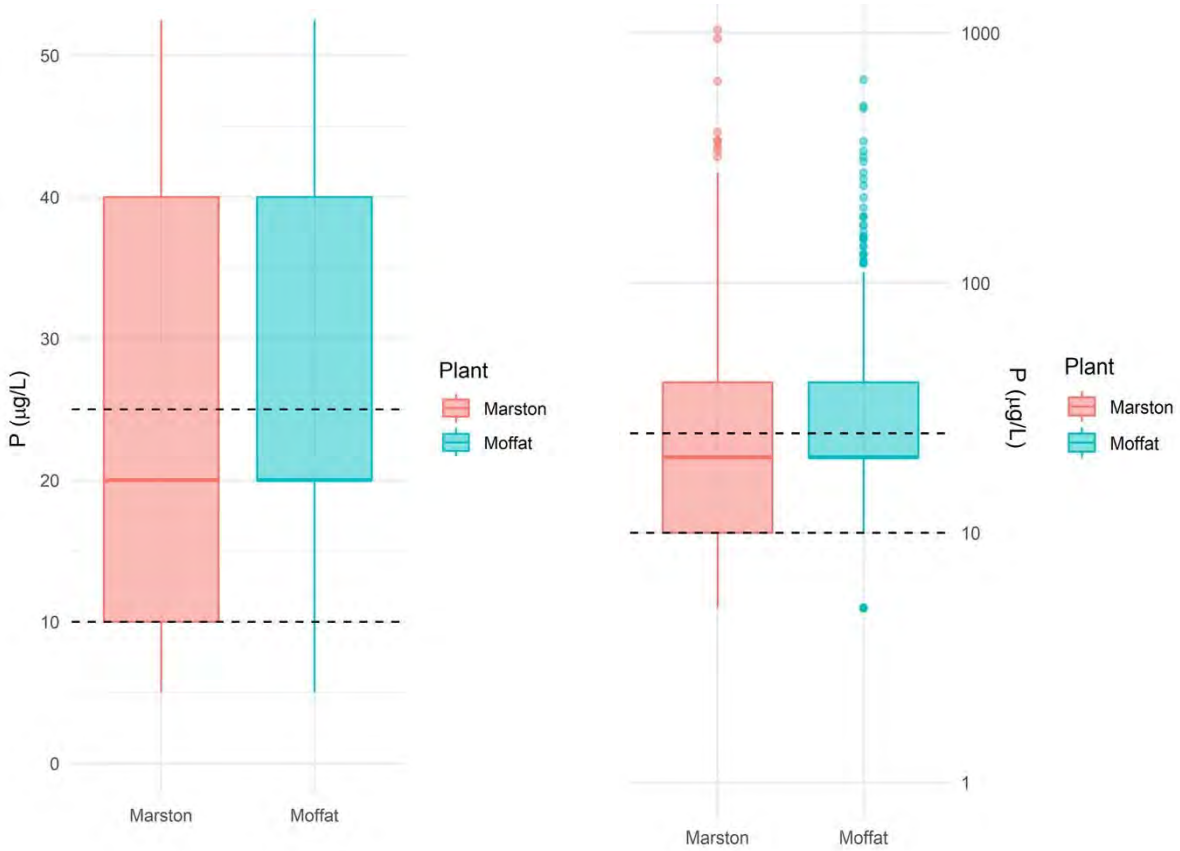

Figure 2 Marson and Moffat plants' influent phosphorus concentrations in arithmetic scale (a) and logarithmic scale (b). The 10 µg/L line represents the minimum concentration of phosphorus required to promote microbial activity, while the 25 µg/L dashed line represents potential phosphate limiting conditions.

Orthophosphate Addition

The addition of orthophosphate for corrosion control in the phosphorus limited distribution system is expected to increase nitrification frequency and severity. Consequently, Denver Water will have to proactively monitor and prevent nitrification to avoid disinfectant residual loss in the distribution system. Lower pH or fluctuations in pH that have been observed in poorly buffered waters, may also exacerbate lead release.

Nitrification control includes strategies to slow the chemical auto decomposition reaction of monochloramine and strategies to inhibit the biological reaction. Denver Water already practices good control of the chemical reaction by i) coagulating organics to reduce concentrations and stabilize the chloramine residual and ii) carefully controlling the chlorine-to-ammonia-as-nitrogen ratio during chloramine formation to minimize free ammonia in the effluent water. The most effective nitrification control strategy available to Denver Water in an orthophosphate CCT scenario is to increase the chloramine dose to prevent the onset of nitrification (Pintar et al., 2005; Zhang et al., 2009; AWWA, 2013). However, increasing the chloramine residual in chloraminated systems can further increase NDMA, TONO,

and other DBPs, as nitrifying biofilms release these compounds' precursors (Zeng & Mitch, 2016). The ability to decrease water age is limited due to Denver Water's distribution system size and the storage management operating strategy. Increasing pH in the orthophosphate scenario as a means to inhibit nitrification is not practical without extensive study as it reduces the effectiveness of lead control (AWWA, 1996).

pH/Alkalinity Adjustment

Under the proposed Lead Reduction Program, corrosion control practices at Denver Water will be modified to operate at a pH of 8.8 instead of the current pH target of 7.8, thereby inhibiting nitrification. Increasing pH to above 8.3 reduces the growth of nitrifying bacteria and reduces chloramine decay (Zhang et al., 2009; AWWA, 2013). Furthermore, Kirmeyer et al. (1993) found that the chlorine-to-ammonia-as-nitrogen ratio became less important at pH above 8.3, as monochloramine residuals are more stable and dichloramine formation (and the associated taste and odor problems associated with dichloramine) is minimized.

Conclusions

Introducing orthophosphate to Denver Water's phosphorus-limited distribution system has the potential to create favorable conditions for microbial growth and consequently, nitrification. Alternatively, increasing pH to 8.8 is expected to inhibit microbial growth, and therefore reduce the potential for nitrification in Denver Water's distribution system. Denver Water has a nitrification action plan, which is due to be updated by the end of the year. This plan describes how chloramine formation is managed, the operations and maintenance practices to reduce water age, and the water quality monitoring program for the distribution system.

References

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APPENDIX IV.A - PROPOSED TERMS AND CONDITIONS

September 2019

DENVER WATER

Note: This document sets forth Denver Water's proposed terms and conditions that will control if the variance to the treatment technique and the modification to the designated OCCT is granted. This document is preliminary and subject to modification.

Denver Water's Proposed Terms and Conditions for its Variance Request for Optimal Corrosion Control Treatment under SDWA 42 U.S.C. § 300g-4(a)(3)

In furtherance of Denver Water's variance request from 40 C.F.R. § 141.82(e) of the Optimal Corrosion Control Treatment Requirements under the Safe Drinking Water Act's Lead and Copper Rule, Denver Water is submitting its proposed terms and conditions which control during the term of the variance approval. The following proposed terms and conditions will become binding on Denver Water only upon the date that a variance becomes effective and so long as the variance remains in place. Except as otherwise provide herein, Denver Water must continue to follow the compliance requirements under the provisions of the Lead and Copper Rule as promulgated under state and federal law, 5 CCR 1002-11, 40 C.F.R. § 141.80-141.91, and as may be modified in the future.

1. Definitions:

A. *"Action level"* has the same meaning as action level in the Lead and Copper Rule, 40 C.F.R. § 141.80(c) and §§ 11.26(1)(c) and (2)(b) of the Colorado Primary Drinking Water Regulations (5 CCR 1002-11).

B. "*Adoption*" or *"Adopted"* for the purposes of the filter survey means that the customer enrolled in the filter program is using a filter NSF/ANSI (53) certified for lead removal for drinking, cooking, and infant fed formula (ingestion). Respondents who indicate that they use bottled water or an alternative NSF/ANSI (53) certified filter for ingestion will count as having adopted the use of a filter under paragraph 5.G.i. below.

C. "*Contact*" means direct mailing, water bill inserts, door hangers, in person contact, email, phone calls, educational materials accompanying filters and cartridges, or any other direct communication channels identified in Denver Water's communications, outreach, and education plan. Communications via information posted on the Denver Water website, social media websites, water bills, distribution of filters and replacement cartridges alone, or public notices required as a corrective action or a failure to meet a condition are excluded from this definition.

D. *"Customer Premise"*, for the purpose of these terms and conditions only, means a property or a residential unit within a multi-family property that receives water service pursuant to a Denver Water or distributor tap license.

E. "*Customer(s) Enrolled in the Filter Program*" means a customer premise, as defined herein where there is a known, suspected or possible lead service line (LSL), that will automatically be distributed a filter under section 5 below, unless otherwise refused by the customer.

F. "*Day*" means calendar day.

G. "*Effective Date*" means ninety-one (91) calendar days following approval of the variance or issuance of the State's modification decision, whichever occurs later.

H. *"Integrated System(s)"* means the defined term used in section 11.42(4) of 5 CCR 1002-11, as may be modified in the future. Currently, "integrated system" is defined as a "wholesale system and one or more consecutive systems with distribution systems that are physically connected [that] . . . choose to operate in a manner where the wholesaler assumes responsibility for compliance with one or more regulatory requirements applicable to the supplier responsible for the consecutive system, if the requirements of … section 11.42(4) are met."

I. *"Ingestion"* means the use of tap water for drinking, cooking, and infant fed formula.

J. *"Investigated"* refers to any activity used to identify the service line materials including a lead water quality test, potholing, visual inspection, or other methods that allows for a determination of the service line material.

K. *"Known LSLs"* are based upon direct evidence that gives a 100% estimated probability that a service line is an LSL.

L. "*Known, suspected and possible LSLs*" collectively refers to known LSLs, suspected LSLs, and possible LSLs.

M. "*Lead and Copper Rule (LCR) Regulatory Sampling*" means the collection of lead and copper tap samples for homes that have lead solder without a lead service lines and homes with lead service lines sampled in accordance with § 11.26 of 5 CCR 1002-11 and 40 C.F.R. § 141.86.

N. Lead Reduction Program Plan (LRPP) means Denver Water's Lead Reduction Program Plan dated September 2019.

O. *"Lead Service Line" or "LSL"* 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. This definition is intended to be inclusive of the term "Lead Service Line" as defined under section 11.26(1)(g) of 5 CCR 1002-11 and 40 C.F.R. § 141.2.

P. *"LSL Replacement"* is defined in paragraph 4.B, below.

Q. "*Orthophosphate Treatment*" means phosphate-based treatment as described in the Colorado Department of Public Health and Environment's (CDPHE) March 20, 2018 letter to Denver Water designating orthophosphate as optimal corrosion control treatment.

R. *"Possible LSLs"* are based on conflicting or missing data that provides an estimated probability value between 50% to 79% that a service line is an LSL.

S. "*Program Year*" has the same meaning as calendar year.

T. "*Public Notice*" for the purpose of this variance means either:

i. a Tier 2 public notice as described in § 11.33 of 5 CCR 1002-11 and 40 C.F.R. § 141.203, initiated within thirty (30) days following a CDPHE notice of a violation of the variance with messaging approved by CDPHE provided to all customers served by Denver Water;

ii. a public notice that contains the same elements of Tier 2 Public Notice described above initiated within sixty (60) days after learning of the need for corrective action provided to customers enrolled in the filter program to be delivered by making at least two (2) forms of direct contact with the customer subset, with messaging approved by CDPHE;

iii. a public notice by Denver Water that meets the requirements as described in § 11.26(7) of 5 CCR 1002-11 and 40 C.F.R. § 141.85, including public education associated with the Lead and Copper Rule initiated within sixty (60) days to all recipients specified in § 11.26(7)(c) of 5 CCR 1002-11 and 40 C.F.R. § 141.85(b);[1]

iv. a notice included in Denver Water's annual summary report; or

v. a Tier 3 public notice as described in § 11.33(4) of 5 CCR 1002-11 and 40 C.F.R. § 141.204, initiated as soon as possible but no later than 365 days following a violation or situation notification from CDPHE.

U. *"Suspected LSLs"* are based upon available data that provides an estimated probability value between 80% to 99% estimated probability (i.e. homes built before 1951) that a service line is an LSL.

V. *"System*" means the community water system that Denver Water owns and operates (PWS ID# CO0116001) and the integrated systems covered under Master Meter, Read and Bill, and Total Service agreements with Denver Water as detailed in Appendix III.B.1 of the Lead Reduction Program Plan submitted by Denver Water in support of its variance request.

W. *"Variance End Date"* means fifteen (15) years after the effective date, unless extended by EPA.

2. Corrosion Control Treatment:

A. *pH/Alkalinity Adjustment Corrosion Control Treatment*. By the effective date, Denver Water must begin to make adjustment to pH and alkalinity as corrosion control

[1] The public notice requirements under Subpart Q of the LCR (40 C.F.R, § 141.201 *et seq.*) will continue to apply if there is a violation of the schedule, and/or any terms and conditions of the variance –tier 1 and tier 2 notices, respectively.

treatment (CCT) according to an implementation schedule and treatment targets approved by CDPHE. Denver Water must maintain the corrosion control parameters and targets within the ranges designated by CDPHE under § 11.26(3)(d)(iii) of 5 CCR 1002-11 and 40 C.F.R. § 141.82(h).

B. *Monitoring and Sampling:*

i. *LCR Regulatory Sampling for Action Level 90th Percentile Calculation.* During the variance, Denver Water must maintain Lead and Copper Rule (LCR) sampling sites pursuant to § 11.26(2) of 5 CCR 1002-11 and 40 C.F.R. § 141.86 for lead service lines and lead solder sites.

ii. *Use of Sampling Results.* Lead water quality tests collected to identify LSLs for the inventory under this variance and to verify lead concentrations post-replacement shall not be used in the calculation of the 90th percentile. Any customer-requested samples that meet the Tier 1 sampling requirements will still be included in Denver Water's compliance calculations.

iii. *Monitoring for Water Quality Parameters*. Denver Water must follow §§ 11.26(4)(j)-(l) of 5 CCR 1002-11 and 40 C.F.R. §§ 141.82(g)-(i) for treatment technique compliance determinations for continued operation and maintenance of the CCT.

C. *CCT Compliance Metrics, Corrective Actions, and Failures.*

i. *CCT Compliance.* For each six-month sampling period, Denver water must achieve LCR Regulatory Sampling at or below the LCR Action Level based upon the 90th percentile calculation.

ii. *Corrective Action.* If compliance has not been achieved under 2.C.i., Denver Water must follow the requirements of the LCR in the case of a lead or copper Action Level exceedance under § 11.26 of 5 CCR 1002-11 and 40 C.F.R. § 141.82. If Denver Water's LCR regulatory sampling exceeds the LCR's Action Level as measured at the 90th percentile for two (2) LCR monitoring periods within the duration of the variance, Denver Water has failed to meet the condition in 2.C.i., and either:

a. this variance shall terminate; or

b. CDPHE will require Denver Water to follow the corrosion control treatment steps under § 11.26(3)(c) of 5 CCR 1002-11, in which case the variance will be continued pending the results from corrosion control treatment studies until CDPHE makes a determination under § 11.26(3)(c)(ii). EPA may nevertheless terminate this variance in the interests of public health under paragraph 7.D below.

c. In either case above, CDPHE will issue Denver Water a treatment technique violation and Denver Water must conduct a Tier 2 public notice to all customers under 1.T.i above.

3. Lead Service Line Inventory:

A. *LSL Inventory.* Denver Water must create and maintain on an ongoing basis an inventory of the material used for each service line used for drinking water that is a known, suspected, and possible LSL associated with a customer premise within Denver Water's system, and update the inventory each program year in agreement with CDPHE as LSLs are replaced and the material used for service lines are investigated. The inventory must include private service lines, and must include all LSLs within the system, including in the service areas of all distributors who are a part of the system. Denver Water must complete the initial LSL inventory no later than thirty-five (35) days after the effective date. The total estimated number of known, suspected, and possible LSLs equals (Y) as further described in paragraph 4.A below. Any updates to (Y) will be submitted in Denver Water's annual summary report described in paragraph 6 below.

B. *Investigation of Service Line Materials*. On an ongoing basis Denver Water must investigate known, suspected, and possible LSLs using lead water quality tests, potholing, visual inspections, or other means that supports a determination of the service line material. The number of known, suspected and possible LSLs for the purpose of investigating properties for the first year following the variance approval will be based on the (Y) factor, as adjusted under paragraph 4.A below. Denver Water must incorporate its findings under this subsection into its required LSL inventory annual updates.

C. *Publication of LSL Inventory.* No later than seventy (70) days following the effective date, Denver Water must provide public access to its LSL inventory on its external customer website, which will allow the public to view whether service line materials used for any customer premise in the system is (i.e. lead, copper, or unknown). During the term of this variance, Denver Water must continue to provide public access to its LSL inventory, including access to any updates to its inventory required under this section 3. For owners or residents of a customer premise who call Denver Water by phone, Denver Water must disclose whether its inventory shows that the owner's or resident's service line is a known, suspected and possible LSL, is unlikely to be an LSL or is a non-lead service line.

D. *LSL Inventory Compliance Metrics, Corrective Actions, and Failures.*

i. *Compliance Metric.* Denver Water must investigate a minimum of 1.4% of the total estimated number of suspected and possible LSLs in the LSL inventory each program year until 20% of the total estimated number of suspected and possible LSLs are investigated based upon the inventory at the beginning of the first program year (based on a subset of Y as described in paragraph 4.A below) as adjusted. These investigations are performed independently of the LSL replacements under paragraph 4 below.

ii. *Corrective Action.* If Denver Water does not conduct the minimum 1.4% of investigations by the end of the program year, the denominator (Y) in paragraph 4.A below will revert to the value established at the beginning of the previous program year, less LSL replacements for the previous program year, until Denver Water achieves compliance with this paragraph. Denver Water must also provide public notice that the metric was not met in its annual summary report under paragraph 1.T.iv above.

iii. *Completion of Inventory.* When Denver Water has completed the confirmation of the material for all suspected and possible LSLs under paragraph 3.D.i., Denver Water must provide written notice to CDPHE and this variance metric will terminate.

4. Accelerated Lead Service Line Replacement Program:

A. *LSL Replacement*. By the effective date, Denver Water must begin to implement accelerated LSL replacement in its system and replace all known LSLs within 15 years of the effective date. By the end of program year 1, Denver Water must achieve a 6.0% replacement rate,[2] and by the end of program year 2, Denver Water must achieve a 6.5% replacement rate based upon the known, suspected and possible LSLs (Y) at the beginning of the program year. By the end of the third program year and every program year thereafter, Denver Water must maintain a minimum cumulative annual average replacement rate of 7.0% per year. At the end of each program year, the cumulative program year average must be calculated using the total number of LSLs replaced during the term of the variance (X) divided by the total estimated number of known, suspected, and possible LSLs (Y), consistent with the most recent update of the LSL inventory. Program year adjustments to (X) and (Y) will be made at the end of each program year with the approval of EPA and CDPHE based upon any changes to the total estimated number of known, suspected and possible LSLs in Denver Water's updated LSL inventory except as otherwise provided in paragraph 3.D.ii above; provided, however, all LSLs must be replaced within 15 years of the effective date. For program year 1, X = 3,838 and Y= 63,955.

B. *LSL Replacement Defined*. For the purpose of calculating the cumulative program year average replacement rate, the following types of LSL replacements will count as credit for an entire LSL replacement:

i. full LSL replacement of a single service line;

ii. replacement of an existing partial LSL that results in a non-lead service line from the main to the first fitting inside the structure;

iii. replacement of a galvanized service line downstream of an existing or previously existing LSL, including any lead that is part of the upstream segment of the service line; and

[2] If the effective date is after January 1, 2020, the 6.0% replacement rate for the first program year will be prorated through December 31, 2020 by dividing the number of remaining full months from the effective date to the end of the Calendar Year by 12 and multiplying this factor by the 6.0% replacement rate.

iv. LSL replacement completed by other governmental agencies, developers, homeowners, non-profits, etc. and inspected by Denver Water.

C. *Replacement to Fitting.* All LSLs must be replaced from the main up to the first fitting inside the structure excluding any portion of the service line that is copper. If there is no fitting within five feet of the location where the service line enters the structure, Denver Water must install a fitting to allow for connection of the service line at a location convenient for Denver Water.

D. *Partial LSL Replacements.* Denver Water may not make a partial replacement of an LSL during the term of the variance except when i. emergency repairs must be made to a service line or water main to protect the distribution system; or ii. property owner consent cannot be obtained or the property cannot be accessed. A partial replacement that does not result in complete replacement of all portions of the LSL shall not be counted as an LSL replacement for the purposes of the accelerated LSL replacement program until the partial LSL is fully replaced.

E. *Post Replacement Samples*. Denver Water must offer to collect and analyze lead samples at homes where LSLs have been replaced six (6) months post LSL replacement.

F. *Test Out.* The "test out" provision in 40 C.F.R. § 141.84(c) and § 11.26(6)(b)(i)(B) of 5 CCR 1002-11 does not apply while Denver is subject to this variance. Any lines that "test out" do not count toward LSLs that were replaced under the terms of this variance.

G. *Property Owner Consent.* Denver Water must contact property owners at the customer premise before replacement to secure the property owner's documented consent. Work at the customer premise may commence once consent is documented. If Denver Water has not made contact with a property owner, Denver Water must use reasonable efforts to secure consent. Reasonable efforts must include at least three attempts to contact the property owner including an attempt to send at least two (2) written requests by U.S. mail to the property owner at the most recent mailing address identified through Denver Water records for consent to replace the LSL at the property, and an attempt to obtain permission by making in-person contact with the property owner if necessary. If documented consent to replace the LSL is not granted after reasonable efforts are made to achieve consent, the property will be added to Denver Water's Service Line Refusal List as described in paragraph 4.H. below.

H. *Customer Refusals and Changes in Customer Accounts.* Denver Water must maintain records of the addresses of all structures at which the property owner does not consent to LSL replacement (Service Line Refusal List). When Denver Water customer account records indicate a change in ownership at the customer premise, Denver Water must determine whether the address is on the Service Line Refusal List, and within ninety-one (91) days of a change in Denver Water account records, undertake reasonable efforts to obtain permission from the new property owner of the customer premise to replace the LSL. Reasonable efforts include the efforts described in paragraph 4.G. above. If permission is granted and conditions allow for

the LSL to be accessed and safely replaced, Denver Water must replace the LSL. By the variance end date, Denver Water must replace all LSLs at properties on the Service Line Refusal List.

I. *LSLs Discovered After Variance Term.* Denver Water must continue to replace any LSL discovered after the variance end date and report any LSL replacements to CDPHE on an annual basis. This condition shall survive the term of the variance.

J. *Accelerated LSL Replacement Compliance Metrics, Corrective Actions, and Failures.*

i. *Compliance Metric*. Denver Water must achieve at least a 6.0% LSL replacement rate by the end of program year 1, 6.5% in program year 2, and beginning the end of program year 3 and thereafter a 7.0% cumulative annual average LSL replacement rate each program year.

ii. *Corrective Action.* If the compliance metric in paragraph 4.J.i. is not achieved after program year 3, Denver Water must increase LSL replacements to achieve a 7.0% cumulative annual average replacement rate by the end of the next program year. In addition, Denver Water shall provide public notice to all customers who have known, suspected, or possible LSLs that correction under this variance metric under 1.T.ii

5. Filter Program:

A. *Filters.* Denver Water must distribute to the occupant of all customer premises with known, suspected and possible LSLs one (1) filter and enough replacement cartridges for the first six months of use. Denver Water shall begin to distribute filters and cartridges within ninety-one (91) days of the effective date and complete distribution one hundred and eighty-two (182) days following the effective date. If Denver Water does not distribute all of the filters and cartridges by the above deadline, then Denver Water must conduct public notice to all customers enrolled in the filter program under paragraph 1.T.ii. All filters and cartridges distributed must be certified NSF/ANSI (53) for lead removal and not remove fluoride. Denver Water need not distribute a filter and replacement cartridge to a customer premises if the occupant confirms that their household uses bottled water, an existing under the sink filter certified NSF/ANSI (53) for lead removal, refrigerator filter certified NSF/ANSI (53) for lead removal, or other lead removal device that is certified NSF/ANSI (53) for lead removal for ingestion purposes.

