

# **Enclosure 1**

## Denver Water's Lead Reduction Program Plan

Denver Water Request for 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



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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.



**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.



**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.



**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.



**Creates a Regional Solution**

The Lead Reduction Program prevents additional phosphorous loading at regional wastewater treatment plants, which is costly to remove.



**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**

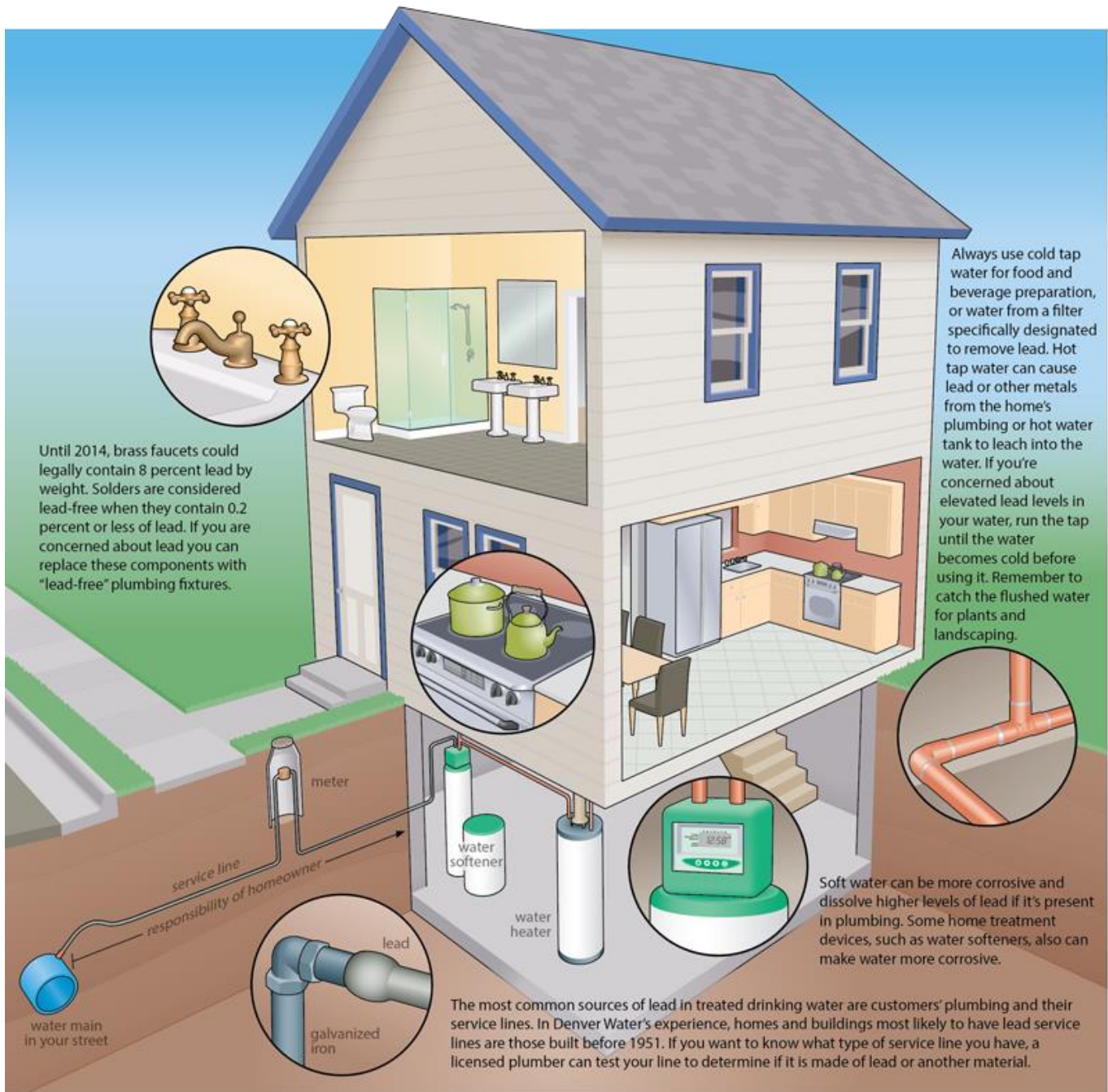


FIGURE 3: HISTORY OF LEAD IN DRINKING WATER

# The Evolution 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
90 <sup>th</sup> 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 90<sup>th</sup> 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<sub>3</sub> 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**

<b>Communications, Outreach and Education</b>
<p><b>Denver Water is committing to:</b></p> <ul style="list-style-type: none"> <li>• Educate and engage with residents, customers, distributors, local public health agencies and government stakeholders about lead awareness and reduction efforts.</li> <li>• Educate the public on measures they can take to reduce their exposure to lead in water used for drinking, cooking and infant formula preparation.</li> <li>• 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.</li> <li>• Seek feedback from residents and other stakeholders to learn best practices and effective ways to implement program activities.</li> <li>• Strive for 100% participation in the Filter Program.</li> </ul>
<b>Lead Service Line Inventory</b>
<p><b>Denver Water is committing to:</b></p> <ul style="list-style-type: none"> <li>• Research, investigate and document the presence of customer-owned lead service lines.</li> <li>• Help customers identify if they have a lead service line.</li> <li>• Maintain a current lead inventory and map.</li> <li>• Confirm materials at properties with a suspected or possible lead service line.</li> <li>• Use the inventory to target communications, outreach and education efforts at areas with the greatest risk.</li> </ul>
<b>Filter Program</b>
<p><b>Denver Water is committing to:</b></p> <ul style="list-style-type: none"> <li>• 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.</li> <li>• Educate and inform residents on the importance of using filters for drinking water.</li> <li>• 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.</li> </ul>
<b>Accelerated Lead Service Line Replacement Program</b>
<p><b>Denver Water is committing to:</b></p> <ul style="list-style-type: none"> <li>• Replace all known lead service lines in 15 years.</li> <li>• Replace 7.0% of the lead service line inventory each program year, based on a cumulative annual average.</li> <li>• 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.</li> <li>• 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.</li> </ul>
<b>Corrosion Control Treatment</b>
<p><b>Denver Water is committing to:</b></p> <ul style="list-style-type: none"> <li>• Maintain water quality by implementing corrosion control treatment through pH/alkalinity adjustment.</li> <li>• 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.</li> </ul>



## 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
<b>Lead Service Line Inventory</b>	Must investigate a minimum of 1.4% of total LSLs in inventory per year.	<ul style="list-style-type: none"> <li>• Achieve compliance by following year.</li> <li>• Provide notice of corrective action to customers with filters.</li> </ul>	If less than 1.4% investigations occur for three program years: <ul style="list-style-type: none"> <li>• Notice to all customers.</li> </ul>
<b>Filter COE</b>	Outreach and education materials provided each year to at least 95% of households enrolled in the Filter Program.	<ul style="list-style-type: none"> <li>• Must achieve compliance by following year.</li> <li>• Notice to customers with filters.</li> </ul>	If Denver Water fails to provide outreach and education materials to at least 95% of households enrolled in the Filter Program for three years: <ul style="list-style-type: none"> <li>• Notice to all customers.</li> </ul>
<b>Filter Program</b>	Achieve minimum filter adoption rate of 65% per year.	<ul style="list-style-type: none"> <li>• If filter adoption rate is less than 65% in a year, increase outreach and education efforts to improve filter use.</li> <li>• Notice of corrective action to customers with filters.</li> </ul>	If failure to achieve 65% adoption rate for three years: <ul style="list-style-type: none"> <li>• Termination of variance.</li> <li>• Notice to all customers.</li> </ul>
<b>Accelerated Lead Service Line Replacement</b>	Must achieve 7.0% cumulative annual average replacement rate each year.	<ul style="list-style-type: none"> <li>• Achieve compliance by following year.</li> <li>• Notice to customers with filters.</li> </ul>	If less than 7.0% of lead service lines are replaced for three years: <ul style="list-style-type: none"> <li>• Termination of variance.</li> <li>• Notice to all customers.</li> </ul>
<b>Corrosion Control Treatment</b>	Lead and Copper Rule sampling results remain below action level for lead.	<ul style="list-style-type: none"> <li>• Must adjust corrosion control and distribution management.</li> <li>• Customer education and notice.</li> </ul>	If action level exceeded for two monitoring periods: <ul style="list-style-type: none"> <li>• Must provide customer notice.</li> <li>• Termination of variance unless CDPHE requires otherwise.</li> </ul>

### 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**

<b>Assumption</b>	<b>Orthophosphate (at 2 mg/L as PO<sub>4</sub>)</b>	<b>Variance</b>
<b>Excluding Existing Service Line Replacement Efforts</b>	\$322M to \$506M	\$265M to \$362M
<b>Including Existing Service Line Replacement Efforts</b>	\$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](http://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](https://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.<sup>1</sup>

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.