B. *Filter Replacement Cartridges.* Denver Water must distribute replacement cartridges to customers enrolled in the filter program per the filter manufacturers' recommended replacement rate unless the customer refuses the filter or replacement cartridges. Replacement filters must be provided to each customer premise enrolled in the filter program until six months after replacement of a customer premise's LSL or until the time the service line of the property is confirmed to be non-lead. If Denver Water does not distribute all of the replacement cartridges per the manufacturers' recommended replacement rate, then Denver Water must conduct public notice to all customers enrolled in the filter program under paragraph 1.T.ii.

C. *Changes in Customer Accounts.* If a change in the customer name of the water account associated with a customer enrolled in the filter program occurs at any time, then Denver Water must distribute a new filter within thirty-five (35) days of the change in customer account and replacement cartridges per manufacturers recommended replacement rate to the new customer so long as the customer premise or a residential unit at the customer premise is enrolled in the filter program.

D. *Filters for Infants in '83 to '87 Customer Premises*. If a customer has a formula-fed infant/child up to 24 months of age and resides in a customer premise that is built between 1983-1987 and served by a copper service line with lead solder, upon customer request Denver Water must provide a free lead water quality test kit. If the water quality results in the first draw show lead concentrations above 3 ppb, Denver Water must offer a filter and enough replacement cartridges to last the customer until a child at the customer-premise exceeds the age of 24 months.

E. *Filter Adoption Assessment.*

i. *Surveys.* Denver Water must conduct a survey each program year of randomly selected customers enrolled in the filter program to receive at minimum 1,059 responses. The minimum number of required responses may be reduced upon written approval of CDPHE and EPA as the number of customers enrolled in the filter program decline during the term of this variance. The survey must inquire whether the customer has adopted the filter for water used for infant formula if applicable, cooking and drinking or is using bottled water or a filter device that is certified NSF/ANSI (53) for lead removal not provided by Denver Water for infant formula, cooking and drinking. The filter survey will be provided to and approved by CDPHE before distribution to customers enrolled in the filter program. If Denver Water:

a. Does not conduct the annual survey during any program year, then Denver Water will be issued a treatment technique violation and must conduct public notice to all customers under paragraph 1.T.i.

b. If Denver Water does not collect the minimum number of received survey responses during any program year, then Denver Water must conduct public notice to all customers enrolled in the filter program under paragraph 1.T.v, unless CDPHE determines that Denver Water must conduct public notice under paragraph 1.T.ii.

ii. *Survey of Filter Adoption Rate.* All of the received survey responses will be used to calculate the filter adoption rate based on the number of responses that confirm adoption of the filter, or use of bottled water or alternative filer device not provided by Denver Water that is certified NSF/ANSI (53) for ingestion. All respondents who indicate that they do not use the filter, bottled water, or alternative filter device that is certified NSF/ANSI (53) for cooking but have adopted for drinking water and infant fed formula, if the latter is applicable to the respondent, will be summed and multiplied by 50% and the result may be counted as having adopted a filter for the purposes of determining the average filter adoption rate in paragraph 5.G.i. below.

iii. *Bottled Water and Alternative Filter Devices*. Customers who indicate that they use bottled water or alternative filter device certified NSF/ANSI (53) will continue to be customers enrolled in the filter program unless they refuse a filter or contact Denver Water to opt-out of the filter program. Denver Water will maintain a list of customers who have refused filters or opted-out of the filter program and provide the list to CDPHE upon request.

F. *Filter Performance*.

i. *Confirmation of Filter Performance Before Distribution*. Before distributing filters to customers enrolled in the filter program in program year one, Denver Water will test the lead removal effectiveness of 12 units of each type of filter to be distributed to customers using water from Denver Water's pipe racks as described in the LRPP from at least one Denver Water treatment plant in accordance with a testing protocol approved by CDPHE to confirm that the filters meet their NSF/ANSI (53) certification. All filter testing results will be reported to CDPHE. Denver Water will not distribute a filter model that fails to meet the NSF/ANSI (53) certification based upon the lead samples collected under this paragraph.

ii. *Confirmation of Filter Performance in Field*. To confirm performance of filters in use at customer premise, Denver Water will collect fifty (50) samples from filters in use by customers enrolled in the filter program who are also enrolled in Denver Water's LCR regulatory sampling program in accordance with a testing protocol approved by CDPHE. Samples will be collected from filters used by customers enrolled in the filter program at the same frequency as LCR regulatory sampling and reported to CDPHE and EPA.

iii. If Denver Water does not complete testing of filters under this section 5.F. in accordance with the CDPHE approved protocols, Denver Water must provide public notice in accordance with paragraph 1.T.ii. above.

G. *Filter Adoption Compliance Metrics, Corrective Actions, and Failures.*

i. *Compliance.* Denver Water must achieve a filter adoption rate of 65% at the end of each program year.

ii. *Corrective Action*. If this metric is not achieved at the end of a program year, then Denver Water must achieve a 65% filter adoption rate by the end of the following program year. Denver Water will also provide public notice to customers enrolled in the filter program under paragraph 1.T.ii.

H. *Filter Communication Compliance Metrics, Corrective Actions, and Failures.*

i. *Compliance*. Denver Water must make direct contact with lead outreach and education materials to 95% of all customers enrolled in the filter program in every program year. Compliance shall be documented by mailing lists and mail receipts,

lists of customer email addresses for customers who elect to receive email communication, or other forms of documentation approved by CDPHE.

ii. *Corrective Action*. If Denver water does not achieve compliance with paragraph 5.H.i., then Denver Water must increase outreach efforts to reach 95% of Denver Water customers enrolled in the filter program, and Denver Water must also provide public notice to all customers enrolled in the filter program of its failure to achieve the metric under paragraph 1.T.ii.

6. Recordkeeping and Reporting Requirements:

A. *Reporting.* In the event that Denver Water determines that it will not meet any of the terms and conditions as defined in this document, Denver Water must notify CDPHE and EPA no later than two business days after the determination occurs. CDPHE will provide any resulting requirements (e.g., notification of violation, public notice requirements, etc.) to Denver Water (and copy EPA) in writing.

B. *Recordkeeping.* On an ongoing basis for the term of the variance, Denver Water shall record, maintain records of, and report each year the following information. Denver Water will provide any of the "raw" data to CDPHE or EPA, when requested. Unless otherwise stated, the reporting and recordkeeping requirements under the LCR remain in effect:

i. *CCT.*

a. all lead and copper regulatory sampling results, as required in § 11.26 of 5 CCR 1002-11;
b. CCT parameters for pH and alkalinity; and
c. all water quality sampling results collected as part of Denver Water's investigation of LSLs and post LSL replacement.

ii. *LSL Inventory.*

a. total number of service lines;
b. the total number of replaced LSLs during the variance;
c. the total number of known, suspected, and possible LSLs;
d. the total number of unlikely LSLs;
e. the total number of non-LSLs;
f. the number of investigations conducted each year to improve the LSL inventory;
g. an updated distribution system map; and
h. the rationale for requesting a change in the status of a service line in the inventory (e.g. investigation, replacement, water quality data, etc.).

iii. *LSL Replacements.*

a. the address and date of all LSL replacements occurring during the variance, including by year;
b. the type of LSL replacement (full, partial including galvanized, by third party);
c. the service line refusal list, including addresses of customer premises on the refusal list and documented attempts to contact the property owner; and
d. those customer premises where Denver Water performed a partial LSL replacement due to an emergency repair and property owner consent could not be obtained.

iv. *Filters.*

a. addresses of customer premises where filters and replacement cartridges have been provided;
b. the total number of filters and replacement cartridges distributed per program year;
c. a summary of filter survey responses per program year (i.e., descriptive statistics), the response rate, the percent filter adoption for each year of the variance, and the specific survey questions and responses;
d. a list of customer accounts reporting the use of bottled water or a filter certified NSF/ANSI (53) for removal of lead, and any changes in the list;
e. a list of customers enrolled in the filter program who have refused a filter or replacement cartridges or have opted out of enrollment in the filter program; and
f. filter lead sampling results collected under paragraph 5.F above.

v. *Compliance Metrics*. Results achieved under the compliance metrics in sections 2.C, 3.D, 4.J, 5.G, and 5.H above.

vi. *Communications, Outreach and Education*. A summary of activities conducted under the Communications, Outreach and Education program, including the updated communications, outreach and education plan for the new program year. The summary will include, at a minimum:

a. a description of outreach activities conducted;
b. a list of any partner organizations who conducted, or were involved in the implementation of the communications, outreach and education plan; and
c. if in-person or telephone surveys are conducted, the answers to filter usage survey questions that were asked, date and time of call.

vii. *Health Equity and Environmental Justice.* A summary of activities conducted and designed to address health equity and environmental justice (HE&EJ) principles set forth in the Lead Reduction Program Plan (LRPP), including:

a. a description of how the HE&EJ principles are being incorporated into the accelerated LSL replacement program, lead filter program, and communications, outreach and education plan;
b. socioeconomic or demographic data collected through the survey that may inform the filter adoption rate by neighborhood or demographic group to the extent practical; and
c. socioeconomic or demographic data collected from or other sources (e.g. census data, local public health agencies) to target communications, outreach and education programs to specific neighborhoods, demographic cohorts, or non-English speaking groups.

C. *Annual Program Year Reports.* No later than thirty-five (35) days following the end of a program year, Denver Water must submit a program year report to CDPHE and EPA, containing a summary of the information and data required under this section 6 for the previous program year, including an assessment of which metrics were achieved and the status of any corrective actions. This requirement remains in effect for the term of the variance. The annual report will also document any modification requests made by Denver Water to the Lead Reduction Program Plan or deviations from the LRPP during the most recent program year, along with a rationale for the request. If CDPHE or EPA provides any comments or requests related to the annual report, Denver Water must provide a written response within thirty-five (35) calendar days that addresses any identified comments/requests.

7. General Miscellaneous Provisions:

A. *Enforcement*. CDPHE has primary implementation and enforcement authority over the variance, subject to EPA oversight. CDPHE will implement, oversee, and enforce these terms and conditions, and may make recommendations to EPA to terminate or continue this variance, provided that EPA has the authority to ultimately decide whether to continue this variance.

B. *Revisions to the Lead and Copper Rule.* If EPA revises the federal LCR in a manner that affects the provisions and conditions of this variance, then EPA may modify or revoke this variance in a manner that is consistent with federal law.

C. *Lead Reduction Program Plan*. Denver Water will work in good faith to fully implement Section III of the LRPP. If Denver Water deviates from Section III the LRPP during the term of the variance or fails to implement Section III of the LRPP, Denver Water will provide notice to CDPHE within thirty-five (35) days with a description of the deviation from section III of the LRPP and the reason for the deviation. In no case shall a deviation from Section III of the LRPP modify these terms and conditions, except as provided in paragraph 7.J below. In the event of a

conflict between these terms and conditions and Section III of the LRPP, these terms and conditions take precedence.

D. *Enforcement.* Notwithstanding any metric and/or corrective action identified herein, EPA and CDPHE may take enforcement if EPA or CDPHE find, in their sole discretion, that Denver Water has not complied with any requirement of the variance in accordance with 42 U.S.C. §§ 300g-3(a)(1) and 300g-4(b) of the SDWA, including when:

i. Denver Water does not comply with its terms and conditions;

ii. A material aspect of Section III of the LRPP has not been implemented in good faith;

iii. Denver Water requests that EPA terminate the variance; or

iv. EPA or CDPHE believes that there is a risk to public health.

An enforcement action does not automatically terminate the variance.

E. A*utomatic Termination of Variance.* This variance terminates if one or more of the following conditions occur:

i. Denver Water fails to replace LSLs at the required minimum cumulative program year average rate of 7.0% for a total of three program years; or

ii. Denver Water fails to achieve a minimum of 65% filter adoption rate in a program year for a total of three program years.

If the variance is terminated Denver Water will provide public notice under 1.T.i

F. *Optimal Corrosion Control Treatment*. If EPA revokes the variance under paragraph 7.D. or the variance automatically terminates under paragraph 7.E, within 182 Days Denver Water shall install and operate orthophosphate as its designated optimal corrosion control treatment, in accordance with CDPHE's March 20, 2018, OCCT determination, and provide public notice to its customers in accordance with paragraph 1.T.i above. The initial dose of orthophosphate must be 2 mg/L. The specific orthophosphate dose may be further modified by CDPHE according to the provisions under 40 C.F.R. § 141.82(h).

G. *Effective Date of Termination or Revocation of the Variance*. Termination or revocation of the variance will be effective within 182 days of automatic termination under paragraph 7.E. above, or EPA's revocation under section 7.D. above, whichever occurs first. Failure to complete installation and operation of orthophosphate by this deadline will be considered a treatment technique violation under § 11.26 of 5 CCR 1002-11.

H. *Notice of Lead Reduction Program Plan.* No later than 14 days following effective date, Denver Water must begin a multi-media public information campaign and customer notification by written letter and pamphlet to notify customers enrolled in the filter program of Denver Water's variance, including the accelerated LSL replacement program and the distribution of the NSF/ANSI (53) certified filters for lead removal.

I. *Term of Variance.* Unless EPA revokes or modifies, the terms, this variance shall extend from the effective date through the variance end date, or until EPA accepts the notice of completion pursuant to section 7.L. below. Additionally, as described in, paragraph 4.I, Denver Water shall replace within six (6) months of discovery, any LSLs discovered after the variance end date. Denver Water must provide an annual summary of these efforts to CDPHE by January 10th of each calendar year for the previous program year.

J. *Modification of Conditions.* EPA may modify the conditions of this variance in consultation with CDPHE. EPA will notify Denver Water thirty-five (35) days prior to the effective date of any modification.

K. *Notices.* All notices, reports, disclosures, or other communications required or related to this variance must be sent via certified U.S. Mail, overnight express delivery service, or electronic means to the recipients and addresses below.

EPA:
Safe Drinking Water Branch Chief
Water Division U.S. Environmental Protection Agency, Region 8
1595 Wynkoop St.
Denver, CO 80202-1129
Current E-mail: **[To be added upon finalization.]**

Denver Water:
James S. Lochhead
CEO/Manager
Denver Water
1600 West 12th Avenue
Denver, Colorado 80204
E-mail: **[To be added upon finalization.]**

Office of General Counsel:
ATTN: Jessica Brody
Denver Water
1600 West 12th Avenue
Denver, Colorado 80204
E-mail: **[To be added upon finalization.]**

CDPHE:
Jill Hunsaker Ryan
Executive Director
Colorado Department of Public Health and Environment
4300 Cherry Creek Drive South
Denver, CO 80246
E-mail: **[To be added upon finalization.]**

All reports will be sent to Drinking Water Compliance Assurance through its on-line portal at https://wqcdcompliance.com/login or through such other means as designated in writing by CDPHE.

Attorney General's Office
ATTN: **[To be added upon finalization.]**

L. *Notice of Completion.* Denver Water may submit a notice of completion of the terms and conditions of this variance to CDPHE, with a copy to EPA, by the variance end date or earlier in accordance with this variance. EPA may either accept or reject Denver Water's notice of completion in writing within thirty-five (35) days of receipt.

APPENDIX VII.A – LEAD REDUCTION PROGRAM COST ESTIMATES

September 2019

DENVER WATER

Cost Estimate Summary:

Denver Water and the MOU stakeholders developed planning level financial impact estimates for the orthophosphate and variance alternatives.

The "Low" capital costs, annual operating costs, and assumptions are shown in Table VII.A-1. The "High" capital costs, annual operating costs, and assumptions are shown in Table VII.A-2.

Denver Water currently replaces lead service lines at a rate of 700 per year, with an additional 500 per year replaced through redevelopment, for a combined total of 1,200 per year. Denver Water will be required to increase the rate of lead service line replacements to 780 per year to replace all lead services for the orthophosphate alternative within 50 years (780 x 50 + 500 x 50). Denver Water's cost for replacement of approximately 780 lead services lines per year is included in the cost estimates. The developers cost for replacement of 500 lead service lines per year is not included in the cost estimates.

A Net Present Value summary for the 50-year period using the capital and operating costs is shown in Table VII.A-3. The low and high cost estimate range reflects different assumptions for the timing and need of various capital projects and associated operating costs. The assumptions are incorporated into the life-cycle costs for both scenarios; specifically 50 years for orthophosphate and 15 years for the variance. The NPV summary reflects a discount rate of 1.5% and an inflation rate of 0%. The discount rate is based on the US Office of Management and Budget memorandum titled *2019 Discount Rates for OMB Circular No. A-94* of December 18, 2018. Assumptions regarding timing for the low and high operating capital and operating costs are shown in Tables VII.A-1 and VII.A-2, respectively.

A total investment summary for the Low and High capital and operating costs for the 50-year and 15-year period is shown in Table VII.A-3. The total investment summary includes the capital and operating costs for the life of the program.

Table VII.A-1:Regional Estimated Financial Impacts For OCCT and LSL Removal Alternatives -Low Cost Estimates in Today's Dollars

Cost Category and Subcategory	Incremental Capital or Total Item Costs					Operating Costs					Assumptions and Notes for the NPV
	Orthophosphate @ 3 mg/L and LSLR in 50 years	Orthophosphate @ 2 mg/L and LSLR in 50-Years	Orthophosphate @ 1 mg/L and LSLR in 50-years	Orthophosphate @ 0.5 mg/L and LSLR in 50-years	Variance Option: pH 8.8 w/ 15-Yr ALSLR Program	Orthophosphate @ 3 mg/L	Orthophosphate @ 2 mg/L	Orthophosphate @ 1 mg/L	Orthophosphate @ 0.5 mg/L	Variance Option: pH 8.8 w/ 15-Yr ALSLR Program	
A - Wastewater Treatment Plant Expenses											
Metro Wastewater Reclamation District (MWRD)	$129,000,000	$129,000,000	$129,000,000	$0	$0	$4,590,000	$3,170,000	$1,790,000	$30,000	$0	Capital cost starting in 2036. O&M start in 2036 through end of 50 year period.
South Platte Water Renewal Partners (SPWRP)	$0	$0	$0	$0	$0	$250,000	$200,000	$80,000	$40,000	$0	Starting in 2023
South Adams County Water and Sanitation District (SACWSD)	$0	$0	$0	$0	$0	$91,200	$60,000	$30,000	$0	$0	Starting in 2025
Broomfield	$0	$0	$0	$0	$0	$256,000	$171,000	$86,000	$43,000	$0	Starting in 2020. Capital costs as referenced in CDPHE July 2019 memo
ACWWA (Inverness Supply)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	Not in WISE group but in Cherry Creek Basin.
WISE Participants (Centennial, etc.)	$4,500,000	$3,000,000	$1,500,000	$700,000	$0	$18,800	$12,500	$6,300	$3,100	$0	Starting in 2020. Capital costs as referenced in CDPHE July 2019 memo
Subtotal A - Wastewater Treatment Plant	***$133,500,000***	***$132,000,000***	***$130,500,000***	***$700,000***	***$0***	***$5,206,000***	***$3,613,500***	***$1,992,300***	***$116,100***	***$0***	
B - Stormwater & Non-Point Irrigation Treatment											
Phosphorus Removal - City and County of Denver Stormwater	$14,080,000	$9,400,000	$4,680,000	$2,360,000	$0	$2,462,000	$1,641,000	$821,000	$410,000	$0	Capital and operating costs starting in 2030.
Phosphorus Removal - Service Areas Outside City and County of Denver Stormwater	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	Included with Above
Subtotal B - Stormwater & Non-Point	***$14,080,000***	***$9,400,000***	***$4,680,000***	***$2,360,000***	***$0***	***$2,462,000***	***$1,641,000***	***$821,000***	***$410,000***	***$0***	
C - Watershed Non-Point Treatment											
Recreational Impacts @ Barr Lake and Milton Reservoir	$0	$0	$0	$0	$0	$364,000	$281,500	$199,000	$116,500	$0	Operating cost start in 2020 and extend through 2029.
Barr/Milton In Canal Treatment	$0	$0	$0	$0	$0	$723,500	$343,900	$147,000	$1,650	$0	Operating costs start in 2020 and extend for 50-years. Costs vary over time.
DW Gravel Lakes Treatment	$0	$0	$0	$0	$0	$290,000	$290,000	$290,000	$290,000	$0	Operating costs start in 2020 and extend through 2035.
Subtotal C - Watershed Non-Point Treatment	***$0***	***$0***	***$0***	***$0***	***$0***	***$1,377,500***	***$915,400***	***$636,000***	***$408,150***	***$0***	
D - Non-Denver Water WTP Improvements											
Thornton	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Aurora	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$0	$157,000	$157,000	$157,000	$157,000	$0	Capital and operating cost start in 2020 (amount for first 15-years then 15% for remainder)
Broomfield OCCT	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$0	$60,000	$40,000	$20,000	$10,000	$30,000	Capital and O&M Starting in 2020. Reduce by 25%.
South Adams County Water and Sanitation District (SACWSD)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	No cost anticipated.
East Cherry Creek Valley (ECCV)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	ECCV will reduce purchase of DW to maintain low phosphorus levels in their watershed basin.
Subtotal D - Non-Denver Water WTP	***$11,000,000***	***$11,000,000***	***$11,000,000***	***$11,000,000***	***$0***	***$217,000***	***$197,000***	***$177,000***	***$167,000***	***$30,000***	
E - Denver Water WTP & Distribution Expenses											
Foothills WTP Upgrade	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$1,000,000	$670,000	$330,000	$170,000	$500,000	Starting in 2020
Marston WTP Upgrade	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$250,000	$167,500	$82,500	$42,500	$100,000	Starting in 2020
Moffat WTP Upgrade	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$250,000	$167,500	$82,500	$42,500	$100,000	Starting in 2020
Denver Water - Marston Washwater Recycling	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$0	$196,000	$196,000	$196,000	$196,000	$0	Starting in 2020
Increased Nitrification Control	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Subtotal E - Denver Water WTP Expenses	***$17,100,000***	***$17,100,000***	***$17,100,000***	***$17,100,000***	***$7,100,000***	***$1,696,000***	***$1,201,000***	***$691,000***	***$451,000***	***$700,000***	
F - Filter Program											
Distribution and Management	$0	$0	$0	$0	$33,406,000	$0	$0	$0	$0	$0	Starting in 2020 and end in 2034, ~93,200 filters distributed in year 2020
Subtotal F - Filter Program	***$0***	***$0***	***$0***	***$0***	***$33,406,000***	***$0***	***$0***	***$0***	***$0***	***$0***	
G - ALSLR Program											
ALSLR Program	$0	$0	$0	$0	$254,250,000	$0	$0	$0	$0	$0	Starting in 2020 and end in 2034, ~64,000 LSL at $4,500/each + 7,500 LSL replaced by developers at no cost.
Potholing and WQ Sampling Program	$0	$0	$0	$0	$5,932,500	$0	$0	$0	$0	$0	Starting in 2020, 9,700 potholes and 39,000 WQ Samples
Subtotal G - ALSLR Program	***$0***	***$0***	***$0***	***$0***	***$260,182,500***	***$0***	***$0***	***$0***	***$0***	***$0***	
H - Current LSLR Process											
Current LSLR Process	$184,275,000	$184,275,000	$184,275,000	$184,275,000		$0	$0	$0	$0	$0	Starting in 2020, 64,000 LSL at $4,500/each + 25,000 LSL replaced by developers at no cost (5% internal management cost)
Potholing and WQ Sampling Program	$5,733,000	$5,733,000	$5,733,000	$5,733,000							Starting in 2020, 10,600 potholes and 42,300 WQ Samples (rely on physical identification versus predictive model, 5% internal management cost)
Subtotal H - Current LSLR Process	***$190,008,000***	***$190,008,000***	***$190,008,000***	***$190,008,000***	***$0***	***$0***	***$0***	***$0***	***$0***	***$0***	
Total Estimated Fiscal Impact	**$365,700,000**	**$359,500,000**	**$353,300,000**	**$221,200,000**	**$300,700,000**	**$11,000,000**	**$7,600,000**	**$4,300,000**	**$1,600,000**	**$730,000**	

Notes:
1. No, unanticipated, and unknown costs are represented as $0.

Table VII.A-2: Regional Estimated Financial Impacts For OCCT and LSL Removal Alternatives - High Cost Estimates in Today's Dollars

Cost Category and Subcategory	Incremental Capital or Total Item Costs					Operating Costs					Assumptions and Notes for the NPV
	Orthophosphate @ 3 mg/L and LSLR in 50 years	Orthophosphate @ 2 mg/L and LSLR in 50-Years	Orthophosphate @ 1 mg/L and LSLR in 50-years	Orthophosphate @ 0.5 mg/L and LSLR in 50-years	Variance Option: pH 8.8 w/ 15-Yr ALSLR Program	Orthophosphate @ 3 mg/L and LSLR in 50 years	Orthophosphate @ 2 mg/L and LSLR in 50-Years	Orthophosphate @ 1 mg/L and LSLR in 50-years	Orthophosphate @ 0.5 mg/L and LSLR in 50-years	Variance Option: pH 8.8 w/ 15-Yr ALSLR Program	
A - Wastewater Treatment Plant Expenses											
Metro Wastewater Reclamation District (MWRD)	$129,000,000	$129,000,000	$129,000,000	$0	$0	$4,590,000	$3,170,000	$1,790,000	$30,000	$0	Capital cost starting in 2036. O&M start in 2036 through end of 50 year period.
South Platte Water Renewal Partners (SPWRP)	$0	$0	$0	$0	$0	$250,000	$200,000	$80,000	$40,000	$0	Starting in 2023
South Adams County Water and Sanitation District (SACWSD)	$0	$0	$0	$0	$0	$91,200	$60,000	$30,000	$0	$0	Starting in 2025
Broomfield	$0	$0	$0	$0	$0	$256,000	$171,000	$86,000	$43,000	$0	Starting in 2020. Capital costs as referenced in CDPHE July 2019 memo
ACWWA (Inverness Supply)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	Not in WISE group but in Cherry Creek Basin.
WISE Participants (Centennial, etc.)	$4,500,000	$3,000,000	$1,500,000	$700,000	$0	$18,800	$12,500	$6,300	$3,100	$0	Starting in 2020. Capital costs as referenced in CDPHE July 2019 memo
Subtotal A - Wastewater Treatment Plant	***$133,500,000***	***$132,000,000***	***$130,500,000***	***$700,000***	***$0***	***$5,206,000***	***$3,613,500***	***$1,992,300***	***$116,100***	***$0***	
B - Stormwater & Non-Point Irrigation Treatment											
Phosphorus Removal - City and County of Denver Stormwater	$177,960,000	$133,800,000	$13,360,000	$6,680,000	$0	$7,623,000	$5,278,000	$2,336,000	$1,168,000	$0	Capital and operating costs starting in 2030.
Phosphorus Removal - Service Areas Outside City and County of Denver Stormwater	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	Included with Above
Subtotal B - Stormwater & Non-Point Irrigation	***$177,960,000***	***$133,800,000***	***$13,360,000***	***$6,680,000***	***$0***	***$7,623,000***	***$5,278,000***	***$2,336,000***	***$1,168,000***	***$0***	
C - Watershed Non-Point Treatment											
Recreational Impacts @ Barr Lake and Milton Reservoir	$0	$0	$0	$0	$0	$364,000	$281,500	$199,000	$116,500	$0	Operating cost start in 2020 and extend through 2029.
Barr/Milton In Canal Treatment	$0	$0	$0	$0	$0	$723,500	$343,900	$146,600	$1,650	$0	Operating costs start in 2020 and extend for 50-years. Costs vary over time.
DW Gravel Lakes Treatment	$0	$0	$0	$0	$0	$290,000	$290,000	$290,000	$290,000	$0	Operating costs start in 2020 and extend through 2035.
Subtotal C - Watershed Non-Point Treatment	***$0***	***$0***	***$0***	***$0***	***$0***	***$1,377,500***	***$915,400***	***$635,600***	***$408,150***	***$0***	
D - Non-Denver Water WTP Improvements											
Thornton	$20,000,000	$20,000,000	$20,000,000	$20,000,000	$0	$200,000	$134,000	$66,000	$33,000	$0	Capital and operating cost start in 2020 (amount for first 15-years then 15% for remainder)
Aurora	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$0	$157,000	$157,000	$157,000	$157,000	$0	Capital and operating cost start in 2020 (amount for first 15-years then 15% for remainder)
Broomfield OCCT	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$0	$60,000	$40,000	$20,000	$10,000	$30,000	Capital and O&M Starting in 2020. Reduce by 25%.
South Adams County Water and Sanitation District (SACWSD)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	No cost anticipated.
East Cherry Creek Valley (ECCV)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	ECCV will reduce purchase of DW to maintain low phosphorus levels in their watershed basin.
Subtotal D - Non-Denver Water WTP	***$31,000,000***	***$31,000,000***	***$31,000,000***	***$31,000,000***	***$0***	***$417,000***	***$331,000***	***$243,000***	***$200,000***	***$30,000***	
E - Denver Water WTP & Distribution Expenses											
Foothills WTP Upgrade	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$2,900,000	$1,000,000	$670,000	$330,000	$170,000	$500,000	Starting in 2020
Marston WTP Upgrade	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$250,000	$167,500	$82,500	$42,500	$100,000	Starting in 2020
Moffat WTP Upgrade	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$250,000	$167,500	$82,500	$42,500	$100,000	Starting in 2020
Denver Water - Marston Washwater Recycling	$10,000,000	$10,000,000	$10,000,000	$10,000,000	$0	$196,000	$196,000	$196,000	$196,000	$0	Starting in 2020
Increased Nitrification Control	$0	$0	$0	$0	$0	$100,000	$100,000	$100,000	$100,000	$0	Starting in 2020
Subtotal E - Denver Water WTP Expenses	***$17,100,000***	***$17,100,000***	***$17,100,000***	***$17,100,000***	***$7,100,000***	***$1,796,000***	***$1,301,000***	***$791,000***	***$551,000***	***$700,000***	
F - Filter Program											
Distribution and Management	$0	$0	$0	$0	$48,501,200	$0	$0	$0	$0	$0	Starting in 2020 and end in 2034, ~119,250 filters distributed in year 2020
Subtotal F - Filter Program	***$0***	***$0***	***$0***	***$0***	***$48,501,200***	***$0***	***$0***	***$0***	***$0***	***$0***	
G - ALSLR Program											
ALSLR Program	$0	$0	$0	$0	$403,975,000	$0	$0	$0	$0	$0	Starting in 2020 and end in 2034, ~64,000 LSL at $6,500/each + 7,500 LSL replaced by developers at no cost.
Potholing and WQ Sampling Program	$0	$0	$0	$0	$6,525,750	$0	$0	$0	$0	$0	Starting in 2020, 9,700 potholes and 39,000 WQ Samples
Subtotal G - ALSLR Program	***$0***	***$0***	***$0***	***$0***	***$410,500,750***	***$0***	***$0***	***$0***	***$0***	***$0***	
H - Current LSLR Process											
Current LSLR Process	$266,175,000	$266,175,000	$266,175,000	$266,175,000		$0	$0	$0	$0	$0	Starting in 2020, 64,000 LSL at $6,500/each + 25,000 LSL replaced by developers at no cost (5% internal management cost)
Potholing and WQ Sampling Program	$5,733,000	$5,733,000	$5,733,000	$5,733,000							Starting in 2020, 10,600 potholes and 42,300 WQ Samples (rely on physical identification versus predictive model, 5% internal management cost)
Subtotal H - Current LSLR Process	***$271,908,000***	***$271,908,000***	***$271,908,000***	***$271,908,000***	***$0***	***$0***	***$0***	***$0***	***$0***	***$0***	
Total Estimated Fiscal Impact	**$631,500,000**	**$585,800,000**	**$463,900,000**	**$327,400,000**	**$466,100,000**	**$16,400,000**	**$11,400,000**	**$6,000,000**	**$2,400,000**	**$730,000**	

Notes:
1. No, unanticipated, and unknown costs are represented as $0.

Table VII.A-3: NPV and Total Investment Summary Information

NPV Summary

1. Ortho Option – Item A, B, C, D, and E (ie. Cost of ortho addition without LSLR)

	Capital			
	3mg/L	2mg/L	1mg/L	0.5mg/L
Ortho w/o LSLR - HIGH	$ 244,042,455	$ 219,718,821	$ 155,932,376	$ 52,744,424
Ortho w/o LSLR - LOW	$ 141,345,606	$ 136,851,806	$ 132,332,228	$ 29,895,257

	Operation			
	3mg/L	2mg/L	1mg/L	0.5mg/L
Ortho w/o LSLR - HIGH	$ 407,708,994	$ 286,059,824	$ 148,434,030	$ 64,720,974
Ortho w/o LSLR - LOW	$ 266,279,775	$ 185,573,545	$ 104,640,372	$ 41,270,955

	Combined			
	3mg/L	2mg/L	1mg/L	0.5mg/L
Ortho w/o LSLR - HIGH	$ 651,751,449	$ 505,778,645	$ 304,366,407	$ 117,465,399
Ortho w/o LSLR - LOW	$ 407,625,381	$ 322,425,351	$ 236,972,600	$ 71,166,212

Total Investment

Ortho Option – Item A, B, C, D, and E (ie. Cost of ortho addition without LSLR)

	Capital			
	3mg/L	2mg/L	1mg/L	0.5mg/L
Ortho w/o LSLR - HIGH	$ 315,070,000	$ 280,450,000	$ 188,620,000	$ 56,348,400
Ortho w/o LSLR - LOW	$ 175,680,000	$ 169,500,000	$ 163,280,000	$ 31,160,000

	Operation			
	3mg/L	2mg/L	1mg/L	0.5mg/L
Ortho w/o LSLR - HIGH	$ 620,209,917	$ 434,470,231	$ 223,496,899	$ 93,400,077
Ortho w/o LSLR - LOW	$ 402,817,113	$ 280,104,859	$ 156,583,063	$ 57,803,607

	Combined			
	3mg/L	2mg/L	1mg/L	0.5mg/L
Ortho w/o LSLR - HIGH	$ 935,279,917	$ 714,920,231	$ 412,116,899	$ 149,748,477
Ortho w/o LSLR - LOW	$ 578,497,113	$ 449,604,859	$ 319,863,063	$ 88,963,607

NPV Summary

2. Variance Option = E + F + G - H (Cost of Variance without LSLR)

	Capital
Variance w/o LSLR - High	$ 336,700,000
Variance w/o LSLR - Low	$ 239,200,000

	Operation
Variance w/o LSLR - High	$ 25,700,000
Variance w/o LSLR - Low	$ 26,000,000

	Combined
Variance w/o LSLR - High	$ 362,400,000
Variance w/o LSLR - Low	$ 265,200,000

Comment: Higher than Total Investment because subtracting a 50-year LSLR NPV from a 15-year variance NPV (NOT A COMPARABLE NPV NUMBER)

Total Investment

Variance Option = E + F + G - H (Cost of Variance without LSLR)

	Capital
Variance w/o LSLR - High	$ 194,200,000
Variance w/o LSLR - Low	$ 136,700,000

	Operation
Variance w/o LSLR - High	$ 36,500,000
Variance w/o LSLR - Low	$ 37,200,000

	Combined
Variance w/o LSLR - High	$ 230,700,000
Variance w/o LSLR - Low	$ 173,900,000

Table VII.A-3: NPV and Total Investment Summary Information

NPV Summary

3. Ortho Option – Item A, B, C, D, E, and H (with Current LSLR)

	Capital			
	3mg/L	2mg/L	1mg/L	0.5mg/L
Ortho w/ LSLR - HIGH	$ 320,900,000	$ 296,600,000	$ 232,800,000	$ 129,600,000
Ortho w/ LSLR - LOW	$ 195,000,000	$ 190,600,000	$ 186,000,000	$ 83,600,000

	Operation			
	3mg/L	2mg/L	1mg/L	0.5mg/L
Ortho w/ LSLR - HIGH	$ 407,700,000	$ 286,100,000	$ 148,400,000	$ 64,700,000
Ortho w/ LSLR - LOW	$ 266,300,000	$ 185,600,000	$ 104,600,000	$ 41,300,000

	Combined			
	3mg/L	2mg/L	1mg/L	0.5mg/L
Ortho w/ LSLR - HIGH	$ 728,600,000	$ 582,700,000	$ 381,200,000	$ 194,300,000
Ortho w/ LSLR - LOW	$ 461,300,000	$ 376,200,000	$ 290,600,000	$ 124,900,000

Total Investment

Ortho Option – Item A, B, C, D, E, and H (with Current LSLR)

	Capital			
	3mg/L	2mg/L	1mg/L	0.5mg/L
Ortho w/ LSLR - HIGH	$ 587,000,000	$ 552,400,000	$ 460,500,000	$ 328,300,000
Ortho w/ LSLR - LOW	$ 365,700,000	$ 359,500,000	$ 353,300,000	$ 221,200,000

	Operation			
	3mg/L	2mg/L	1mg/L	0.5mg/L
Ortho w/ LSLR - HIGH	$ 620,200,000	$ 434,500,000	$ 223,500,000	$ 93,400,000
Ortho w/ LSLR - LOW	$ 402,800,000	$ 280,100,000	$ 156,600,000	$ 57,800,000

	Combined			
	3mg/L	2mg/L	1mg/L	0.5mg/L
Ortho w/ LSLR - HIGH	$ 1,207,200,000	$ 986,900,000	$ 684,000,000	$ 421,700,000
Ortho w/ LSLR - LOW	$ 768,500,000	$ 639,600,000	$ 509,900,000	$ 279,000,000

NPV Summary

4. Variance Option = E + F + G (with Current LSLR)

	Capital
Variance - High	$ 413,500,000
Variance - Low	$ 292,900,000

	Operation
Variance - High	$ 25,700,000
Variance - Low	$ 26,000,000

	Combined
Variance - High	$ 439,200,000
Variance - Low	$ 318,900,000

Total Investment

Variance Option = E + F + G (with Current LSLR)

	Capital
Variance - High	$ 466,100,000
Variance - Low	$ 326,700,000

	Operation
Variance - High	$ 36,500,000
Variance - Low	$ 37,200,000

	Combined
Variance - High	$ 502,600,000
Variance - Low	$ 363,900,000

NPV Summary

5. Delta Between Orthophosphate Option at 2 mg/L and Variance (without Current LSLR)

	Combined
Variance - High	$ 66,600,000
Variance - Low	$ 3,500,000

Total Investment

Delta Between Orthophosphate Option at 2 mg/L and Variance (without Current LSLR)

	Combined
Variance - High	$ 212,300,000
Variance - Low	$ 85,700,000

NPV Summary

6. Delta Between Orthophosphate Option at 2 mg/L and Variance (with Current LSLR)

	Combined
Variance - High	$ 143,500,000
Variance - Low	$ 57,300,000

Total Investment

Delta Between Orthophosphate Option at 2 mg/L and Variance (with Current LSLR)

	Combined
Variance - High	$ 484,300,000
Variance - Low	$ 275,700,000

EXECUTIVE SUMMARY

Introduction

Denver Water is committed to delivering safe water to 1.4 million people in the metro area, which is why Denver Water is working to significantly reduce lead exposure risks for customers with lead service lines and plumbing. The water we deliver to homes and businesses is lead-free, but lead can get into the water as it moves through customer-owned service lines and lead-containing plumbing.

This Lead Reduction Program Plan has been prepared in support of Denver Water's request to the Environmental Protection Agency for a variance from the optimal corrosion control treatment requirements under the Safe Drinking Water Act's Lead and Copper Rule.

Currently, Denver Water maintains a pH of 7.8 to reduce corrosion of lead service lines and plumbing. Denver Water conducted a study on multiple treatment options to reduce the potential for lead to enter drinking water from lead service lines and household plumbing. Based on the results, the Colorado Department of Public Health and Environment, the state regulatory agency that oversees drinking water regulations, required Denver Water to begin adding orthophosphate by March 2020, in accordance with regulatory requirements.

Despite its benefits, orthophosphate added to drinking water can increase phosphorus levels in wastewater and stormwater, resulting in adverse impacts to wastewater treatment plants and downstream reservoirs, streams and rivers. Once started, orthophosphate cannot easily be discontinued without causing an increase in corrosion, making orthophosphate a potentially permanent treatment method.

Due to these concerns, Denver Water, along with the Colorado Department of Public Health and Environment and other stakeholders, convened working groups in 2018 to further evaluate the benefits and risks of orthophosphate alongside other options to reduce lead exposure. As part of this process, Denver Water investigated whether a lower dose of orthophosphate, a higher pH of 9.2 with alkalinity adjustment or a multi-faceted approach including pH/alkalinity adjustment to 8.8 combined with the accelerated replacement of lead service lines and the provision of filters to customers could achieve the same or greater reduction in lead exposure risk. Based on this analysis, and as highlighted in Figure 1, Denver Water seeks to implement the multi-faceted Lead Reduction Program in place of adding orthophosphate to drinking water because the Lead Reduction Program provides the greatest benefit to public health and the environment.

FIGURE 1: LEAD REDUCTION PROGRAM PLAN BENEFITS

Protects Future Generations
The Lead Reduction Program permanently removes the largest source of lead within 15 years through accelerated lead service line replacement versus more than 50 years of using orthophosphate.

Focuses on Health Equity and Environmental Justice
The components of the Lead Reduction Program provide equal access for everyone to benefit from reducing overall lead exposure.

Provides Better Water Quality
For customers with lead service lines, Denver Water will provide filters that reduce lead by 97% until their lead service line can be replaced.

Creates a Regional Solution
The Lead Reduction Program prevents additional phosphorous loading at regional wastewater treatment plants, which is costly to remove.

Protects Infants and Children
The Lead Reduction Program prioritizes filter distribution and lead service line replacement in areas at greatest risk to lead exposure, namely areas with young families, child care providers and schools.

Protects Environmental Health
Upon implementation, the Lead Reduction Program will prevent introduction of a new source of phosphorous into reservoirs, rivers and streams. Nutrients can impair water for aquatic life as well as downstream wastewater and water utilities.

The Lead Reduction Program includes multiple elements, the most essential of which involve:

- Development of a lead service line inventory to identify and track lead service line replacement.
- A filter program.
- An accelerated lead service line replacement program.
- Corrosion control treatment with pH/alkalinity adjustment.
- Communications, outreach and education plans.

Overall, as compared to orthophosphate, the Lead Reduction Program provides a holistic and permanent lead reduction approach that is as effective at protecting public health, more efficient in reducing lead exposure, less harmful to the environment, more equitable in its public health benefits and more cost-effective with fewer regional risks.

History

How does lead enter drinking water?

Lead exposure, whether from paint, soil, air or water, is a significant public health concern because it has the potential to adversely affect some of our most vulnerable populations, especially children. When it comes to lead in drinking water, no levels are considered safe. That is why Denver Water is working with the Colorado Department of Public Health and Environment, the Environmental Protection Agency and Denver Water's customers to reduce the risks of lead exposure as drinking water moves through homes and businesses with lead service lines and lead plumbing.

While Denver Water delivers safe, lead-free water to customers' homes, lead can enter the water through three sources: (1) a customer's lead service line, which conveys water from the water main in the street to the customer's home, (2) a customer's household plumbing that contains lead solder and (3) a customer's plumbing fixtures that contain lead (e.g., faucets, valves). Figure 2 highlights the sources of lead in drinking water.

Denver Water studies show that lead service lines, typically found in homes built before 1951 within the Denver Water service area, are the primary source of lead in drinking water.

What has Denver Water done historically to control lead and reduce lead exposure?

For decades, Denver Water has been working to reduce lead in drinking water. Figure 3 highlights the history of lead in drinking water and provides an overview of Denver Water's activities to reduce lead exposure. Since 1992, Denver Water has tested water from inside customer homes with known lead service lines or lead solder as part of the Safe Drinking Water Act's Lead and Copper Rule. Additionally, Denver Water has provided corrosion control treatment in the form of pH adjustment of the water delivered to customers' homes to minimize the corrosion of customer-owned lead service lines and plumbing.

FIGURE 2: SOURCES OF LEAD IN DRINKING WATER

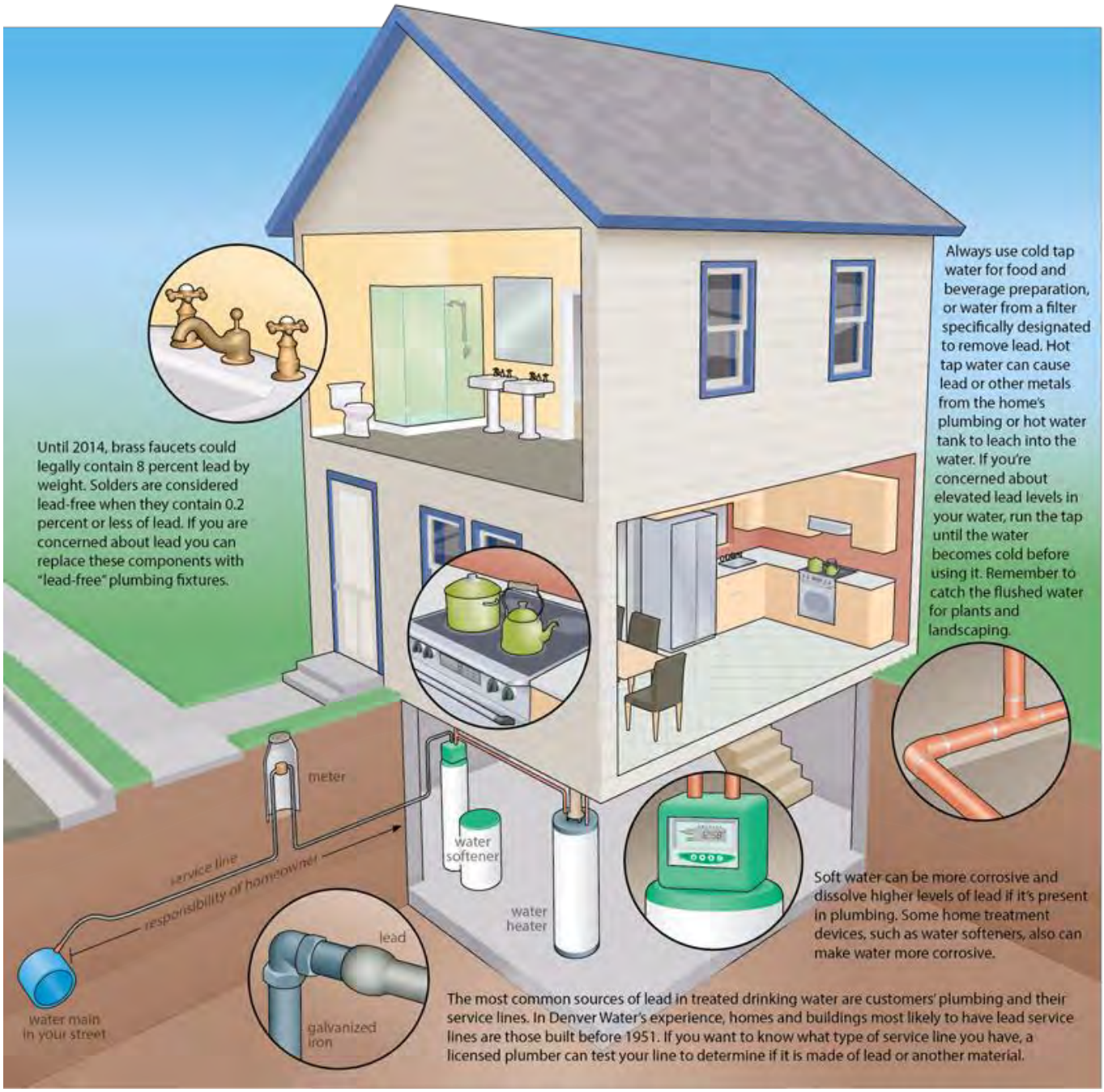

FIGURE 3: HISTORY OF LEAD IN DRINKING WATER

Since 1994, Denver Water has been authorized to maintain a minimum pH/alkalinity of 7.5. In accordance with this authorization, in recent years, Denver Water has sought to consistently maintain a pH of 7.8. This approach has resulted in the following lead concentrations measured from Tier 1 homes as defined in the Lead and Copper Rule. A Tier 1 home is a sample site that is a single-family structure built between 1983 and 1987 that (1) contains copper pipes with lead solder, (2) contains lead pipes and/or (3) is supplied by a lead service line.

Category	Lead Concentration Range (1997-2019 data) (expressed in units of ppb – parts per billion)
Average lead concentrations for Tier 1 homes	4 to 8
90th percentile lead concentrations for Tier 1 homes	7 to 17*

* Lead and Copper Rule action level is 0.015 mg/L = 15 ppb; 17 ppb was reported once in 2012.

Although these treatment efforts were largely effective for many years, in 2012, the 90th percentile value for sample results of lead concentrations in tap water was 17 ppb, exceeding the Lead and Copper Rule action level of 15 ppb. Since the Lead and Copper Rule was adopted in 1992, the 2012 exceedance of the lead action level was Denver Water's first and only exceedance.

As a result of this one exceedance, Denver Water was required to investigate the cause and evaluate alternative treatment solutions. These studies included a lead service line pipe rack study that required the harvesting of lead service lines from homes in the distribution system. These studies, especially the pipe rack study, required a significant investment of time and resources by Denver Water and resulted in the submittal of an Optimal Corrosion Control Treatment Report in late 2017. Based on the data in the report, in March 2018, the Colorado Department of Public Health and Environment designated orthophosphate be added to drinking water as the optimal corrosion control treatment and directed Denver Water to prepare to implement orthophosphate treatment by March 2020.

Corrosion Control

What is corrosion control?

When water interacts with metal, the metal can oxidize, resulting in corrosion. By adjusting the chemistry of the water, it is possible to cause a buildup or coating on pipe walls, which reduces the amount of lead released from lead-containing pipes and fixtures. This protective coating, however, requires the maintenance of a delicate chemistry in the water. To reduce corrosion and maintain the coating, the Lead and Copper Rule requires drinking water systems to maintain "optimal corrosion control treatment," which means a corrosion control treatment that minimizes the lead and copper concentrations at customers' taps. This can be done through orthophosphate addition, pH/alkalinity adjustment or calcium hardness adjustment. Depending on the chemistry of the water, some corrosion control treatment methods can be more effective than others.

What is orthophosphate?

Orthophosphate is a phosphate-based corrosion control inhibitor that changes the chemistry of water to create a protective coating on service lines and plumbing that, in turn, reduces the corrosion that causes lead releases. Although orthophosphate is effective at reducing lead exposure, it can increase phosphorus levels in wastewater and add excessive nutrients to surface water, adversely affecting rivers, streams and lakes in our region. To remove phosphorus, wastewater treatment plants would need to invest in facility upgrades. In addition, once Denver Water begins to treat with orthophosphate, it will likely need to continue treatment indefinitely to avoid upsetting the delicate chemistry of the water that maintains the protective coating on service lines and plumbing.

Are there effective alternatives to orthophosphate?

Because of concerns about the negative impact of orthophosphate on wastewater treatment plants and the environment, Denver Water engaged stakeholders to assess alternatives to using orthophosphate that may provide even greater protection to Denver Water customers.

These studies investigated two treatment approaches: (1) the lowest effective dose of orthophosphate (3, 2 or 1 mg/L as orthophosphate) required to minimize lead at drinking water taps in Denver Water's system and (2) the effects of a higher pH of 9.2 as a corrosion control treatment method on lead releases. Denver Water and stakeholders also analyzed the costs to remove phosphorus from the watershed as well as the costs to counter the potential effects of increasing pH. In addition, Denver Water developed a lead control model, demonstrating the efficiency of replacing lead service lines in combination with both use of lead removal filters and pH/alkalinity adjustment, as compared with orthophosphate corrosion control treatment alone.

Based upon these studies, Denver Water is proposing an alternative, holistic approach that directly tackles the biggest issue, customer-owned lead service lines, at its source by accelerating the replacement of those lines through a Lead Reduction Program. The Lead Reduction Program would reduce the risk of public exposure to lead beyond what can be achieved by adding orthophosphate to the drinking water by:

- Developing a lead service line inventory so our customers can investigate the likelihood of having a lead service line.
- Implementing the Filter Program, a program that would distribute filters to all homes with a known, suspected or possible lead service line, reducing lead by 97% or more.
- Implementing an accelerated lead service line replacement program that would replace the major source of lead decades ahead of the current rate of replacement: approximately 63,955 lead service lines would be replaced within 15 years versus 50 years or more under current practices.
- Adjusting pH from 7.8 to 8.8 and maintaining alkalinity above 30 mg/L as $CaCO_3$ for corrosion control treatment to reduce corrosion of lead service lines, household plumbing

and fixtures (note: treatment objectives for pH/alkalinity adjustment will be approved by the Colorado Department of Public Health and Environment).

- Enhancing the communications, outreach and education program to help customers understand the Lead Reduction Program and ways that they can reduce their exposure to lead.

How will this change my water quality?

The proposed pH/alkalinity adjustment to improve corrosion control will have little-to-no noticeable impacts to Denver Water customers, their plumbing, and appliances. Results from internal and external taste tests show that changes in taste and odor are not anticipated to be an issue with either proposed corrosion control treatment alternatives. Further, there is no evidence that the effectiveness of fluoride would be impacted.

For customers with chemistry dependent uses (pools, fish tanks, breweries, etc.), the customers will be informed of the change and prepare accordingly. Proper maintenance of appliances to prevent excessive scale build-up should be part of general maintenance practices regardless of the water quality that enters premise plumbing.

Variance Request and Lead Reduction Program

How does the Environmental Protection Agency determine whether an alternative treatment method is as effective or better than orthophosphate?

To implement the Lead Reduction Program, Denver Water must apply for a variance from the Environmental Protection Agency. Under 42 U.S.C. § 300g-4(a)(3) and 40 C.F.R. § 142.46, the Environmental Protection Agency may grant a variance from the optimal corrosion control treatment requirements under the Safe Drinking Water Act's Lead and Copper Rule *"upon a showing from any person that an alternative treatment technique not included in such requirement is at least as efficient in lowering the level of the contaminant with respect to which such requirements was prescribed."*

Is Denver Water proposing the Lead Reduction Program on a voluntary basis?

Denver Water is proposing the Lead Reduction Program on a voluntary basis as an alternative to orthophosphate treatment under the Lead and Copper Rule. Denver Water cares about the 1.4 million people it serves and the safety of the water at their taps. Denver Water wants to provide the best short- and long-term solution to prevent lead exposure. In addition, Denver Water is concerned about the adverse impact that orthophosphate could have on the downstream reservoirs, rivers and streams, the quality of the source of supply and the costs wastewater treatment and stormwater management providers would incur to remove phosphorus. For these reasons, Denver Water is proposing the Lead Reduction Program as a proactive measure to permanently replace lead service lines from its service area as efficiently as possible, provide additional public health protection that cannot be achieved through orthophosphate treatment alone, protect the watersheds and help reduce regional costs that would be incurred to remove phosphorus from wastewater.

What commitments is Denver Water making?

Denver Water will actively engage its customers within the City and County of Denver and the service areas of its distributors that collectively make up Denver Water's "integrated system." The Lead Reduction Program will aim to reduce lead concentrations by distributing filters to customers with known, suspected or possible lead service lines, replacing 7.0% of the lead service lines annually and replacing all lead service lines within 15 years. Denver Water's commitments are described in more detail in Table 1.

TABLE 1: DENVER WATER'S PROPOSED LEAD REDUCTION PROGRAM COMMITMENTS

Communications, Outreach and Education
Denver Water is committing to: • Educate and engage with residents, customers, distributors, local public health agencies and government stakeholders about lead awareness and reduction efforts. • Educate the public on measures they can take to reduce their exposure to lead in water used for drinking, cooking and infant formula preparation. • Tailor and support a communications, outreach and education program focused on expecting and existing families with formula-fed infants/children up to age 2, at homes with copper piping with lead solder, with special emphasis on homes built 1983-1987. • Seek feedback from residents and other stakeholders to learn best practices and effective ways to implement program activities. • Strive for 100% participation in the Filter Program.
Lead Service Line Inventory
Denver Water is committing to: • Research, investigate and document the presence of customer-owned lead service lines. • Help customers identify if they have a lead service line. • Maintain a current lead inventory and map. • Confirm materials at properties with a suspected or possible lead service line. • Use the inventory to target communications, outreach and education efforts at areas with the greatest risk.
Filter Program
Denver Water is committing to: • Provide filters and filter cartridge replacements to properties with known, suspected and possible lead service lines for up to 15 years during the life of the Lead Reduction Program. • Educate and inform residents on the importance of using filters for drinking water. • Denver Water is striving for 100% adoption in the Filter Program; if filter adoption is less than 75%, Denver Water will increase outreach and education efforts in low adoption areas to improve filter use.
Accelerated Lead Service Line Replacement Program
Denver Water is committing to: • Replace all known lead service lines in 15 years. • Replace 7.0% of the lead service line inventory each program year, based on a cumulative annual average. • Use the predictive model to help prioritize lead service line replacements, taking into consideration public health/toxicology concerns, child care providers, primary schools, neighborhoods with a high density of young families and socioeconomic and environmental factors. • Follow up with residents and provide filters until the service line is confirmed as non-lead or until six months after the lead service line is replaced.
Corrosion Control Treatment
Denver Water is committing to: • Maintain water quality by implementing corrosion control treatment through pH/alkalinity adjustment. • For homes built from 1983 to 1987 with copper piping with lead solder where water quality tests exceed 3 ppb, provide equivalent treatment by offering free filters and replacement cartridges for expecting and existing families with formula-fed infants/children up to age 24 months, per CDPHE guidance.

Learning by Doing
Denver Water is committing to: • Evaluate the performance of the Lead Reduction Program to improve outcomes. • Establish an Advisory Committee to inform Denver Water on more efficient and effective ways to implement the Lead Reduction Program to achieve the variance goals.
Health Equity and Environmental Justice
Denver Water is committing to: • Create equitable access for all communities within the integrated system so that all residents will benefit from the reduction in lead exposure. • Prioritize the integration of health equity and environmental justice principles by measuring the community needs and tailoring outreach efforts to reach vulnerable populations. • Consult and collaborate with community organizations and members, health equity and environmental justice experts, stakeholders and customers to continually improve upon the Lead Reduction Program.

How will the performance of the Lead Reduction Program be evaluated?

Denver Water will use the criteria shown in Table 2 to evaluate the performance of the Lead Reduction Program. An annual report will detail the program's success and provide regulators with clear criteria to determine when to require correction or take enforcement action.

TABLE 2: LEAD REDUCTION PROGRAM EVALUATION FOR COMPLIANCE

Element	Definition of Compliance	Correction Active	Failure to Meet Condition
Lead Service Line Inventory	Must investigate a minimum of 1.4% of total LSLs in inventory per year.	• Achieve compliance by following year. • Provide notice of corrective action to customers with filters.	If less than 1.4% investigations occur for three program years: • Notice to all customers.
Filter COE	Outreach and education materials provided each year to at least 95% of households enrolled in the Filter Program.	• Must achieve compliance by following year. • Notice to customers with filters.	If Denver Water fails to provide outreach and education materials to at least 95% of households enrolled in the Filter Program for three years: • Notice to all customers.
Filter Program	Achieve minimum filter adoption rate of 65% per year.	• If filter adoption rate is less than 65% in a year, increase outreach and education efforts to improve filter use. • Notice of corrective action to customers with filters.	If failure to achieve 65% adoption rate for three years: • Termination of variance. • Notice to all customers.
Accelerated Lead Service Line Replacement	Must achieve 7.0% cumulative annual average replacement rate each year.	• Achieve compliance by following year. • Notice to customers with filters.	If less than 7.0% of lead service lines are replaced for three years: • Termination of variance. • Notice to all customers.
Corrosion Control Treatment	Lead and Copper Rule sampling results remain below action level for lead.	• Must adjust corrosion control and distribution management. • Customer education and notice.	If action level exceeded for two monitoring periods: • Must provide customer notice. • Termination of variance unless CDPHE requires otherwise.

What is the estimated cost of each alternative?

Denver Water estimated the life cycle cost for each alternative. This effort included incorporating cost data from other water and wastewater utilities, stormwater entities, watershed authorities and recreational entities. CDPHE requested a summary of costs to support the implementation of, or resulting from, the variance or orthophosphate alternatives, and excluding costs related to Denver Water's existing lead service line replacement work. Denver Water also calculated the costs including the costs for the existing lead service line replacement work because these efforts will continue under either alternative. As seen in Table 3, under either assumption, the variance alternative is more cost effective.

TABLE 3: LIFE CYCLE COSTS IN TERMS OF NET PRESENT VALUE

Assumption	Orthophosphate (at 2 mg/L as PO_4)	Variance
Excluding Existing Service Line Replacement Efforts	$322M to $506M	$265M to $362M
Including Existing Service Line Replacement Efforts	$376M to $582M	$319M to $439M

How will Denver Water fund the Lead Reduction Program?

Denver Water will fund the Lead Reduction Program through rates, loans, grants and donations. In addition, as a show of support for the Lead Reduction Program Plan, Metro Wastewater Reclamation District committed $22.5 million in funding in a resolution adopted on July 16, 2019.

"The Metro Wastewater Reclamation District strongly supports the Lead Reduction Program because it is a permanent and holistic solution that benefits both public health and the environment across the unique arid west region. In furtherance of its support, the Metro Wastewater Reclamation District Board of Directors has made a commitment of up to $22.5 million to the Lead Reduction Program if the variance is approved by Environmental Protection Agency."

What if the variance request is not approved or the variance criteria are not met?

Following the Colorado Department of Public Health and Environment's designation of orthophosphate for optimal corrosion control treatment, Denver Water initiated design and construction of chemical feed systems to dose orthophosphate at 3 mg/L at Denver Water's three treatment plants. If the variance request is not approved, these systems will begin introducing orthophosphate on March 20, 2020.

If the variance is granted and certain criteria in Table 2 are not met during the 15-year period of the Lead Reduction Program, Denver Water might also be required to implement orthophosphate using the chemical feed systems.

More details on the optimal corrosion control treatment designation of orthophosphate can be found at: www.colorado.gov/cdphe/lead-dw-treatment

Public comment period for the Lead Reduction Program Plan

Denver Water conducted a public comment period from July 12 to August 7, 2019 to gather feedback on the program benefits, filter input, communication preferences and overall support. The information was distributed through a variety of different engagement channels such as newsletters, targeted emails to stakeholders and customers who have expressed an interest in Denver Water's lead reduction efforts, TAP news site distribution, social media, distributors, neighborhood groups, etc. During this four-week period, 406 comments were received from unique IP addresses that have indicated that more than 98% of respondents support the Lead Reduction Program, emphasizing benefits for future generations, environmental health and protecting infants and children. Public feedback has been incorporated throughout the plan. Full results can be found in Appendix I.A.

Denver Water also received letters of support from various public health agencies, copies of which can be found in Appendix I.B.

How to navigate through this Lead Reduction Program Plan

This executive summary introduces the Lead Reduction Program Plan, the variance request and Denver Water's commitments if the variance is approved by the Environmental Protection Agency.

Section I presents the history of lead occurrence and control in the Denver Water system, from the single exceedance of the action level for lead in 2012 until the designation of orthophosphate for optimal corrosion control treatment by the Colorado Department of Public Health and Environment in March 2018.

Section II provides a summary of the investigations undertaken by Denver Water since March 2018 to demonstrate that the Lead Reduction Program is as effective as the alternative of orthophosphate at reducing lead concentrations in drinking water. An overview of the elements that together make up the Lead Reduction Program is presented.

Section III describes how Denver Water will implement all six elements of the Lead Reduction Program.

Section IV details how Denver Water will evaluate the performance of the Lead Reduction Program and ultimately maintain regulatory compliance with the Lead and Copper Rule.

Section V describes how Denver Water will address health equity and environmental justice needs through the Lead Reduction Program.

Section VI presents the implementation schedule for the Lead Reduction Program.

Section VII presents the estimated costs of the Lead Reduction Program.

A series of technical memoranda were prepared during the development of the Lead Reduction Program and are included in the appendices to this plan.

What is Denver Water asking of the customer?

- Understand that lead can get into water as it moves through customer-owned lead service lines and lead solder and what you can do to reduce lead exposure.
- Help us identify if you have a lead service line – learn more at denverwater.org/Lead
- If you have a lead service line:
  - Allow Denver Water to replace the lead service line at no cost to the property owner.
  - Use a filter until the lead service line can be replaced.
- If you have sources of lead in premise plumbing inside the home:
  - Replace faucets and indoor plumbing with lead-free components.

To minimize exposure to lead when using water for drinking, cooking and making beverages, ice and infant formula:

- Use a filter certified by NSF International to remove lead for drinking and cooking. Replace the filter cartridge according to the manufacturer's instructions.
- Use only cold water for drinking, cooking and making baby formula. Remember, boiling water does not remove lead from water and hot water often contains higher levels of lead than cold water.
- If water has not been used in the home for a few hours, such as first thing in the morning or when getting home from work or school, run the kitchen or any bathroom faucet for five minutes (remember to capture the water and reuse it!). You can also run the dishwasher, take a shower or do a load of laundry to help flush water in your internal plumbing before drinking or cooking.
- Regularly clean your faucet's screen (also known as an aerator).
- Consider replacing faucets and indoor plumbing with lead-free components.

ATTACHMENT

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DC Water and Raftelis Review Comments on INDEPENDENT VERIFICATION AND VALIDATION OF THE LEAD FREE DC LEAD SERVICE LINE REMOVAL PLAN FROM DC WATER: DRAFT REPORT, July 2022 by Safe Water Engineering, LLC
Date: 8/12/2022

Raftelis is under a long-term contract to provide financial planning, rate sustainability consulting, and management consulting services for DC Water. Raftelis is an industry expert in financial and capital planning, analysis of cost of service and cost allocation, budget development, utility rate and affordability analysis, and economic feasibility analysis and evaluation for water/wastewater utilities and municipal governments. Raftelis reviewed and provided comment on SWE's drat report behalf of DC Water.

The response below includes high-level comments from Raftelis, followed by four tables: a full list of comments from DC Water and Raftelis (Table 1), comments specific to "Table 16" from the draft SWE report (Table 2), questions submitted by DC Water to SWE (Table 3), and response to questions provided by SWE to DC Water (Table 4).

Consistency with Financial Practices and Policies

DC Water is a municipally owned utility following a modified cash basis of accounting. DC Water revenues must exceed cash expenditures in the fiscal year to satisfy Board-adopted financial policies and bond covenants. Compliance with these guidelines require utilities to utilize budgeting, including appropriate level contingencies, in compliance with industry standards, such as the American Association of Cost Engineers (AACE) guidelines. The SWE draft report suggests reducing costs based on economies of scale, changing DDOT paving requirements to lower paving costs, and benchmarking from select peer utility lead service line replacement (LSLR) programs. Reduction in plan cost estimates beyond what can be documented through sound industry standard estimating practice or actual procurement results places the utility in a precarious financial position and may prevent project objectives from being met.

DC Water's LSLR cost may be lower as the program matures and work becomes more efficient. However, for planning purposes DC Water's cost estimate for the total program follows the industry standard Class 4 AACE cost estimating guidelines, which uses an accuracy range of -20% (to account for potential cost reductions) to +30% (to account for unknowns such as additional identified LSLs). DC Water's cost estimating for the overall program is appropriate and aligned with industry standards. Making an assumption that costs will be less as the program matures (best case scenario) for calculating the initial program cost is not aligned with industry standards and inconsistent with current price inflation and labor shortages.

Basis for DC Water and SWE Cost Estimates

DC Water's total program cost is estimated to be $944M (low side) to $1,139M (high side).
SWE's total program cost is estimated to be $829.3M [$480M + $349.3M] (low side) to $1,082.5M [$628.4M + ($349.3 x 30% contingency] (high side). This includes the water main replacement cost of $349.3M as noted in Table 17 because the water main replacement has to occur to properly replace the LSLs. The water main replacement is a necessary cost of the LFDC program. If the public side LSLs are replaced and the old water main is left in place to be replaced in some other future project that approach adds cost and inefficiencies to the overall

program and ratepayers. Figure 7.1 LFDC Decision Tree clearly shows that private side LSLs, where no public side LSLs are located, are separately replaced independent of water main condition, which is appropriate. Funding for the priority water main replacement and the LSLR to be performed together, per DC Water's prioritized program, needs to be considered and secured to keep total costs to DC Water's ratepayers as low and predictable as possible.

DC Water Total Cost = $944M - $1,139M
SWE Total Cost = $829.3M - $1082.5M
Difference = $56.5M - $114.7M (4.96% - 12.2% difference)

The two costs are between 5% and 12% of each other with the high and low estimates which for planning level costs are the same order of magnitude. SWE's program indicates the cost includes replacing 42,323 LSLs. SWE is using the assumed cost savings from 1) their assumption of reduced paving cost $148.4M, and 2) their assumption of reduced programmatic costs of $90.1M (total of 1 & 2 = $238.5M) to essentially cover the additional cost of the 14,348 LSLRs [42,323 - 27,975 (DC Water total)] assumed in their 42,323 LSL total.

If DC Water's total program cost included the $148.4M savings from reduced paving, total cost would be $795.6M - $990.6M which is a lower total program cost than SWE's total program cost of $829.3M - $1082.5M and would essentially cover the cost of the added 14,348 LSLRs included in SWE's cost. It is not aligned with AACE cost estimating industry standards to assume the best case scenario and the potential for reduced costs when developing a planning level cost estimate, as done in SWE's cost estimate. DC Water has tried to negotiate lower paving costs with DDOT. SWE noted DDOT paving requirements in their report but should not automatically make an assumption that lower paving costs could be realized. SWE could have also asked DC Water for their actual programmatic costs versus making an assumption that costs could be lowered without sufficient backup to support the lowered costs.

Viability of SWE-Proposed Timeline

SWE proposes completion of approximately 42,000 LSLRs in a six-year period from 2024-2029 including over 7,000 replacements each year. LFDC proposed 28,000 LSLRs in a nine-year period from 2021-2029 and between 2,800 and 4,700 replacements per year. It is unclear whether the proposed SWE timeline and annual LSLR capacity is feasible. SWE did not evaluate this feasibility of program size and contractor capacity in their report.

SWE Noted Changes to the Priority of LSL Replacements

The report shows in Map 3 the prioritization results of SWE's modified model (parameters listed in Table 6). The prioritization results between DC Water LFDC's model and SWE's model show very similar results. SWE's model results in Map 3 appear to validate DC Water LFDC's model results versus shifting the prioritization locations, as the report states. Given the number of LSLRs scheduled by DC Water for each year through 2030 (as shown in the maps in the DC Water's June 2021 report) we do not see how SWE's model provides more accurate results or a necessary change to DC Water's priority LSLR locations by year.

Eliminate Bifurcation of LSLR Programs and Distinction Between Funding Options

SWE's Report states, "*To successfully implement the recommended program, the Council of the District of Columbia will need to eliminate the bifurcation of LSLR programs and the distinction between funding options for partial lead service lines and full lead service lines. The current LFDC distinctions of funding sources, funding eligibility, and program administration decrease the efficiency of the LFDC plan*." We agree with this statement. The extent to which private and public LSLRs funding can be clearly defined and provided will greatly increase the efficiency of DC Water's program which currently assumes only a 70% customer participation rate. Since DC Water cannot currently spend the cash it collects on private LSLRs a dedicated funding source is needed for the private LSLRs. DC Water's June 2021 Program Report identifies a number of policy recommendations to increase the efficiency and reduce costs of the LSLR program.

Table 1: Full Comments from DC Water and Raftelis re: SWE Draft Report

Comment Number	PDF Page Number	Comment	Commenter
1	3	DC Water has worked to implement recommendations from the Council-appointed Lead Task Force related to the prioritization model.	JD
2	4	Agree with report's statement: "*We strongly support DC Water's recommendation in the LFDC Plan to eliminate unnecessary* *bifurcation of programs and the distinction between funding options for partial lead service lines* *and full lead service lines. The distinctions of funding sources, funding eligibility, and program* *administration decrease the efficiency of the LFDC Plan. Breaking down these distinctions and* *merging programs to function at the neighborhood scale will greatly improve efficiency and the* *timeline for removing all LSLs.*" Addressing DC Water's recommendation and risks is critical to the success of the LFDC program completion by 2030.	BCV
3	7	"account for replacement of 14,348 more than LSLs than the original LFDC Plan" Recommend clarifying definition of LSL used in this report: lead, galvanized iron, and brass.	JD
4	8	filters - the Lead Task Force has discussed recommendations for a filter program beyond post-LSL replacement (DC Water best practice, standard, LCRR).	JD
5	8	"These replacements are necessary for maintenance of DC Water infrastructure, and LSLR will be least expensive if completed at the same time, but these are expenses DC Water must plan for even in the absence of a LFDC Plan." Poor condition water main replacement in conjunction with LSR goes beyond a cost-saving measure, and is best practice to avoid water quality issues, correct?	JD

6	8	Recommend clarifying last paragraph for reader about elimination bifurcation of LSLR programs. Reference what law will required amending that establishes CIPERR & LPRAP - and the impact - eliminating customer-initiated replacement program for private-only LSRs, all replacements would be 100% for homeowners that don't go through VFRP.	JD
7	10	Do the 6 utilities surveyed (excludes Baltimore) represent a comprehensive review of best practices in LSLR or are they presented more to provide alternative practices for consideration by DC Water?	JPD
8	13	Figure 2. The Premex database was a data output from the CIS since the 2004. When V1 replaced CIS, the Premex database was fed by V1 and Maximo.	MS
9	13	"About 2,900 of those homes with known or probable lead service lines have lead concentration of more than 20 ug/L" – clarify with quotation marks that the sentence is from the report or describe that the lead concentrations were from samples collected prior to the publication of the report and therefore not representative if today's lead occurrence in water in the District of Columbia.	MS
10	14	"Based on DC Water's records review ~~and~~ of current field work.." -- "and" should be "of"	MS
11	14	"Based on DC Water's records review.." the data presented are from the 2022 LFDC By-Block field work to date. These blocks are expected to contain more LSLs compared to neighborhoods without any identified LSLs, so is important to note the data source.	MS
12	14	"Further, in January 2021…" the data presented were from a 2020 data analysis.	MS
13	15	2nd to last paragraph - We understand DCWater agrees with the District of Columbia's addition of brass and galvanized service lines to the definition of lead service lines. DCWater included lead and galvanized service line replacements by 2030 and planned to replace brass lines in areas where galvanized and lead lines were identified. DCWater indicated they will discuss if all of the brass lines also need to be replaced by 2030.	BCV
14	15	Table 2 should clarify if "public" or "private" since Table 1 lists both and costs of public and private work differ substantially. The note below the table is confusing. More explanation of how the data were derived for Table 2 is needed. A shapefile is using data from the same inventory, so please clarify why the numbers change from analyzing with using a shapefile.	MS
15	15	Table 2 – "Lead, to be verified" = "Lead, to be replaced". Please clarify why they are equal since some of the data has been verified by excavations.	MS
16	16	(pages 16 and 50) Safe Water Engineering (SWE) estimates that 42,323 lines are lead, brass, and galvanized and assumes all of these are to be replaced by 2030. This number assumes that 20% of all historic copper lines will turn out to be lead lines upon inspection. DCWater indicated they will discuss if their current estimate of 27,975 lines to be replaced by 2030 should be modified and if brass lines need to also be replaced by 2030. The use of collected water quality data for the concentrations of lead in known brass SL areas could be used as part of this discussion.	BCV

17	16	3. Maintain historical records… DC Water does have records of changes to pipe materials. The data are archived in Maximo. Prior to the use of Maximo we have records of the DC Premex datasets going back to 2004.	MS
18	16	1. "Stop using water quality sampling…" DC Water provides a customer-initiated way for customers to determine the presence of a lead source ahead of a test-pitting verification. DC Water is required by law to provide a free lead test kit on an annual basis when requested. Sunsetting program would require regulatory change.	JD
19	17	Report states, "*Stop using water quality sampling for lead service line verification.*" DCWater lead service line replacement report dated June 2021 states that water quality testing at private properties for measuring lead levels is used to verify if lead service lines exist at the private properties. This testing is required by EPA regulations. This should not be stopped as the report appears to state. In addition, water quality sampling for Iron and Chlorine is used by DCWater to determine locations for unlined cast iron water mains. These mains require replacement over time which is important to coordinate with lead service lines also in need of replacement connected to those unlined cast iron mains. For these reasons, we do not agree with the report that this water quality sampling should be stopped.	BCV
20	17	I am unclear as to why sampling for lead would not be a valid consideration. The report seems to contend that this practice is antithetical to the ability to identify opportunities for LSLR.	JPD
21	17	Report states, "*We recommend all outreach materials, clearly state that, especially for homes or properties developed before 1977, that positive documentation and verification of the buried service line material is necessary to ensure there is a non-lead service line*." We agree with this recommendation for clarity.	BCV
22	17	Report states, "*Maintain historical service line data, even when records are updated*." If there is uncertainty with the newly collected data then the historical record should be maintained. However, if the new data is updating a pipe material or diameter and DCWater is confident in the new data then changing or overwriting the data to reflect the new data is appropriate.	BCV
23	17	We agree with the report's recommendation to "*continuing DC Water's approach of verifying every service line as they work block by block.*" DCWater is implementing a LSLR approach that is flexible and allows for additional lead service lines to be replaced as they are discovered during the work.	BCV
24	17	Worth mentioning up front that DC Water is working with the Task Force to improve the prioritization model. Below is an excerpt from the draft Task Force report with Task Force recommendations compared to version 1 of the prioritization model.	JD

		Current Prioritization Criteria (June 2021 Category: Criteria Physical Condition: Main Breaks Water Quality: Iron Concentration; Chlorine Concentration; Service Line Pipe Material Health and Social Equity: Area Deprivation Index Vulnerable Population: Children under 18; Daycares Proposed Prioritization Criteria Category: Criteria Water Quality: Service Line Pipe Material Vulnerable Population: Children under 5; Blood Lead Levels* Health and Social Equity: Black/African-American Households; Median Income *DC Water does not currently have access to this data but is working with DOE Understanding to obtain available data set on blood lead levels. **Sensitivity analyses have not been conducted because not all of this data is c percentage weights in the proposed priortization may change.
25	17	Recommend including citation to ADI.	JD
26	18	Report states, "*Consider statistical methods to identify areas with copper that turn out to be lead and brass service lines that are found to be lead or brass*." As DCWater collects more information on locations of brass and copper water lines, using statistical analyses could provide some benefit for confirming lead and brass service line locations. DCWater will discuss if all of the brass lines also need to be replaced by 2030.	BCV
27	19	Include full citation for Berg 2017 for reference.	JD
28	21	Disagree that DC Water model includes "parameters that do not relate to the risk of LSLs" - these factors are associated with the risk that are posed by LSLs. Does it not stand to reason that repairs for water main breaks create the potential for physical disturbance of LSLs on block which is related to increased risk of particulate release of lead from LSLs?	JD
29	22	Report states, "*Use Higher Resolution American Community Survey (ACS) data for children 5 and under*." Given how DCWater setup their prioritization model with the various criteria, it is not clear if using census block data for children 5 and under, versus the census tract data that DCWater used, will cause a change in priority LSLR locations. If DCWater thinks this block data will change the priority results, they may wish to run a GIS scenario with this block data to see if any priority locations change.	BCV

30	22	These maps are comparing two different data sets (18 and under and 5 and under) at two different levels (census tract vs census block group). What is it conveying?	JD
31	23	Report states, "*Remove iron and chlorine sampling parameters*." It is not clear from the information available to us if the iron and chlorine data is biasing the prioritization of LSLR locations. DCWater should offer comment on if the iron and chlorine data used in the prioritization is representative of the entire service area. If No, perhaps the weighting should be reduced?	BCV
32	24	Recommend clarifying does this report recommend in Table 6 that Lead, Unknown, Brass, Galvanized all receive the same prioritization weight for replacement?	JD
33	25	(pages 25-26) The report shows in Map 3 the prioritization results of SWE's modified model (parameters listed in Table 6). The prioritization results between DCWater LFDC's model and SWE's model show very similar results. SWE's model results in Map 3 appear to validate DCWater LFDC's model results versus shifting the prioritization locations, as the report states. Given the number of LSLRs scheduled by DCWater for each year through 2030 (as shown in the maps in the DC Water's June 2021 report) we don't see how SWE's model provides more accurate results or a necessary change to DC Water's priority LSLR locations by year.	BCV
34	25	Table 6 - One Likelihood of Lead (LoL) parameter does not seem to facilitate necessary prioritization. This seems to discount likeliness altogether. The parameters used in DC Water's LFDC prioritization more appropriately capture the likelihood of finding lead service lines.	JPD
35	26	Recommend noting that DCW runs this model annually based on updated inventory information, and that this report's analysis is based on the first model run in June 2021.	JD
36	30	"1. Create a new DC Water-initiated Neighborhood Scale LSLR Program" - recommend more clearly explaining how this modifies existing block-by-block program. A comparison chart may be helpful of how current block-by-block vs new neighborhood scale program achieve the bullet strategies on the top of page 31.	JD
37	31	Report states, "*Every potential LSL must be included as part of a planned, systematic approach to LSLR before individual services get pulled into priority programs*." It appears DC Water's program is already doing this. DC Water's prioritization criteria accounts for determining potential LSLs (See Figure 7.1 in SWE's report). Figure 7.1 also shows DC Water's program includes determining unknown service line materials as work is being performed in priority neighborhood locations.	BCV
38	31	(pages 31-32) Report states, "*Create a new DC Water-initiated Neighborhood Scale LSLR Program*." It appears DC Water's LSLR program is already doing this. If you closely review the annual implementation maps included in DC Water's June 2021 report, they have grouped the LSLR work by neighborhood and by block. Further clarity from SWE on what they think DCWater is not doing in this area could be helpful.	BCV

39	32	Report states, "*Create a new district-wide DC Water-initiated Individual, High-Priority LSLR Program*." and "*As a result, all day care facilities should have confirmed non-lead service lines by the end of 2024*." It appears DC Water's current program has properly prioritized and identified individual LSLs to be replaced. The results on Map 3 in the report from SWE's model validate DC Water's prioritization. See comment 14 above. It is not clear from the information we have, if all day care facilities will have LSLs replaced by 2024. DCWater indicated they will confirm all day care facilities have a prioritized schedule for completion of LSLRs, where applicable.	BCV
40	32	Use of the term "jump the line" is incorrect. Jumping the line implies that those in the line then have an increased wait. The Voluntary Full Replacement Program has a separate contract, so those activities continue at the pace determined by only that program (and weather).	MS
41	33	Report states, "*DC Water's LSLR model uses water main condition only to identify needed water main replacements associated with LSLR. It does not consider the number of LSLs on a water main as a reason to replace a water main*." This does not appear to be correct. Figure 7.1 LFDC Decision Tree clearly shows the number of LSLs on a water main and the condition of the water main are used in determining when a water main should be replaced.	BCV
42	33	The existing water main replacement program and LFDC that includes water main replacement are two separate, important initiatives each with their own rules of prioritization. They should be separated in capital planning. The existing program is funded by the Water System Replacement Fee and prioritizes water lines in the District that are, on average, 80+ years old. Water lines addressed in LFDC are prioritized differently and funded differently.	JPD
43	33	Report states, "*Group all LSLRs associated with water main replacements together in the CIP to create the CIP Water Main Replacement LSLR Program*." It appears DC Water's program is already setup this way. DC Water's program includes the Capital Improvement Project and Emergency Repair Replacement (CIPERR) Costs program that groups prioritized water main replacement with prioritized LSLRs. Further clarity from SWE on what they think DCWater is not doing in this area could be helpful.	BCV

44	33	Report states, "*We recommend including and adding all water main replacement costs to the CIP and separating them from LFDC Plan costs. These water main replacements are necessary and must happen at the same time as LSLR, though water main asset management must be accounted for in the CIP, not as an added cost resulting from the LSLR initiative.*" We don't see the water main replacement as an added cost to the LSLR initiative. The water main replacement is a necessary cost of the LFDC program as part of replacing the LSLs. If the public side LSLs are replaced and the old water main is left in place to be replaced in some other future project that approach adds cost and inefficiencies to the overall program and ratepayers. Figure 7.1 LFDC Decision Tree clearly shows that private side LSLs, where no public side LSLs are located, are separately replaced independent of water main condition, which is appropriate. Funding for the priority water main replacement and the LSLR to be performed together, per DC Water's prioritized program, needs to be considered and secured together to keep total costs to DC Water's ratepayers as low as possible.	BCV
45	33	Report states, "*Continue the VFRP program from the LFDC plan*." We agree with this recommendation.	BCV
46	34	(pages 34-36) Report states, "*We recommend the decision tree structure in Figure 4 for assigning blocks to the four recommended LSLR programs. The 4 program areas account for and replace all lead, brass, and galvanized service lines, as well as test any historic or unknown service lines to identify and verify material type. These programs would all be initiated by DC Water and do not rely on customers initiating replacement. Table 8 below shows the number of LSLs in each category*." We are not able to verify the numbers shown in Table 8 as we do not have that data. However, DC Water's current program appears to already address the above issues and specifically includes a step in their decision tree (Figure 7.1 of the report) that accounts for addressing unknown material service lines. We don't think changing DC Water's program to the above recommendations would provide any significant value or improvements.	BCV
47	36	"voluntary customer-initiated programs" strike the word "voluntary" as to not confuse reader since that number includes both VFRP and LPRAP	JD
48	36	Include the definition of "block" as defined in the Infoasset Model Planner Appendix referenced before. Unclear how "Census Block Group" compares with "block" used in DCW planning, and thus obfuscates recommendation for improvement on page 38.	JD

49	39	(pages 39-40) Report states, "*Plan to complete all lead service line replacements in 6 years (2024-2029)*." We don't understand why the report would recommend stopping the LSLR work in 2022 and 2023 and starting again in 2024. We agree with DCWater that continuing this work through 2030 is a reasonable but aggressive schedule. Table 10 in the report recommends ramping up to over 7,000 LSLs being replaced per year as compared to DC Water's projected schedule of 4,000 - 5,000 LSLRs per year. The added program management, engineering, construction inspection and overall DCWater added staff costs to manage this 40% - 75% increase in LSLRs do not appear to be factored into the report's recommendation. As noted in the DCWater June 2021 report, DC Water and the Washington Aqueduct have effectively implemented optimum corrosion control treatment, which has reduced water lead levels to 2-3 ppb at the 90th percentile compared to the EPA lead action level of 15 ppb. So there is no regulatory requirement for DCWater to increase their annual LSLRs to over 7,000 per year and incur the added management and implementation costs.	BCV
50	39	Report states, "*Schedule the majority of LSLRs using the prioritization model at the Census Block Group Scale.*" The prioritization results between DCWater LFDC's model and SWE's model show very similar results in Map 3. SWE's model results in Map 3 appear to validate DCWater LFDC's model results versus shifting the prioritization locations, as the report states. Given the number of LSLRs scheduled by DCWater for each year through 2030 (as shown in the maps in the DC Water's June 2021 report) we don't see how SWE's model provides more accurate results or a necessary change to DC Water's priority LSLR locations by year.	BCV
51	39	Table 10 - include assumptions used for how this report determined small diameter water main replacement rate and "CIP blocks".	JD
52	40	The recommended schedule does not produce more LSLRs until FY2026 and it assumes the more aggressive schedule of 7k+ per year is feasible. SWE does not discuss the feasibility of replacing over 7,000 LSLs per year, impact on staffing and the available construction contractors to perform this accelerated work.	JPD
53	41	I do not understand how the seemingly minimal differentiation in risk measurement on Map 3 can result in such a big differentiation for LSLR by year between Maps 6 and 7. Given the number of LSLRs scheduled by DCWater for each year through 2030 (as shown in the maps in the DC Water's June 2021 report) we don't see how SWE's model provides more accurate results or a necessary change to DC Water's priority LSLR locations by year.	JPD & BCV
54	41	Report states, "*Complete service line verifications and LSLRs at all day care centers during the first year*." It appears DC Water's current program has properly prioritized and identified individual LSLs to be replaced. The results on Map 3 from SWE's model validate DC Water's prioritization. It is not clear from the information we have, if all day care facilities will have LSLs replaced by 2024. DCWater indicated they will confirm all day care facilities have a prioritized schedule for completion of LSLRs, where applicable.	BCV

55	41	Recommend reference to file and presentation of cost estimate provided to Task Force that reduced LFDC program cost from $680 to $598 million; can include change log that shows justification for revisions.	JD
56	41	add 2b. LFDC cost estimate assumes all test pitting of historic information will be done through BBB program as opposed to By Premise LSR programs	JD
57	41	3b. That depends on the contract	JD
58	41	3c. Partially accurate - total LSRs is based off 50% unknowns	JD
59	41	5. The cost of water main replacement is SHOWN in LFDC cost estimate for CIP planned SDWMR; only cost of water main replacement for BBB is INLCUDED in LFDC cost estimate. You later clarify this on page 45, first sentence under charts, and on page 57 in second to last paragraph. Recommend doing the same up front on page 41.	JD
60	41	6. "Costs range significantly based on program" due to factors like type, scale & quantities of contract, who performs the work e.g., plumber for LPRAP vs large contractor for SDWMR	JD
61	42	"Some public outreach materials state" - No. DC Water confirms that "6-month filter supply is provided"	JD
62	47	Table 14 - Recommend revising or providing additional table that shows comparison of line items in LFDC estimate vs the estimate in this Report to clearly lay out where changes were made, similar to what you do in Tables 15 and 18	JD
63	48	Table 13 should be updated to reflect the increased construction cost in Washington DC compared to the stated locations. For example, cost of living is 45% lower in Denver, Co, and 31% lower in Newark, NJ compared to Wash DC.	BCV
64	48	Based on current experience $1,525 for public-side LSR under SDWMR is low and will likely increase over a period to 2030.	JD
65	50	(pages 51-52) The report indicates DCWater should reduce the LFDC programmatic costs from the estimated percentage of 43% to 19%. This includes Planning/Permitting, Design, Program Management, Outreach and Stakeholder Engagement, Construction Management, and Data Management. DCWater indicated they have updated LFDC programmatic costs based on recent data and program management costs that will be used to compare DC Water's actual costs to the report's recommended 19% programmatic cost percentage. We do not see the relevancy of comparing FTEs between the two programs in Table 15. DCWater staff are not included in the LFDC cost estimate.	BCV
66	50	footnote 16 - DC Water OMAC budget doesn't capture Clean Rivers or similar marketing for large-scale capital projects. Disingenuous comparison.	JD
67	51	Recommend noting that the BBB Contracts used in cost estimate were change orders to existing contracts so that DCW could ramp up as fast as possible, and is pursuing BBB specific contracts.	JD
68	51	"without public bidding" is not entirely accurate - 4 qualified firms with contracts with DCW bid on the projects, 2 were selected.	JD

69	52	Table 15 includes a number of assumed reductions in programmatic costs without backup to support the proposed reductions. For example, the 10% efficiency reduction assumed by SWE does not appear to be supported by actual data relevant to DC Water's program. Assuming a 10% efficiency, by SWE neglects to take into account the 70% customer participation rate that DCWater is currently experiencing due in part to not being able to pay for private side LSLRs. Moving design cost to 0% also does not appear appropriate as design work will be needed for the LSLRs. DCWater cannot assume the design cost will be zero dollars when developing their planning level program cost estimate.	BCV
70	52	The report states, "*The resulting unit cost of $13,625 is higher than for benchmarking cities and cost benchmarking shown in Table 13*." Table 13 does not account for the construction cost differences between Denver, Newark and Washington DC. The cost of living in these 2 cities compared to Wash DC is 45% and 31% lower respectively. Accounting for the higher cost of construction in Wash DC would make the quoted costs in these 2 cities much closer to the indicated DCWater cost of $13,625 per LSLR.	BCV
71	52	Report states, "*In addition, benchmarking cities Denver and Cincinnati both found that prices decreased over time as contractors become more efficient with repeat work. We anticipate that the cost of the Neighborhood Scale LSLR Program will be lower than estimated here*." DC Water's LSLR cost may be lower as the program matures and work becomes more efficient. However, for planning purposes DC Water's cost estimate for the total program follows the industry standard Class 4 AACE cost estimating guidelines, which uses an accuracy range of -20% (to account for these potential cost reductions) to +30% (to account for unknowns such as additional identified LSLs). DC Water's cost estimating for the overall program is appropriate and aligned with industry standards. Making an assumption that costs will be less as the program matures (best case scenario) for calculating the initial program cost is not aligned with industry standards and inconsistent with current price inflation and labor shortages.	BCV
72	53	Report states, "*Include the cost of providing certified lead reducing filters to all residents with potential LSLs*." DCWater provides filters to residents at the time their lead service lines are replaced.	BCV

73	53	Report states, "*Approximately $10,360 of the cost of a LSLR is attributed to the restoration cost (restoration+ programmatic fees). The emergency/vulnerable population program only spends $4,741 in restoration and restoration related programmatic fees. The difference in cost comes from street paving*." And, "*we suggest DC Water, Council of the District of Columbia, and DDOT work together to develop an appropriate metric for triggering street paving*." It appears 42% of the LSLR cost ($10,360/$24,535) is pavement restoration. If an appropriate metric for requiring DCWater to repave entire streets was discussed and agreed upon with the District and DDOT, the cost of the LSLR program could potentially be significantly reduced. We understand DCWater has attempted to lower the paving costs for LSLRs by proposing alternatives to DDOT. However, to-date, DDOT has not been willing to change their requirements. Therefore, DCWater has to assume the higher paving cost in the program cost estimate.	BCV
74	54	Table 16 - See spreadsheet tab labeled "Table 16 Comments".	BCV
75	54	Utility budgeting requires the full costs of the program to be encumbered before the project can begin. Encumbering a piece of a larger project or encumbering an amount that does not include adequate contingencies is disingenuous to the Board who approves the budget, lenders who fund construction, and rate payers who ultimately pay the costs. Utility budgeting requires the full costs of the program to be encumbered before the project can begin.	JPD
76	54	Since DC Water is responsible for the administration and achieving the objectives of the LFDC program, it seems prudent not to undercut their cost estimates. If economies are achieved over the course of the work, benefits accrue to all in the form of reduced costs and better outcomes. DC Water's cost estimate for the total program follows the industry standard Class 4 AACE cost estimating guidelines, which uses an accuracy range of -20% (to account for these potential cost reductions) to +30% (to account for unknowns such as additional identified LSLs). DC Water's cost estimating for the overall program is appropriate and aligned with industry standards. Making an assumption that costs will be less as the program matures (best case scenario) for calculating the initial program cost is not aligned with industry standards and inconsistent with current price inflation and labor shortages.	JPD & BCV

77	58	Table 17 - DC Water's total program cost is estimated to be $944M (low side) to $1,139M (high side). SWE's total program cost is estimated to be $829.3M [$480M + $349.3M] (low side) to $1,082.5M [$628.4M + ($349.3 x 1.3)] (high side). This includes the water main replacement cost of $349.3M as noted in Table 17 because the water main replacement has to occur to properly replace the LSLs. The SWE high side cost includes 30% contingency added to the water main cost. DCWater Total Cost = $944M - $1,139M SWE Total Cost = $829.3M - $1082.5M Difference = $56.5M - $114.7M (4.96% - 12.2% difference) The two costs are between 5% and 12% of each other with the high and low estimates which for planning level costs are the same order of magnitude. SWE's program indicates the cost includes replacing 42,323 LSLs. SWE is using the assumed cost savings from 1) assumption of reduced paving cost $148.4M, and 2) assumption of reduced programmatic costs of $90.1M (total of 1 & 2 = $238.5M) to essentially cover the additional cost of the 14,348 LSLRs [42,323 - 27,975] assumed in their 42,323 LSL total. As we noted in the above comments, it is not aligned with AACE cost estimating industry standards to assume the best case scenario and the potential for reduced costs when developing a planning level cost estimate. As noted above, DCWater has tried to negotiate lower paving costs with DDOT. SWE should have noted this in their report and not made the assumption that lower paving costs could be realized. SWE should have also asked DCWater for their actual programmatic costs versus making an assumption that costs could be lowered without sufficient backup to support the lowered costs.	BCV
78	58	Report states in Table 17, "**The low and high estimate are calculated using optimized street paving verses street paving as suggested by DDOT current regulations*." Table 16 indicates the optimized street paving to save $148.4M. DC Water's total program cost does not include the $148.4M cost savings because this is currently not allowed by regulation. If DC Water's total program cost included the $148.4M savings, total cost would be $795.6M - $990.6M which is a lower total program cost than SWE's total program cost of $829.3M - $1082.5M and would essentially cover the cost of the added 14,348 LSLRs included in SWE's cost.	BCV

79	58	Report states, "*Our LFDC Plan Recommendations are designed to achieve the following:* *• Account for identification and removal of all potential LSLs;* *• Prioritize critical customers and equity;* *• Consolidate programs and timelines to generate cost efficiencies;* *• Provide certified lead reducing filters to all potential LSL locations to provide an* *immediate source of safe drinking water for all residents; and* *• Encourage and increase public participation through lower costs, fewer participation* *barriers, and increased public engagement*." It appears from our review of this report and DC Water's June 2021 LSL Program Report that DC Water's program achieves these same objectives, except for possibly not providing lead reducing filters to LSL locations (DCWater to confirm if this objective is addressed). DC Water's LSLR program appears to achieve these same objectives for about the same total cost as SWE's total program cost. And if some or all of the cost savings identified by SWE from optimized street paving can be agreed upon by the District, DDOT and DCWater this would result in a DCWater total program cost less than SWE's estimated total program cost. See comment 32.	BCV
80	59	(pages 59-60) Table 18 appears to have some confusing costs as compared to Table 17 and only accounts for certain water main replacement costs. Table 17 costs appear to be repeated in Table 18. Therefore, for ease of understanding, Table 17 costs were used when comparing SWE's costs to DC Water's costs.	BCV
81	59	Report states, "*we recommend that these water main replacements be included in the CIP budget rather than the LFDC budget. These replacements are necessary for maintenance of DC Water infrastructure, and LSLR will be least expensive if completed at the same time, but these are expenses DC Water must plan for even in the absence of a LFDC Plan.*" We don't see the water main replacement as an added cost to the LSLR initiative. The water main replacement is a necessary cost of the LFDC program as part of replacing the LSLs. If the public side LSLs are replaced and the old water main is left in place to be replaced in some other future project that approach adds cost and inefficiencies to the overall program and ratepayers. Figure 7.1 LFDC Decision Tree clearly shows that private side LSLs where no public side LSLs are located are separately replaced independent of water main condition, which is appropriate. Funding for the priority water main replacement and the LSLR to be performed together, per DC Water's prioritized program, needs to be considered and secured together to keep total costs to DC Water's ratepayers as low as possible.	BCV

82	59	Report states, "*To successfully implement the recommended program, the Council of the District of Columbia will need to eliminate the bifurcation of LSLR programs and the distinction between funding options for partial lead service lines and full lead service lines. The current LFDC distinctions of funding sources, funding eligibility, and program administration decrease the efficiency of the LFDC plan.*" We agree with this statement. To the extent that private and public LSLRs funding can be clearly defined and provided this will greatly increase the efficiency of DC Water's program which currently only has a 70% volunteer participation rate by the public. Since DCWater cannot currently spend the money it collects on private LSLRs a dedicated funding source is needed for the private LSLRs. DC Water's June 2021 Program Report identifies a number of policy recommendations to increase the efficiency and reduce costs of the LSLR program.	BCV
83	61	(pages 61-62) The report provides 9 recommendations to eliminate barriers to participation in the LSLR program and meet the LFDC Plan goals. The 9 recommendations appear reasonable. Does DCWater have any concerns with implementing these recommendations or are some recommendations already being implemented? Has DCWater and/or the District already secured BIL funding through the DWSRF for the LSLR program and public and private side replacements?	BCV
84	61	"Every LSLR should be completed within one business day. If an emergency prevents this, the water should remain off until the FLSLR has been completed." While DC Water strives to complete repairs and replace all services in an 8-hour period and does in most cases, weather and field conditions can cause the work to stop. Examples of field conditions include and are not limited to: the service line changes direction and comes to close to a tree which requires Urban Forestry to assess and approve the excavation; another utility service is mismarked and struck; the service line is deeper than 8 feet and requires additional excavation and shoring to complete the work; the service line from the meter to the house cannot be found; and the service line inside the home is not accessible and the homeowner must move large items to provide access.	MS
85	61	"The Water Service Specification should include in-home flushing per AWWA C810-17 to be completed by the contractor at the time water service is restored." AWWA C810-17 does not state that the flush must be completed by the "contractor". Instead, Section 4.4.1 describes the utility flush through the outside hose-bib and Section 4.4.2 describes the flushing by the customer. DC Water follows these same procedures. Requiring work or operation of plumbing inside the home adds significant liability to the contractor, thus increasing costs.	MS
86	61	"Contractor should provide documentation to the resident and owner of replaced/ non-lead service line every time they leave any service location, in addition to all contract recordkeeping requirements." DC Water (not the contractor) communicates with the customer and provides the documentation after any excavation or replacement work is conducted.	MS

87	61	“The specification should not allow reinstalling any automatic meter reading (AMR) type meter greater than or equal to 1” diameter if it does not meet the revised definition of “lead-free” under the RLDWA.” DC Water replaced all meters less than 3 inches between 2016 and 2020 with meters meeting the “Lead-free” definition.	MS
88	61	(pages 61-62) “Update all standard drawings to include public health protection onsite details, including 1) turn off water before work begins, 2) don’t turn water on after the new service is installed until flushing in-home plumbing, talking with the resident, and delivering a 6-month supply of certified lead reducing filters is complete. This would appear with standard notes re: storm water control and tree protections.” DC Water follows industry standards for service line repair and replacement. Suggest stating to following AWWA C810-17 and not beyond to avoid confusion. The #2 comment is not accounting for some of the water installation testing and flushing steps. Water is “turned on” to test for leaks and may be turned on-and-off through that testing, then “on” for flushing through outside hose-bib with a jumper in the place of the meter, turned off to remove the jumper and place the meter in, and turned on and flushed to again check for leaks with meter in place.	MS
89	62	(pages 62-63) The report provides 12 primary recommendations to "Improve Water Service Specifications to Protect Public Health and Improve Clarity and Consistency". We are not intimately familiar with DC Water’s LSL specifications and design drawings so we cannot directly comment on if DCWater is already performing these recommendations. Does DCWater have any concerns with implementing these recommendations or are some recommendations already being implemented?	BCV
90	63	(pages 63-66) The report provides a number of future strategies, including ordinances, code enforcement, contract administration, and community outreach ideas for DCWater to consider. These ideas appear reasonable. To the extent DCWater thinks these ideas will help their program and are not already implemented, DCWater should consider implementing any relevant listed ideas.	BCV

Table 2. Comments specific to SWE "Table 16: Costs of Recommended Revisions Compared to 2022 LFDC Revised Cost"

Corrections to 20220331 LFDC Revised Cost Estimate	Difference	Raftelis Comments
Update AA12 to correct calculation error in applying 10% contingency	$ (47,530,653.00)	We do not have this spreadsheet so we are not able to verify these listed potential cost savings items. Has DCWater verified if these two items are correct?
Remove Test pit charges for Service Lines that are determined to be Lead per contract specifications	$ (60,628,934.00)	
Analysis of Recommendations		
Move all CIP-BBB Poor Quality Main SDWMR costs to CIP	$ (140,577,987.00)	We don't see the water main replacement as an added cost to the LSLR initiative. The water main replacement is a necessary cost of the LFDC program as part of replacing the LSLs and should be included in the LFDC total cost. See comment 44.
Adjust restoration to most cost-effective method cost: full street paving or individual site restoration	$ (148,394,279.00)	See Comment 73.
Account for efficiencies of scale for neighborhood scale replacement for non-water main replacement projects	$ (29,398,712.00)	See Comments 69, 71, 76.
Adjust Design, Engagement, Management, and Data Costs	$ (90,125,122.00)	See Comment 65, 69, and 71.
Adjust Service Line replacement costs per DC Water bids	$32,350,860	Perhaps DCWater can clarify. Are bids coming in higher than DC Water's estimates?
Account for test pitting all Unknowns and Historic Brass in addition to Historic Copper	$18,284,697	Figure 7.1 LFDC Decision Tree in the report includes a step for material investigation for unknown services. DCWater included lead and galvanized service line replacements by 2030 and planned to replace brass lines in areas where galvanized and lead lines were identified. DCWater indicated they will discuss if all of the brass lines also need to be replaced by 2030.
Add filters for all potential LSLs and 6 months post replacement	$24,145,432	DCWater already included the cost for filters after the LSLs are replaced

Account for Individual High-Priority LSLR Program	**$8,524,177**	We don't understand how this cost was calculated. It appears DC Water's program has appropriately prioritized LSL for replacement.
Account for replacing LSLs found from Historic Brass and Copper test pits	**$143,822,464**	See Comment 16.
Account for replacing all brass and galvanized service lines	**$34,895,254**	

Table 3. DC Water's Questions Submitted to SWE 08/07/22

Page	Questions (*Response not provided to highlighted questions in Table 4*)
20	Recommend explaining what "modeled" blood lead levels in children consists of - i.e., are they using any actual data of Blood Lead Levels in Denver? What is the sample size? Is this updated annually? Etc.
21	Does ACS data for children under 5 exist at the Census Block Group level?
31	Why multifamily buildings vs single home buildings with occupants age 5 and younger?
40	Was Map 7 created with prioritization model?
46	Did Denver Water "street paving" include curb to curb or same extent as DDOT requirement? Did DW provide cost per SQ YD or average block length/street width? What about Maintenance of Traffic or Civil Design/TCP requirements (or did DW have blanket permits due to LCR exceedance? Full table comparison of bid item UNIT PRICES of DC and benchmarking utilities can help provide clarity. Note: Newark had 1 cent per test pit on Roman Contract 40 & 41, and winning contract also had street paving in the $10,000's vs the Engineer Estimate in the $1,000,000s. Recommend noting that contracts and costs between cities can vary widely due to these types of factors that aren't explicitly stated or made clear in section "How does this compare to benchmark cities?" and Table 12. Recommend also noting assumptions that density of housing was not considered in comparison of costs and could significantly affect costs. Cities like Denver has spacious residential streets with large single family home lots compared to East Coast/historic cities – this affects costs associated with complexity of MOT and tree protection requirements and compliance, requirements for backfill and restoration.
48	The industry has noted the impact inflation will have on future infrastructure/construction costs. Was annual escalation/inflation accounted for in this cost estimate? Recommend noting reasoning for why/why not in this section "How Did We Calculate Program Costs?".
48	Does your efficiency measure take into account that this is a non-mandated program or does it assume the mandate you recommend on page 63?
49	42,323 service lines /6 years = more than 7,000 LSRs a year and 44,361 test pits associated with inventory verification not resulting in LSR / 6 years = 7,400 test pits a year. Does your report discuss the feasibility of achieving those numbers in relation to the amount of allowable construction in the city, contractor capacity, or timeline? (6 years of LSLR taken from footnote 1 of Table 15 on page 51).
50	Design - noting the extent of BBB Civil Designs and TCPs required this year by DDOT and shared with files, where is the cost of producing these captured? Was consideration given to the more complex BBB with SDWM Designs and TCPs that will be required in future years?
50	What reference did you use to come to specific percentages (3 vs 5) for CM and DM?
52	Where did recommendation of 100 ft of road as trigger for curb to curb street repaving come from?

Table 4. SWE Response to DC Water's Questions Provided 08/09/22

Page	Questions	SWE Response	SWE Proposed Changes to Report
46	Did Denver Water "street paving" include curb to curb or same extent as DDOT requirement? Did DW provide cost per SQ YD or average block length/street width? What about Maintenance of Traffic or Civil Design/TCP requirements (or did DW have blanket permits due to LCR exceedance? Full table comparison of bid item UNIT PRICES of DC and benchmarking utilities can help provide clarity. Note: Newark had 1 cent per test pit on Roman Contract 40 & 41, and winning contract also had street paving in the $10,000's vs the Engineer Estimate in the $1,000,000s. Recommend noting that contracts and costs between cities can vary widely due to these types of factors that aren't explicitly stated or made clear in section "How does this compare to benchmark cities?" and Table 12. Recommend also noting assumptions that density of housing was not considered in comparison of costs and could significantly affect costs. Cities like Denver has spacious residential streets with large single family home lots compared to East Coast/historic cities – this affects costs associated with complexity of MOT and tree protection requirements and	We did not investigate the paving requirements for Denver Water that are included in their cost per LSLR as shown in Table 12. We decided to rely upon the paving costs provided by DC Water and consider strategies to complete paving work in a more cost effective strategy.	Add a note that contracts and costs can vary widely between cities due to city specific requirements and building density. Since we did not use other cities' dollar values to re-estimate DC Water's costs, we do not plan additional analysis in this section.

	compliance, requirements for backfill and restoration.		
48	The industry has noted the impact inflation will have on future infrastructure/construction costs. Was annual escalation/inflation accounted for in this cost estimate? Recommend noting reasoning for why/why not in this section "How Did We Calculate Program Costs?".	We did not include a price escalation for inflation in our estimate. The benchmarking cities mostly found that costs decrease over time as contractors become more efficient in their work, and Denver found this to be true for 2021 even as inflation was increasing. Detroit did observe inflation affecting prices without a corresponding decrease due to improved workflow, but they are not completing LSLR work at the same scale	Add text to the report for clarity

		as the other programs that would allow them to build up program efficiencies (~340 LSLRs per year). We chose to not include an escalation for inflation nor a decrease for programmatic efficiencies.	
48	Does your efficiency measure take into account that this is a non-mandated program or does it assume the mandate you recommend on page 63?	Our efficiency measure assumes costs are decreased based on consolidating work in space and time. We did not model customer participation in a non-mandated program. We approached this study with the perspective that the DC Council is motivated to remove all lead service lines in Washington DC and is willing to take aggressive steps to make that possible. We hope this includes passing a mandate for LSLR, which will provide additional efficiencies.	Add discussion of how a LSLR mandate will further improve cost savings and emphasize the mandate recommendation.

49	42,323 service lines /6 years = more than 7,000 LSRs a year and 44,361 test pits associated with inventory verification not resulting in LSR / 6 years = 7,400 test pits a year. Does your report discuss the feasibility of achieving those numbers in relation to the amount of allowable construction in the city, contractor capacity, or timeline? (6 years of LSLR taken from footnote 1 of Table 15 on page 51).	We were not aware of limits to allowable construction in the city. Please provide copies of any requirements that need to be incorporated into our analysis. Regarding contractor capacity, our observation has been that when projects are advertised and money is on the table, companies see and fill the need. If you have examples of projects you have put out to bid that received no qualified bids, please let us know and we can modify this section as necessary. We approached this study with the perspective that the DC Council is motivated to remove all lead service lines in Washington DC and is willing to take aggressive steps to make that possible. Newark has replaced nearly 6,955 per year (23,182 on 8/5/22 since March 2019). (https://www.newarkleadserviceline.com/replacement#:~:text=About%20the%20Program,-Newark%20has%20planned&text=Construction%20for%20the%20first%20phase,replace%20them%20with%20copper%20pipes.)	No Change

50	Design - noting the extent of BBB Civil Designs and TCPs required this year by DDOT and shared with files, where is the cost of producing these captured? Was consideration given to the more complex BBB with SDWM Designs and TCPs that will be required in future years?	As discussed in the draft report, all SDWMR costs are separated from the LSLR program because we were only contracted to evaluate the cost of the LSLR program. All SDWMR designs are included in the SDWMR estimate from DC Water and provided in Table 17	No Change
50-51	What reference did you use to come to specific percentages (3 vs 5) for CM and DM?	Denver Water provided the following: "Project management (includes internal, construction management, data management, filter PM, Water quality testing PM, regulatory reporting) costs for the program are roughly 15% of the total cost of the program."	No change; reference included in report.
52	Where did recommendation of 100 ft of road as trigger for curb to curb street repaving come from?	Safe Water Engineering provided the concept of using the number of LSLRs per 100ft of road as a metric to consider for establishing when it is appropriate to pave at individual LSLRs vs curb to curb. We know current practices are defined and required by DDOT. This is a concept we present for exploration to bring down paving costs while meeting reasonable quality of life expectations.	No change
Appendix B	Is this the correct version of this document?	Thank you for pointing this out.	We will clean this up for the final submission and provide an introduction. Disregard the comments.

ATTACHMENT

M

DC Water and Raftelis Review Comments on INDEPENDENT VERIFICATION AND VALIDATION OF THE LEAD FREE
Date: 8/12/2022
Commenters: M. Schmelling (MS, DC Water), J. Deignan (JD, DC Water), B. Vatter (BCV, Raftelis), J. Davis (JPD, Raftelis).

Comment Number	Draft PDF Page Number	Comment	Comme	SWE response
1	3	DC Water has worked to implement recommendations from the Council-appointed Lead Task Force related to the prioritization model.	JD	no change
2	4	Agree with report's statement: "*We strongly support DC Water's recommendation in the LFDC Plan to eliminate unnecessary bifurcation of programs and the distinction between funding options for partial lead service lines and full lead service lines. The distinctions of funding sources, funding eligibility, and program administration decrease the efficiency of the LFDC Plan. Breaking down these distinctions and merging programs to function at the neighborhood scale will greatly improve efficiency and the timeline for removing all LSLs.* " Addressing DC Water's recommendation and risks is critical to the success of the LFDC program completion by 2030.	BCV	no change
3	7	"account for replacement of 14,348 more than LSLs than the original LFDC Plan" Recommend clarifying definition of LSL used in this report: lead, galvanized iron, and brass.	JD	Added: In addition to a subset of unknown service **and copper lines**, this includes brass and galvanized service lines that the Council of the District of Columbia added to its definition of lead service lines that require replacement in January 2021.
4	8	filters - the Lead Task Force has discussed recommendations for a filter program beyond post-LSL replacement (DC Water best practice, standard, LCRR).	JD	no change
5	8	"These replacements are necessary for maintenance of DC Water infrastructure, and LSLR will be least expensive if completed at the same time, but these are expenses DC Water must plan for even in the absence of a LFDC Plan." Poor condition water main replacement in conjunction with LSR goes beyond a cost-saving measure, and is best practice to avoid water quality issues, correct?	JD	"These replacements are necessary for maintaining water quality and infrastructure integrity, and LSLR will be least expensive if completed at the same time. "
6	8	Recommend clarifying last paragraph for reader about elimination bifurcation of LSLR programs. Reference what law will required amending that establishes CIPERR & LPRAP - and the impact - eliminating customer-initiated replacement program for private-only LSRs, all replacements would be 100% for homeowners that don't go through VFRP.	JD	DC Council will identify the laws that need to be amended. No change
7	10	Do the 6 utilities surveyed (excludes Baltimore) represent a comprehensive review of best practices in LSLR or are they presented more to provide alternative practices for consideration by DC Water?	JPD	"Information from these programs is presented to illustrate alternative strategies, practices, and implementation data from other cities that have some overlapping characteristics with Washington, DC. Rather than a comprehensive review of best practices, the benchmarking data presented in this report provides real world examples of how alternative strategies could play out in Washington, DC."
8	13	Figure 2. The Premex database was a data output from the CIS since the 2004. When V1 replaced CIS, the Premex database was fed by V1 and Maximo.	MS	Noah Clarify. Revised figure?
9	13	"About 2,900 of those homes with known or probable lead service lines have lead concentration of more than 20 ug/L" – clarify with quotation marks that the sentence is from the report or describe that the lead concentrations were from samples collected prior to the publication of the report and therefore not representative if today's lead occurrence in water in the District of Columbia.	MS	"About 2,900 of those homes with known or probable lead service lines have lead concentration of more than 20 ug/L according to the data published in 1990."
10	14	"Based on DC Water's records review ~~and~~ of current field work.." -- "and" should be "of"	MS	Done
11	14	"Based on DC Water's records review.." the data presented are from the 2022 LFDC By-Block field work to date. These blocks are expected to contain more LSLs compared to neighborhoods without any identified LSLs, so is important to note the data source.	MS	Noah Clarify
12	14	"Further, in January 2021…" the data presented were from a 2020 data analysis.	MS	Noah Clarify
13	15	2nd to last paragraph - We understand DCWater agrees with the District of Columbia's addition of brass and galvanized service lines to the definition of lead service lines. DCWater included lead and galvanized service line replacements by 2030 and planned to replace brass lines in areas where galvanized and lead lines were identified. DCWater indicated they will discuss if all of the brass lines also need to be replaced by 2030.	BCV	No change
14	15	Table 2 should clarify if "public" or "private" since Table 1 lists both and costs of public and private work differ substantially. The note below the table is confusing. More explanation of how the data were derived for Table 2 is needed. A shapefile is using data from the same inventory, so please clarify why the numbers change from analyzing with using a shapefile.	MS	Revised column header to "Number of public and/or private services to be verified."
15	15	Table 2 – "Lead, to be verified" = "Lead, to be replaced". Please clarify why they are equal since some of the data has been verified by excavations.	MS	Deleted lead to be verified. Note change to table 18

16	16	(pages 16 and 50) Safe Water Engineering (SWE) estimates that 42,323 lines are lead, brass, and galvanized and assumes all of these are to be replaced by 2030. This number assumes that 20% of all historic copper lines will turn out to be lead lines upon inspection. DCWater indicated they will discuss if their current estimate of 27,975 lines to be replaced by 2030 should be modified and if brass lines need to also be replaced by 2030. The use of collected water quality data for the concentrations of lead in known brass SL areas could be used as part of this discussion.	BCV	DC Council requires removal of brass service lines. No change.
17	16	3. Maintain historical records… DC Water does have records of changes to pipe materials. The data are archived in Maximo. Prior to the use of Maximo we have records of the DC Premex datasets going back to 2004.	MS	No change. We made recommendations for best practices for which we did not find evidence in any of the documentation provided. If DC Water is doing it, keep doing it.
18	16	1. "Stop using water quality sampling…" DC Water provides a customer-initiated way for customers to determine the presence of a lead source ahead of a test-pitting verification. DC Water is required by law to provide a free lead test kit on an annual basis when requested. Sunsetting program would require regulatory change.	JD	added "Lead in water sampling should continue to be made available for purposes other than lead service line identification. "
19	17	Report states, "*Stop using water quality sampling for lead service line verification.* " DCWater lead service line replacement report dated June 2021 states that water quality testing at private properties for measuring lead levels is used to verify if lead service lines exist at the private properties. This testing is required by EPA regulations. This should not be stopped as the report appears to state. In addition, water quality sampling for Iron and Chlorine is used by DCWater to determine locations for unlined cast iron water mains. These mains require replacement over time which is important to coordinate with lead service lines also in need of replacement connected to those unlined cast iron mains. For these reasons, we do not agree with the report that this water quality sampling should be stopped.	BCV	EPA regulations do not require lead sampling to identify LSLs. The EPA LCR requires that comliance samples be collected at confirmed LSL locations. Revised to: "1.Stop using lead in water sampling for lead service line verification. " to eliminate possible confusion over chlorine and iron sampling.
20	17	I am unclear as to why sampling for lead would not be a valid consideration. The report seems to contend that this practice is antithetical to the ability to identify opportunities for LSLR.	JPD	Added: "Presence of lead in water samples can indicate the presence of an LSL or lead components, but low or non-detect lead results cannot prove the absence of an LSL.17 This practice can lead to confusing messaging or interpretation at the household level regarding whether an LSL exists at the house. " Since all services will be confirmed via test pits, it is unnecessary to introduce this confusion.
21	17	Report states, "*We recommend all outreach materials, clearly state that, especially for homes or properties developed before 1977, that positive documentation and verification of the buried service line material is necessary to ensure there is a non-lead service line* ." We agree with this recommendation for clarity.	BCV	no change
22	17	Report states, "*Maintain historical service line data, even when records are updated* ." If there is uncertainty with the newly collected data then the historical record should be maintained. However, if the new data is updating a pipe material or diameter and DCWater is confident in the new data then changing or overwriting the data to reflect the new data is appropriate.	BCV	No change. Even when new data are confirmed in the field, older data can help tell a story of the evolution at an individual house. For example galvanized replaced with plastic could leave an opportunity for a lead gooseneck at the water main that may not have been confirmed at the time the plastic service line was confirmed in a test pit.
23	17	We agree with the report's recommendation to "*continuing DC Water's approach of verifying every* *service line as they work block by block.* " DCWater is implementing a LSLR approach that is flexible and allows for additional lead service lines to be replaced as they are discovered during the work.	BCV	no change
24	17	Worth mentioning up front that DC Water is working with the Task Force to improve the prioritization model. Below is an excerpt from the draft Task Force report with Task Force recommendations compared to version 1 of the prioritization model.	JD	no change. This information was not provided to the SWE project team
25	17	Recommend including citation to ADI.	JD	added
26	18	Report states, "*Consider statistical methods to identify areas with copper that turn out to be lead* *and brass service lines that are found to be lead or brass* ." As DCWater collects more information on locations of brass and copper water lines, using statistical analyses could provide some benefit for confirming lead and brass service line locations. DCWater will discuss if all of the brass lines also need to be replaced by 2030.	BCV	no change. DC Council requires replacement of brass service lines
27	19	Include full citation for Berg 2017 for reference.	JD	Full citation not provided in Denver. Table footnote states "As published by Denver Water"
28	21	Disagree that DC Water model includes "parameters that do not relate to the risk of LSLs" - these factors are associated with the risk that are posed by LSLs. Does it not stand to reason that repairs for water main breaks create the potential for physical disturbance of LSLs on block which is related to increased risk of particulate release of lead from LSLs?	JD	Deleted "water main failures"
29	22	Report states, "*Use Higher Resolution American Community Survey (ACS) data for children 5 and under* ." Given how DCWater setup their prioritization model with the various criteria, it is not clear if using census block data for children 5 and under, versus the census tract data that DCWater used, will cause a change in priority LSLR locations. If DCWater thinks this block data will change the priority results, they may wish to run a GIS scenario with this block data to see if any priority locations change.	BCV	No change. See next comment.

30	22	These maps are comparing two different data sets (18 and under and 5 and under) at two different levels (census tract vs census block group). What is it conveying?	JD	These maps convey the difference between the two data sets and why we recommend using census block groups for 5 and under.
31	23	Report states, "*Remove iron and chlorine sampling parameters* ." It is not clear from the information available to us if the iron and chlorine data is biasing the prioritization of LSLR locations. DCWater should offer comment on if the iron and chlorine data used in the prioritization is representative of the entire service area. If No, perhaps the weighting should be reduced?	BCV	no change
32	24	Recommend clarifying does this report recommend in Table 6 that Lead, Unknown, Brass, Galvanized all receive the same prioritization weight for replacement?	JD	Table and supporting text updated to clarify: "The Likelihood of Lead score would be calculated using only the likelihood that each service line needs to be replaced. Each service line would be assigned a score according to the following: • Lead and galvanized lines: 10. • Unknowns: 5 • Historic brass lines: 4.7 • Historic copper: 2, and • Non-lead: 0."
33	25	(pages 25-26) The report shows in Map 3 the prioritization results of SWE's modified model (parameters listed in Table 6). The prioritization results between DCWater LFDC's model and SWE's model show very similar results. SWE's model results in Map 3 appear to validate DCWater LFDC's model results versus shifting the prioritization locations, as the report states. Given the number of LSLRs scheduled by DCWater for each year through 2030 (as shown in the maps in the DC Water's June 2021 report) we don't see how SWE's model provides more accurate results or a necessary change to DC Water's priority LSLR locations by year.	BCV	We disagree that the maps provide similar results. New Map 4 better highlights the differences between the two.
34	25	Table 6 - One Likelihood of Lead (LoL) parameter does not seem to facilitate necessary prioritization. This seems to discount likeliness altogether. The parameters used in DC Water's LFDC prioritization more appropriately capture the likelihood of finding lead service lines.	JPD	As discussed in the report, the one parameter used for likeilhood of lead is a measure of the actual likelihood of finding a lead, galvanized, or brass service line based on DC Water's data collection. No change.
35	26	Recommend noting that DCW runs this model annually based on updated inventory information, and that this report's analysis is based on the first model run in June 2021.	JD	"DC Water runs the model annually based on updated inventory information." added to "what did DC Water do?" Study description clearly states "This report examines the LFDC (2021) and cost updates from March 31, 2022. "
36	30	"1. Create a new DC Water-initiated Neighborhood Scale LSLR Program" - recommend more clearly explaining how this modifies existing block-by-block program. A comparison chart may be helpful of how current block-by-block vs new neighborhood scale program achieve the bullet strategies on the top of page 31.	JD	Clarified: "This program would complete the majority of LSLRs and service line verifications in a DC Water-initiated neighborhood scale program that is prioritized by the risk model, described in the Prioritization Criteria section of this report, at the Census Block Group scale. The program would encompass any service lines not in the DC Water CIP or in streets with poor quality water mains. Working at the Census Block Group scale, this program will allow DC Water to take advantage of economies of scale, with larger numbers of excavations and LSLRs within a concentrated area prioritized by consequence and likelihood of lead. This program will need to rely on external funding sources, such as the new federal LSLR funding. This recommended program is further illustrated in the Program Timelines and Geographies section of this report. "
37	31	Report states, "*Every potential LSL must be included as part of a planned, systematic approach to LSLR before individual services get pulled into priority programs* ." It appears DC Water's program is already doing this. DC Water's prioritization criteria accounts for determining potential LSLs (See Figure 7.1 in SWE's report). Figure 7.1 also shows DC Water's program includes determining unknown service line materials as work is being performed in priority neighborhood locations.	BCV	While there is an appearance that the LFDC plan addresses this, the underlying LFDC analysis shows that it does not. There are unknowns and historic brass lines that are not in prioirty neighborhoods that are not included in the LFDC plan. DC Water cannot accurately plan or estimate costs to achieve the goal of replacing all lead, galvanized, and brass service lines in Washington, DC with outstanding unknowns. No change.
38	31	(pages 31-32) Report states, "*Create a new DC Water-initiated Neighborhood Scale LSLR Program* ." It appears DC Water's LSLR program is already doing this. If you closely review the annual implementation maps included in DC Water's June 2021 report, they have grouped the LSLR work by neighborhood and by block. Further clarity from SWE on what they think DCWater is not doing in this area could be helpful.	BCV	As addressed in comment 36, the text was clarified.
39	32	Report states, "*Create a new district-wide DC Water-initiated Individual, High-Priority LSLR Program* ." and "*As a result, all day care facilities should have confirmed non-lead service lines by the end of 2024* ." It appears DC Water's current program has properly prioritized and identified individual LSLs to be replaced. The results on Map 3 in the report from SWE's model validate DC Water's prioritization. See comment 14 above. It is not clear from the information we have, if all day care facilities will have LSLs replaced by 2024. DCWater indicated they will confirm all day care facilities have a prioritized schedule for completion of LSLRs, where applicable.	BCV	We recommend prioritizing identification and replacement of all potential LSLs at childcare facilities in the first year. No change.
40	32	Use of the term "jump the line" is incorrect. Jumping the line implies that those in the line then have an increased wait. The Voluntary Full Replacement Program has a separate contract, so those activities continue at the pace determined by only that program (and weather).	MS	revised: "The scope of the VFRP program is decreased to include only those homeowners and developers who want to pay in full and replace their LSL on their own schedule. "

41	33	Report states, "*DC Water's LSLR model uses water main condition only to identify needed water main replacements associated with LSLR. It does not consider the number of LSLs on a water main as a reason to replace a water main* ." This does not appear to be correct. Figure 7.1 LFDC Decision Tree clearly shows the number of LSLs on a water main and the condition of the water main are used in determining when a water main should be replaced.	BCV	"3.6 Group all LSLRs associated with water main replacements together to create the CIP Water Main Replacement LSLR Program. We estimate about 20% of the total LSLs will get replaced through this program and recommend incorporating both the CIP program and the water mains DC Water identified as being in poor condition in the LFDC Plan. Additionally, we recommend including and adding all water main replacement costs to the CIP and separating them from LFDC Plan costs. The LFDC Model uses a threshold of 4 or more LSLs per block as a condition for DC Water initiated LSLR. Of those blocks with 4 or more LSLs, those with poor water main condition are identified for water main replacements at the same time as LSLR. From a water infrastructure planning perspective, any main with a condition rated as poor should be accounted for and planned for replacement through the CIP program. All the water main replacements identified in the LFDC Plan meet the criterion of poor quality main regardless of the number of LSLs connected to the water main. The cost of water main replacement is not an added cost resulting from the LSLR initiative. These water main replacements are necessary and will be most cost effective if they happen at the same time as LSLR. We recommend that DC Water add all poor condition water mains to the CIP so they can prioritize, plan, and budget for these necessary replacements. This may require revisions to the 2% water main replacement CIP goal. "
42	33	The existing water main replacement program and LFDC that includes water main replacement are two separate, important initiatives each with their own rules of prioritization. They should be separated in capital planning. The existing program is funded by the Water System Replacement Fee and prioritizes water lines in the District that are, on average, 80+ years old. Water lines addressed in LFDC are prioritized differently and funded differently.	JPD	This is new information that was provided as part of the final review, so it was not incorporated. As noted in comment 41, revisions have been made to clarify the recommendation.
43	33	Report states, "*Group all LSLRs associated with water main replacements together in the CIP to create the CIP Water Main Replacement LSLR Program* ." It appears DC Water's program is already setup this way. DC Water's program includes the Capital Improvement Project and Emergency Repair Replacement (CIPERR) Costs program that groups prioritized water main replacement with prioritized LSLRs. Further clarity from SWE on what they think DCWater is not doing in this area could be helpful.	BCV	As noted in comment 41, clarifications have been made. The CIPERR program in the LFDC program includes two different WMR programs - one in the CIP and one that is not in the CIP. The CIPERR program also includes the emergency/vulnerable population program which has not been clearly defined. Our recommendation was made to combine all WMR associated with LSLR in a single program and ensure that the majority of LSLRs are completed in the neighborhood scale program at the Census Block Group scale.
44	33	Report states, "*We recommend including and adding all water main replacement costs to the CIP and separating them from LFDC Plan costs. These water main replacements are necessary and must happen at the same time as LSLR, though water main asset management must be accounted for in the CIP, not as an added cost resulting from the LSLR initiative.* " We don't see the water main replacement as an added cost to the LSLR initiative. The water main replacement is a necessary cost of the LFDC program as part of replacing the LSLs. If the public side LSLs are replaced and the old water main is left in place to be replaced in some other future project that approach adds cost and inefficiencies to the overall program and ratepayers. Figure 7.1 LFDC Decision Tree clearly shows that private side LSLs, where no public side LSLs are located, are separately replaced independent of water main condition, which is appropriate. Funding for the priority water main replacement and the LSLR to be performed together, per DC Water's prioritized program, needs to be considered and secured together to keep total costs to DC Water's ratepayers as low as possible.	BCV	See clarifications provided in comment 41 and response in comment 43.
45	33	Report states, "*Continue the VFRP program from the LFDC plan* ." We agree with this recommendation.	BCV	no change
46	34	(pages 34-36) Report states, "*We recommend the decision tree structure in Figure 4 for assigning blocks to the four recommended LSLR programs. The 4 program areas account for and replace all lead, brass, and galvanized service lines, as well as test any historic or unknown service lines to identify and verify material type. These programs would all be initiated by DC Water and do not rely on customers initiating replacement. Table 8 below shows the number of LSLs in each category* ." We are not able to verify the numbers shown in Table 8 as we do not have that data. However, DC Water's current program appears to already address the above issues and specifically includes a step in their decision tree (Figure 7.1 of the report) that accounts for addressing unknown material service lines. We don't think changing DC Water's program to the above recommendations would provide any significant value or improvements.	BCV	This was provided in the summary tab of appendix E, but we added a table 8 tab to the final appendix E to make it easier to find. According to figure 7.1, blocks with less than 1/3 unknowns and no public or private lead service lines are put in catagory H. No Action. There are approximately 1400 unknown service lines whose test pitting and replacement are ignored in the LFDC plan.
47	36	"voluntary customer-initiated programs" strike the word "voluntary" as to not confuse reader since that number includes both VFRP and LPRAP	JD	Deleted "voluntary"

48	36	Include the definition of "block" as defined in the Infoasset Model Planner Appendix referenced before. Unclear how "Census Block Group" compares with "block" used in DCW planning, and thus obfuscates recommendation for improvement on page 38.	JD	Text box revised: Census Block Groups are US Census defined geographies that consist of 600-3,000 people on average. There are 450 Census Block Groups in Washington, DC. Blocks are geographies defined by DC Water and are a length of street between two intersections/dead ends and the houses on both sides of said street. There are roughly 30 LFDC Blocks in each Census Block Group. Defined in InfoAsset Planner LFDC Model.6
49	39	(pages 39-40) Report states, "*Plan to complete all lead service line replacements in 6 years (2024-2029)* ." We don't understand why the report would recommend stopping the LSLR work in 2022 and 2023 and starting again in 2024. We agree with DCWater that continuing this work through 2030 is a reasonable but aggressive schedule. Table 10 in the report recommends ramping up to over 7,000 LSLs being replaced per year as compared to DC Water's projected schedule of 4,000 - 5,000 LSLRs per year. The added program management, engineering, construction inspection and overall DCWater added staff costs to manage this 40% - 75% increase in LSLRs do not appear to be factored into the report's recommendation. As noted in the DCWater June 2021 report, DC Water and the Washington Aqueduct have effectively implemented optimum corrosion control treatment, which has reduced water lead levels to 2-3 ppb at the 90th percentile compared to the EPA lead action level of 15 ppb. So there is no regulatory requirement for DCWater to increase their annual LSLRs to over 7,000 per year and incur the added management and implementation costs.	BCV	clarified: "Ramp up to complete all lead service line replacements in approximately 6 years (2024-2029). " There is no recommendation to stop work. The report states "This ramp up schedule accounts for the planning time required to get contracts into place and a year of padding at the end to complete the work in 2030." The management costs are a percent of LSLRs so it scales accordingly.
50	39	Report states, "*Schedule the majority of LSLRs using the prioritization model at the Census Block Group Scale.* " The prioritization results between DCWater LFDC's model and SWE's model show very similar results in Map 3. SWE's model results in Map 3 appear to validate DCWater LFDC's model results versus shifting the prioritization locations, as the report states. Given the number of LSLRs scheduled by DCWater for each year through 2030 (as shown in the maps in the DC Water's June 2021 report) we don't see how SWE's model provides more accurate results or a necessary change to DC Water's priority LSLR locations by year.	BCV	See new Map 4 that more clearly illustrates the differences.
51	39	Table 10 - include assumptions used for how this report determined small diameter water main replacement rate and "CIP blocks".	JD	Noah - clarify that we used DC Water's assumptions
52	40	The recommended schedule does not produce more LSLRs until FY2026 and it assumes the more aggressive schedule of 7k+ per year is feasible. SWE does not discuss the feasibility of replacing over 7,000 LSLs per year, impact on staffing and the available construction contractors to perform this accelerated work.	JPD	The schedule provided allows for ramp up to the 7,000 LSLRs in the first year, clarified in the updated text.
53	41	I do not understand how the seemingly minimal differentiation in risk measurement on Map 3 can result in such a big differentiation for LSLR by year between Maps 6 and 7. Given the number of LSLRs scheduled by DCWater for each year through 2030 (as shown in the maps in the DC Water's June 2021 report) we don't see how SWE's model provides more accurate results or a necessary change to DC Water's priority LSLR locations by year.	PD & BC	The grouping by census block creates the biggest change in LSLR by year between maps 6 and 7. This is described in the text and reflected in the revised map title: "MAP 7: Recommendation for LSL Replacements by Year Using the Prioritization Model at the Census Block Group Scale." The revised spatial distribution will result in cost efficiencies and better customer support because the same neighborhoods will not be interrupted several times through 2030.
54	41	Report states, "*Complete service line verifications and LSLRs at all day care centers during the* *first year* ." It appears DC Water's current program has properly prioritized and identified individual LSLs to be replaced. The results on Map 3 from SWE's model validate DC Water's prioritization. It is not clear from the information we have, if all day care facilities will have LSLs replaced by 2024. DCWater indicated they will confirm all day care facilities have a prioritized schedule for completion of LSLRs, where applicable.	BCV	We recommend prioritizing identification and replacement of all potential LSLs at childcare facilities in the first year. No change.
55	41	Recommend reference to file and presentation of cost estimate provided to Task Force that reduced LFDC program cost from $680 to $598 million; can include change log that shows justification for revisions.	JD	This cost estimate was not provided to the SWE project team. No change.
56	41	add 2b. LFDC cost estimate assumes all test pitting of historic information will be done through BBB program as opposed to By Premise LSR programs	JD	Noah - clarify what DC Water is doing. Also clarify how this is missing critical work that is necessary to meet the DC Council goal - they will be ignoring the places that are not in the BBB program
57	41	3b. That depends on the contract	JD	"The water service specification provided by DC Water states that contractor cannot charge for test pits at LSLs that are verified and replaced."
58	41	3c. Partially accurate - total LSRs is based off 50% unknowns	JD	"This does not account for test pits at unknown service lines not found to be lead (50%)."
59	41	5. The cost of water main replacement is SHOWN in LFDC cost estimate for CIP planned SDWMR; only cost of water main replacement for BBB is INLCUDED in LFDC cost estimate. You later clarify this on page 45, first sentence under charts, and on page 57 in second to last paragraph. Recommend doing the same up front on page 41.	JD	Text added on page 41: "The CIP-SDWM program does not include restoration or SDWM costs as they are funded by the CIP program."
60	41	6. "Costs range significantly based on program" due to factors like type, scale & quantities of contract, who performs the work e.g., plumber for LPRAP vs large contractor for SDWMR	JD	"Costs range significantly based on program due to factors such as number of replacements, size of contractor, etc."

61	42	"Some public outreach materials state" - No. DC Water confirms that "6-month filter supply is provided"	JD	No change. We recommended it because it's not documented in any cost or procedure documents provided for this project. If it is not clear to the third party reviewers whether this is happening, it is also not clear to DC residents and updates should be made to all program cost estimates and outreach materials to ensure all residents understand they should be receiving filters as part of this program.
62	47	Table 14 - Recommend revising or providing additional table that shows comparison of line items in LFDC estimate vs the estimate in this Report to clearly lay out where changes were made, similar to what you do in Tables 15 and 18	JD	Noah Clarify
63	48	Table 13 should be updated to reflect the increased construction cost in Washington DC compared to the stated locations. For example, cost of living is 45% lower in Denver, Co, and 31% lower in Newark, NJ compared to Wash DC.	BCV	No change. This was a benchmarking exercise and we reported the data provided to us by the benchmarking cities. We provided these data to show the reader an example of costs experienced elsewhere. We did not use any raw cost data in any estimates for Washinton, DC.
64	48	Based on current experience $1,525 for public-side LSR under SDWMR is low and will likely increase over a period to 2030.	JD	This calculation was made using the cost data DC Water provided, as recommended by DC Water. No change.
65	50	(pages 51-52) The report indicates DCWater should reduce the LFDC programmatic costs from the estimated percentage of 43% to 19%. This includes Planning/Permitting, Design, Program Management, Outreach and Stakeholder Engagement, Construction Management, and Data Management. DCWater indicated they have updated LFDC programmatic costs based on recent data and program management costs that will be used to compare DC Water's actual costs to the report's recommended 19% programmatic cost percentage. We do not see the relevancy of comparing FTEs between the two programs in Table 15. DCWater staff are not included in the LFDC cost estimate.	BCV	Added note on page 42: "•DC Water states that the programmatic cost estimates do not include personnel costs. Those costs are significant and must be considered to get an accurate total." It is relevant to consider how many FTEs are supported by the programmatic costs, and whether the number of staff is appropriate for the work that needs to be completed.
66	50	footnote 16 - DC Water OMAC budget doesn't capture Clean Rivers or similar marketing for large-scale capital projects. Disingenuous comparison.	JD	The statistic provided is used as a reference point for the size and relative magnitude of the communications budget. No change.
67	51	Recommend noting that the BBB Contracts used in cost estimate were change orders to existing contracts so that DCW could ramp up as fast as possible, and is pursuing BBB specific contracts.	JD	"The two LSLR contracts these costs come from were issued as change orders without public bidding so LSLR could ramp up as fast as possible, which may contribute to the higher unit prices. New bids for contracts designed for the recommended programs may have lower unit prices. "
68	51	"without public bidding" is not entirely accurate - 4 qualified firms with contracts with DCW bid on the projects, 2 were selected.	JD	No change.
69	52	Table 15 includes a number of assumed reductions in programmatic costs without backup to support the proposed reductions. For example, the 10% efficiency reduction assumed by SWE does not appear to be supported by actual data relevant to DC Water's program. Assuming a 10% efficiency, by SWE neglects to take into account the 70% customer participation rate that DCWater is currently experiencing due in part to not being able to pay for private side LSLRs. Moving design cost to 0% also does not appear appropriate as design work will be needed for the LSLRs. DCWater cannot assume the design cost will be zero dollars when developing their planning level program cost estimate.	BCV	No change The assumed reductions are based on redesigning the LFDC program based on strategies and cost data from other cities, especially Denver. There are no actual data from DC because DC has not implemented programs with the recommended design. None of the current contracts have a design line item that is not associated with WMR. DC Water also says these costs do not include DC Water staff. Because there is no demonstrated need for design in LSLR only contracts we did not include it in our estimate. The report recommends that DC Council approve budgeting and paying for all private side replacements, which will make a large change in the 70% participation rate if approved.
70	52	The report states, "*The resulting unit cost of $13,625 is higher than for benchmarking cities and cost benchmarking shown in Table 13* ." Table 13 does not account for the construction cost differences between Denver, Newark and Washington DC. The cost of living in these 2 cities compared to Wash DC is 45% and 31% lower respectively. Accounting for the higher cost of construction in Wash DC would make the quoted costs in these 2 cities much closer to the indicated DCWater cost of $13,625 per LSLR.	BCV	No change. Report clearly states "we relied on the contract bids that DC Water used to estimate the cost of their CIP-BBB program but updated the unit costs to reflect the units on the bid sheets."
71	52	Report states, "*In addition, benchmarking cities Denver and Cincinnati both found that prices decreased over time as contractors become more efficient with repeat work. We anticipate that the cost of the Neighborhood Scale LSLR Program will be lower than estimated here* ." DC Water's LSLR cost may be lower as the program matures and work becomes more efficient. However, for planning purposes DC Water's cost estimate for the total program follows the industry standard Class 4 AACE cost estimating guidelines, which uses an accuracy range of -20% (to account for these potential cost reductions) to +30% (to account for unknowns such as additional identified LSLs). DC Water's cost estimating for the overall program is appropriate and aligned with industry standards. Making an assumption that costs will be less as the program matures (best case scenario) for calculating the initial program cost is not aligned with industry standards and inconsistent with current price inflation and labor shortages.	BCV	Agree. We described this as a reason to expect our estimate is on the high side. We made no cost estimate modifications to estimate potential savings. No change.

72	53	Report states, "*Include the cost of providing certified lead reducing filters to all residents with potential LSLs* ." DCWater provides filters to residents at the time their lead service lines are replaced.	BCV	No change. This is a recommendation to proactively provide filters until LSLs are replaced.
73	53	Report states, "*Approximately $10,360 of the cost of a LSLR is attributed to the restoration cost (restoration+ programmatic fees). The emergency/vulnerable population program only spends $4,741 in restoration and restoration related programmatic fees. The difference in cost comes from street paving* ." And, "*we suggest DC Water, Council of the District of Columbia, and DDOT work together to develop an appropriate metric for triggering street paving* ." It appears 42% of the LSLR cost ($10,360/$24,535) is pavement restoration. If an appropriate metric for requiring DCWater to repave entire streets was discussed and agreed upon with the District and DDOT, the cost of the LSLR program could potentially be significantly reduced. We understand DCWater has attempted to lower the paving costs for LSLRs by proposing alternatives to DDOT. However, to-date, DDOT has not been willing to change their requirements. Therefore, DCWater has to assume the higher paving cost in the program cost estimate.	BCV	No change. Agree that changing paving requirements is critical. This report is a recommendation to DC Council on how to reduce cost. Paving is a significant opportunity. That's why it's included as a recommendation, but as a range because it's not approved yet. DC council can choose to make these demands/requests of DC Water, DDOT, and other relevant agencies as appropriate.
74	54	Table 16 - See spreadsheet tab labeled "Table 16 Comments".	BCV	Documentation for Table 16 was provided in Appendix E, tab "Summary Table 16 of Changes," columns B-F
75	54	Utility budgeting requires the full costs of the program to be encumbered before the project can begin. Encumbering a piece of a larger project or encumbering an amount that does not include adequate contingencies is disingenuous to the Board who approves the budget, lenders who fund construction, and rate payers who ultimately pay the costs. Utility budgeting requires the full costs of the program to be encumbered before the project can begin.	JPD	Not sure what commenter is looking for here. No change.
76	54	Since DC Water is responsible for the administration and achieving the objectives of the LFDC program, it seems prudent not to undercut their cost estimates. If economies are achieved over the course of the work, benefits accrue to all in the form of reduced costs and better outcomes. DC Water's cost estimate for the total program follows the industry standard Class 4 AACE cost estimating guidelines, which uses an accuracy range of -20% (to account for these potential cost reductions) to +30% (to account for unknowns such as additional identified LSLs). DC Water's cost estimating for the overall program is appropriate and aligned with industry standards. Making an assumption that costs will be less as the program matures (best case scenario) for calculating the initial program cost is not aligned with industry standards and inconsistent with current price inflation and labor shortages.	PD & BC	Agree. We described this as a reason to expect our estimate is on the high side. We did not make any assumption to reduce initial program costs.
77	58	Table 17 - DC Water's total program cost is estimated to be $944M (low side) to $1,139M (high side). SWE's total program cost is estimated to be $829.3M [$480M + $349.3M] (low side) to $1,082.5M [$628.4M + ($349.3 x 1.3)] (high side). This includes the water main replacement cost of $349.3M as noted in Table 17 because the water main replacement has to occur to properly replace the LSLs. The SWE high side cost includes 30% contingency added to the water main cost. DCWater Total Cost = $944M - $1,139M SWE Total Cost = $829.3M - $1082.5M Difference = $56.5M - $114.7M (4.96% - 12.2% difference) The two costs are between 5% and 12% of each other with the high and low estimates which for planning level costs are the same order of magnitude. SWE's program indicates the cost includes replacing 42,323 LSLs. SWE is using the assumed cost savings from 1) assumption of reduced paving cost $148.4M, and 2) assumption of reduced programmatic costs of $90.1M (total of 1 & 2 = $238.5M) to essentially cover the additional cost of the 14,348 LSLRs [42,323 - 27,975] assumed in their 42,323 LSL total. As we noted in the above comments, it is not aligned with AACE cost estimating industry standards to assume the best case scenario and the potential for reduced costs when developing a planning level cost estimate. As noted above, DCWater has tried to negotiate lower paving costs with DDOT. SWE should have noted this in their report and not made the assumption that lower paving costs could be realized. SWE should have also asked DCWater for their actual programmatic costs versus making an assumption that costs could be lowered without sufficient backup to support the lowered costs.	BCV	Our job is to show DC Council where the LFDC program does not meet the 2030 goal of replacing all lead, galvanized, and brass service lines and to identify areas where they can expect to find savings. DC Council can choose to make these demands/requests of DC Water, DDOT, and other relevant agencies as appropriate. No change.
78	58	Report states in Table 17, "**The low and high estimate are calculated using optimized street paving verses street paving as suggested by DDOT current regulations* ." Table 16 indicates the optimized street paving to save $148.4M. DC Water's total program cost does not include the $148.4M cost savings because this is currently not allowed by regulation. If DC Water's total program cost included the $148.4M savings, total cost would be $795.6M - $990.6M which is a lower total program cost than SWE's total program cost of $829.3M - $1082.5M and would essentially cover the cost of the added 14,348 LSLRs included in SWE's cost.	BCV	This is an inaccurate comparison that does not account for the analysis and recommendations provided throughout the report. No change.

79	58	Report states, "*Our LFDC Plan Recommendations are designed to achieve the following:* *• Account for identification and removal of all potential LSLs;* *• Prioritize critical customers and equity;* *• Consolidate programs and timelines to generate cost efficiencies;* *• Provide certified lead reducing filters to all potential LSL locations to provide an immediate source of safe drinking water for all residents; and* *• Encourage and increase public participation through lower costs, fewer participation* *barriers, and increased public engagement* ." It appears from our review of this report and DC Water's June 2021 LSL Program Report that DC Water's program achieves these same objectives, except for possibly not providing lead reducing filters to LSL locations (DCWater to confirm if this objective is addressed). DC Water's LSLR program appears to achieve these same objectives for about the same total cost as SWE's total program cost. And if some or all of the cost savings identified by SWE from optimized street paving can be agreed upon by the District, DDOT and DCWater this would result in a DCWater total program cost less than SWE's estimated total program cost. See comment 32.	BCV	Evidence is presented throughout the report describing why the LFDC plan does not achieve the objective of removing all LSLs (including galvanized and brass service lines) in DC by 2030 and how the recommended revisions will both achieve the 2030 goal and reduce overall costs. No change.
80	59	(pages 59-60) Table 18 appears to have some confusing costs as compared to Table 17 and only accounts for certain water main replacement costs. Table 17 costs appear to be repeated in Table 18. Therefore, for ease of understanding, Table 17 costs were used when comparing SWE's costs to DC Water's costs.	BCV	Table 18 is our best effort to provide a 1:1 comparison between LFDC and the report recommendations, to clarify how the two line up in total. Table 17 is a simplified version of the same information
81	59	Report states, "*we recommend that these water main replacements be included in the CIP budget rather than the LFDC budget. These replacements are necessary for maintenance of DC Water infrastructure, and LSLR will be least expensive if completed at the same time, but these are expenses DC Water must plan for even in the absence of a LFDC Plan.* " We don't see the water main replacement as an added cost to the LSLR initiative. The water main replacement is a necessary cost of the LFDC program as part of replacing the LSLs. If the public side LSLs are replaced and the old water main is left in place to be replaced in some other future project that approach adds cost and inefficiencies to the overall program and ratepayers. Figure 7.1 LFDC Decision Tree clearly shows that private side LSLs where no public side LSLs are located are separately replaced independent of water main condition, which is appropriate. Funding for the priority water main replacement and the LSLR to be performed together, per DC Water's prioritized program, needs to be considered and secured together to keep total costs to DC Water's ratepayers as low as possible.	BCV	See clarifications provided in comment 41 and response in comment 43.
82	59	Report states, "*To successfully implement the recommended program, the Council of the District of Columbia will need to eliminate the bifurcation of LSLR programs and the distinction between funding options for partial lead service lines and full lead service lines. The current LFDC distinctions of funding sources, funding eligibility, and program administration decrease the efficiency of the LFDC plan.* " We agree with this statement. To the extent that private and public LSLRs funding can be clearly defined and provided this will greatly increase the efficiency of DC Water's program which currently only has a 70% volunteer participation rate by the public. Since DCWater cannot currently spend the money it collects on private LSLRs a dedicated funding source is needed for the private LSLRs. DC Water's June 2021 Program Report identifies a number of policy recommendations to increase the efficiency and reduce costs of the LSLR program.	BCV	The clarified recommendation on Page 32, "1. Pass an LSLR mandate and provide funding for all private side LSLRs." makes a much stronger case for making these necessary changes.
83	61	(pages 61-62) The report provides 9 recommendations to eliminate barriers to participation in the LSLR program and meet the LFDC Plan goals. The 9 recommendations appear reasonable. Does DCWater have any concerns with implementing these recommendations or are some recommendations already being implemented? Has DCWater and/or the District already secured BIL funding through the DWSRF for the LSLR program and public and private side replacements?	BCV	no change
84	61	"Every LSLR should be completed within one business day. If an emergency prevents this, the water should remain off until the FLSLR has been completed." While DC Water strives to complete repairs and replace all services in an 8-hour period and does in most cases, weather and field conditions can cause the work to stop. Examples of field conditions include and are not limited to: the service line changes direction and comes to close to a tree which requires Urban Forestry to assess and approve the excavation; another utility service is mismarked and struck; the service line is deeper than 8 feet and requires additional excavation and shoring to complete the work; the service line from the meter to the house cannot be found; and the service line inside the home is not accessible and the homeowner must move large items to provide access.	MS	Agree. This is why the recommendation is to complete the LSLR within one day, with a backup plan to protect the resident when it is not possible. No change.

85	61	"The Water Service Specification should include in-home flushing per AWWA C810-17 to be completed by the contractor at the time water service is restored." AWWA C810-17 does not state that the flush must be completed by the "contractor". Instead, Section 4.4.1 describes the utility flush through the outside hose-bib and Section 4.4.2 describes the flushing by the customer. DC Water follows these same procedures. Requiring work or operation of plumbing inside the home adds significant liability to the contractor, thus increasing costs.	MS	Although not required, this is a recommendation for a best practice to ensure the work gets done and protects the customer. Many residents, especially older residents or those with mobility challenges can find it very difficult to complete the flushing instructions. Other cities have chosen to require the contractor to complete the work. This recommendation is made to ensure the DC Council is aware that there is an opportunity to be more protective of the resident. No change.
86	61	"Contractor should provide documentation to the resident and owner of replaced/ non-lead service line every time they leave any service location, in addition to all contract recordkeeping requirements." DC Water (not the contractor) communicates with the customer and provides the documentation after any excavation or replacement work is conducted.	MS	No change. We made recommendations for best practices for which we did not find evidence in any of the documentation provided. If DC Water is doing it, keep doing it.
87	61	"The specification should not allow reinstalling any automatic meter reading (AMR) type meter greater than or equal to 1" diameter if it does not meet the revised definition of "lead-free" under the RLDWA." DC Water replaced all meters less than 3 inches between 2016 and 2020 with meters meeting the "Lead-free" definition.	MS	No change. We made recommendations for best practices for which we did not find evidence in any of the documentation provided. If DC Water is doing it, keep doing it.
88	61	(pages 61-62) "Update all standard drawings to include public health protection onsite details, including 1) turn off water before work begins, 2) don't turn water on after the new service is installed until flushing in-home plumbing, talking with the resident, and delivering a 6-month supply of certified lead reducing filters is complete. This would appear with standard notes re: storm water control and tree protections." DC Water follows industry standards for service line repair and replacement. Suggest stating to following AWWA C810-17 and not beyond to avoid confusion. The #2 comment is not accounting for some of the water installation testing and flushing steps. Water is "turned on" to test for leaks and may be turned on-and-off through that testing, then "on" for flushing through outside hose-bib with a jumper in the place of the meter, turned off to remove the jumper and place the meter in, and turned on and flushed to again check for leaks with meter in place.	MS	Clarified: "and 2) restore water service to the house only after in-home plumbing is flushed, information is shared with the resident, and a 6-month supply of certified lead reducing filters is provided to the resident."
89	62	(pages 62-63) The report provides 12 primary recommendations to "Improve Water Service Specifications to Protect Public Health and Improve Clarity and Consistency". We are not intimately familiar with DC Water's LSL specifications and design drawings so we cannot directly comment on if DCWater is already performing these recommendations. Does DCWater have any concerns with implementing these recommendations or are some recommendations already being implemented?	BCV	no change
90	63	(pages 63-66) The report provides a number of future strategies, including ordinances, code enforcement, contract administration, and community outreach ideas for DCWater to consider. These ideas appear reasonable. To the extent DCWater thinks these ideas will help their program and are not already implemented, DCWater should consider implementing any relevant listed ideas.	BCV	no change

Table 16 from SWE July 2022 Report Reproduced below with added comments

Table 16: Costs of Recommended Revisions Compared to 2022 LFDC Revised Cost

Corrections to 20220331 LFDC Revised Cost Estimate	Difference	Raftelis Comments	Response
Update AA12 to correct calculation error in applying 10% co	$ (47,530,653.00)	We do not have this spreadsheet so we are not able to verify these listed potential cost savings items. Has DCWater verified if these two items are correct?	The spreadsheet was provided as Appendix G
Remove Test pit charges for Service Lines that are determined to be Lead per contract specifications	$ (60,628,934.00)		The spreadsheet was provided as Appendix G
Analysis of Recommendations			
Move all CIP-BBB Poor Quality Main SDWMR costs to CIP	$ (140,577,987.00)	We don't see the water main replacement as an added cost to the LSLR initiative. The water main replacement is a necessary cost of the LFDC program as part of replacing the LSLs and should be included in the LFDC total cost. See comment 44.	See response to comment 44
Adjust restoration to most cost-effective method cost: full street paving or individual site restoration	$ (148,394,279.00)	See Comment 73.	See response to comment 73
Account for efficiencies of scale for neighborhood scale replacement for non-water main replacement projects	$ (29,398,712.00)	See Comments 69, 71, 76.	See responses to comments 69, 71, 76
Adjust Design, Engagement, Management, and Data Costs	$ (90,125,122.00)	See Comment 65, 69, and 71.	See responses to comments 65, 69, 71
Adjust Service Line replacement costs per DC Water bids	$32,350,860	Perhaps DCWater can clarify. Are bids coming in higher than DC Water's estimates?	See revised table 14 which reflects information that was originally provided in Appendix F
Account for test pitting all Unknowns and Historic Brass in addition to Historic Copper	$18,284,697	Figure 7.1 LFDC Decision Tree in the report includes a step for material investigation for unknown services. DCWater included lead and galvanized service line replacements by 2030 and planned to replace brass lines in areas where galvanized and lead lines were identified. DCWater indicated they will discuss if all of the brass lines also need to be replaced by 2030.	The Material Investigation in the LFDC Decision Tree does not account for blocks with less than 1/3 public unknowns. The LFDC plan does not include the cost of test pitting all unknowns and Historic Brass. Test pitting all historic brass and unknown service lines will be necessary to removal all Lead service lines in DC by 2030.
Add filters for all potential LSLs and 6 months post replacem	$24,145,432	DCWater already included the cost for filters after the LSLs are replaced	This cost was not included in any of the documentation provided
Account for Individual High-Priority LSLR Program	$8,524,177	We don't understand how this cost was calculated. It appears DC Water's program has appropriately prioritized LSL for replacement.	The calculation was provided in Appendix E, tab "Summary Table 16 of Changes," columns B-F
Account for replacing LSLs found from Historic Brass and Co	$143,822,464	See Comment 16.	See response to comment 16
Account for replacing all brass and galvanized service lines	$34,895,254		See response to comment 16

Page	Questions	Response/Changes made
20	Recommend explaining what "modeled" blood lead levels in children consists of - i.e., are they using any actual data of Blood Lead Levels in Denver? What is the sample size? Is this	Denver Water's Lead Reduction Program Plan is made available as Appendix K.i
21	Does ACS data for children under 5 exist at the Census Block Group level?	Yes, we used it for our analysis.
31	Why multifamily buildings vs single home buildings with occupants age 5 and younger?	Single family buildings are already prioritized via probablility of lead service lines, since lead service lines are typically less than 3" in diameter. Our recommended model criteria use children under 5 to prioritize LSLR. Multifamily buildings are less likely to have lead service lines (although duplexes and small garden style buildings may have LSLs) but may have young children at elevated risk of lead exposure due to lead in the service line and/or household plumbing. This option provides the ability to accelerate LSLR in a mulitfamily building especially where more children may be affected compared to a single family building.
40	Was Map 7 created with prioritization model?	Yes. See updated map title for clarity.
46	Did Denver Water "street paving" include curb to curb or same extent as DDOT requirement? Did DW provide cost per SQ YD or average block length/street width? What about Maintenance of Traffic or Civil Design/TCP requirements (or did DW have blanket permits due to LCR exceedance? Full table comparison of bid item UNIT PRICES of DC and benchmarking utilities can help provide clarity. Note: Newark had 1 cent per test pit on Roman Contract 40 & 41, and winning contract also had street paving in the $10,000's vs the Engineer Estimate in the $1,000,000s. Recommend noting that contracts and costs between cities can vary widely due to these types of factors that aren't explicitly stated or made clear in section "How does this compare to benchmark cities?" and Table 12. Recommend also noting assumptions that density of housing was not considered in comparison of costs and could significantly affect costs. Cities like Denver has spacious residential streets with large single family home lots compared to East Coast/historic cities – this affects costs associated with complexity of MOT and tree protection requirements and compliance, requirements for backfill and restoration.	"Contracts and costs can vary widely between cities due to city specific requirements, building density, and cost of living." Since we did not use other cities' dollar values to re-estimate DC Water's costs, we did not complete additional analysis.
48	The industry has noted the impact inflation will have on future infrastructure/construction costs. Was annual escalation/inflation accounted for in this cost estimate? Recommend noting reasoning for why/why not in this section "How Did We Calculate Program Costs?".	"We did not include a price escalation for inflation in our estimate. The benchmarking cities mostly found that costs decrease over time as contractors become more efficient in their work, and Denver found this to be true for 2021 even as inflation was increasing."
48	Does your efficiency measure take into account that this is a non-mandated program or does it assume the mandate you recommend on page 63?	Added to Page 32: "It is most efficient to do this through DC Water initiated work, which requires new funding and policy support to go forward. 1.Pass an LSLR mandate and provide funding for all private side LSLRs. The pathway to ensuring all full and partial LSLs are removed in Washington, DC will be facilitated by a carrot and stick approach by the Council of the District of Columbia: mandating LSLR and providing funding for verification and replacement of all potential LSLs so that all residents can readily participate. The mandate compels residents to participate, and the funding removes the largest barrier to participation. Requirements for customers to pay, even when there is capacity for financial assistance, create unnecessary barriers and delays to LSLR. Any program requiring customers to pay or apply for assistance will result in partial LSLRs which increase the risk of exposure to lead in water and increase the overall cost of the LFDC Plan. In addition, the revised LFDC plan should focus on eliminating as many barriers to participation as possible.
49	42,323 service lines /6 years = more than 7,000 LSRs a year and 44,361 test pits associated with inventory verification not resulting in LSR / 6 years = 7,400 test pits a year. Does your report discuss the feasibility of achieving those numbers in relation to the amount of allowable construction in the city, contractor capacity, or timeline? (6 years of LSLR taken from footnote 1 of Table 15 on page 51).	No Change
50	Design - noting the extent of BBB Civil Designs and TCPs required this year by DDOT and shared with files, where is the cost of producing these captured? Was consideration given to the more complex BBB with SDWM Designs and TCPs that will be required in future years?	No Change
50	What reference did you use to come to specific percentages (3 vs 5) for CM and DM?	No change; reference included in report.
52	Where did recommendation of 100 ft of road as trigger for curb to curb street repaving come from?	No change
Appendix B	Is this the correct version of this document?	No. Revised document provided.

Page	Questions	SWE Response	SWE Proposed Changes to Report
46	Did Denver Water "street paving" include curb to curb or same extent as DDOT requirement? Did DW provide cost per SQ YD or average block length/street width? What about Maintenance of Traffic or Civil Design/TCP requirements (or did DW have blanket permits due to LCR exceedance? Full table comparison of bid item UNIT PRICES of DC and benchmarking utilities can help provide clarity. Note: Newark had 1 cent per test pit on Roman Contract 40 & 41, and winning contract also had street paving in the $10,000's vs the Engineer Estimate in the $1,000,000s. Recommend noting that contracts and costs between cities can vary widely due to these types of factors that aren't explicitly stated or made clear in section "How does this compare to benchmark cities?" and Table 12. Recommend also noting assumptions that density of housing was not considered in comparison of costs and could significantly affect costs. Cities like Denver has spacious residential streets with large single family home lots compared to East Coast/historic cities – this affects costs associated with complexity of MOT and tree protection requirements and compliance, requirements for backfill and restoration.	We did not investigate the paving requirements for Denver Water that are included in their cost per LSLR as shown in Table 12. We decided to rely upon the paving costs provided by DC Water and consider strategies to complete paving work in a more cost effective strategy.	"Contracts and costs can vary widely between cities due to city specific requirements, building density, and cost of living." Since we did not use other cities' dollar values to re-estimate DC Water's costs, we did not complete additional analysis.
48	The industry has noted the impact inflation will have on future infrastructure/construction costs. Was annual escalation/inflation accounted for in this cost estimate? Recommend noting reasoning for why/why not in this section "How Did We Calculate Program Costs?".	We did not include a price escalation for inflation in our estimate. The benchmarking cities mostly found that costs decrease over time as contractors become more efficient in their work, and Denver found this to be true for 2021 even as inflation was increasing. Detroit did observe inflation affecting prices without a corresponding decrease due to improved workflow, but they are not completing LSLR work at the same scale as the other programs that would allow them to build up program efficiencies (~340 LSLRs per year). We chose to not include an escalation for inflation nor a decrease for programmatic efficiencies.	"We did not include a price escalation for inflation in our estimate. The benchmarking cities mostly found that costs decrease over time as contractors become more efficient in their work, and Denver found this to be true for 2021 even as inflation was increasing."
48	Does your efficiency measure take into account that this is a non-mandated program or does it assume the mandate you recommend on page 63?	Our efficiency measure assumes costs are decreased based on consolidating work in space and time. We did not model customer participation in a non-mandated program. We approached this study with the perspective that the DC Council is motivated to remove all lead service lines in Washington DC and is willing to take aggressive steps to make that possible. We hope this includes passing a mandate for LSLR, which will provide additional efficiencies.	Added to Page 32: "It is most efficient to do this through DC Water initiated work, which requires new funding and policy support to go forward. 1. Pass an LSLR mandate and provide funding for all private side LSLRs. The pathway to ensuring all full and partial LSLs are removed in Washington, DC will be facilitated by a carrot and stick approach by the Council of the District of Columbia: mandating LSLR and providing funding for verification and replacement of all potential LSLs so that all residents can readily participate. The mandate compels residents to participate, and the funding removes the largest barrier to participation. Requirements for customers to pay, even when there is capacity for financial assistance, create unnecessary barriers and delays to LSLR. Any program requiring customers to pay or apply for assistance will result in partial LSLRs which increase the risk of exposure to lead in water and increase the overall cost of the LFDC Plan. In addition, the revised LFDC plan should focus on eliminating as many barriers to participation as possible.

49	42,323 service lines /6 years = more than 7,000 LSRs a year and 44,361 test pits associated with inventory verification not resulting in LSR / 6 years = 7,400 test pits a year. Does your report discuss the feasibility of achieving those numbers in relation to the amount of allowable construction in the city, contractor capacity, or timeline? (6 years of LSLR taken from footnote 1 of Table 15 on page 51).	We were not aware of limits to allowable construction in the city. Please provide copies of any requirements that need to be incorporated into our analysis. Regarding contractor capacity, our observation has been that when projects are advertised and money is on the table, companies see and fill the need. If you have examples of projects you have put out to bid that received no qualified bids, please let us know and we can modify this section as necessary. We approached this study with the perspective that the DC Council is motivated to remove all lead service lines in Washington DC and is willing to take aggressive steps to make that possible. Newark has replaced nearly 6,955 per year (23,182 on 8/5/22 since March 2019). (https://www.newarkleadserviceline.com/replacement#:~:text=About%20the%20Program,-Newark%20has%20planned&text=Construction%20for%20the%20first%20phase,replace%20them%20with%20copper%20pipes.)	No Change
50	Design - noting the extent of BBB Civil Designs and TCPs required this year by DDOT and shared with files, where is the cost of producing these captured? Was consideration given to the more complex BBB with SDWM Designs and TCPs that will be required in future years?	As discussed in the draft report, all SDWMR costs are separated from the LSLR program because we were only contracted to evaluate the cost of the LSLR program. All SDWMR designs are included in the SDWMR estimate from DC Water and provided in Table 17	No Change
50-51	What reference did you use to come to specific percentages (3 vs 5) for CM and DM?	Denver Water provided the following: "Project management (includes internal, construction management, data management, filter PM, Wq testing PM, regulatory reporting) costs for the program are roughly 15% of the total cost of the program."	No change; reference included in report.
52	Where did recommendation of 100 ft of road as trigger for curb to curb street repaving come from?	Safe Water Engineering provided the concept of using the number of LSLRs per 100ft of road as a metric to consider for establishing when it is appropriate to pave at individual LSLRs vs curb to curb. We know current practices are defined and required by DDOT. This is a concept we present for exploration to bring down paving costs while meeting reasonable quality of life expectations.	No change
Appendix B	Is this the correct version of this document?	Thank you for pointing this out.	Introduction added and comments removed.