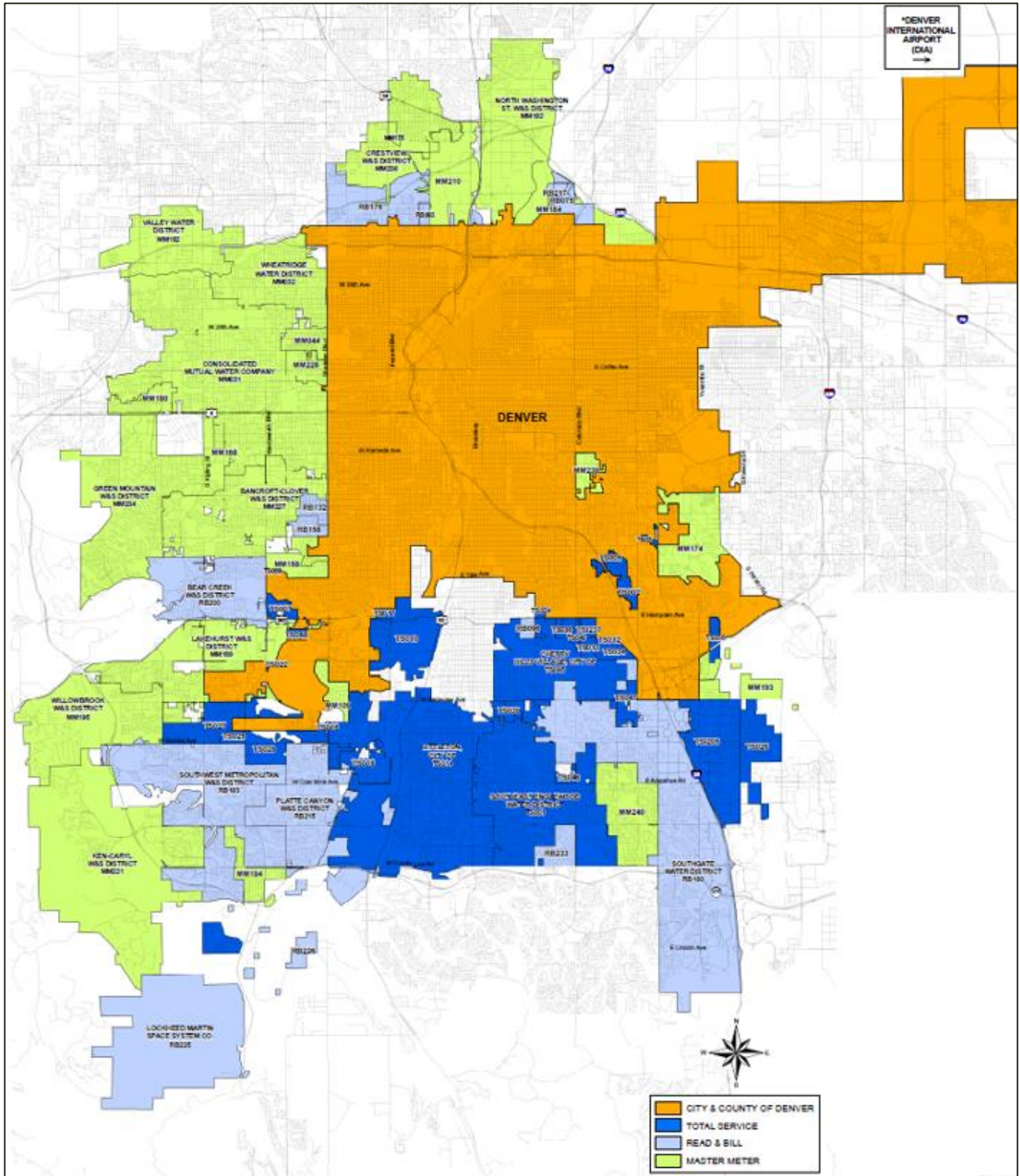
## Actions taken by Denver Water to protect customers from lead in drinking water

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.

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<sup>1</sup> See Rule 11.42(1), 5 CCR 1002-11 and Appendix III.B.1.

**FIGURE 4: DENVER WATER SERVICE AREA INCLUDING INTEGRATED SYSTEMS**

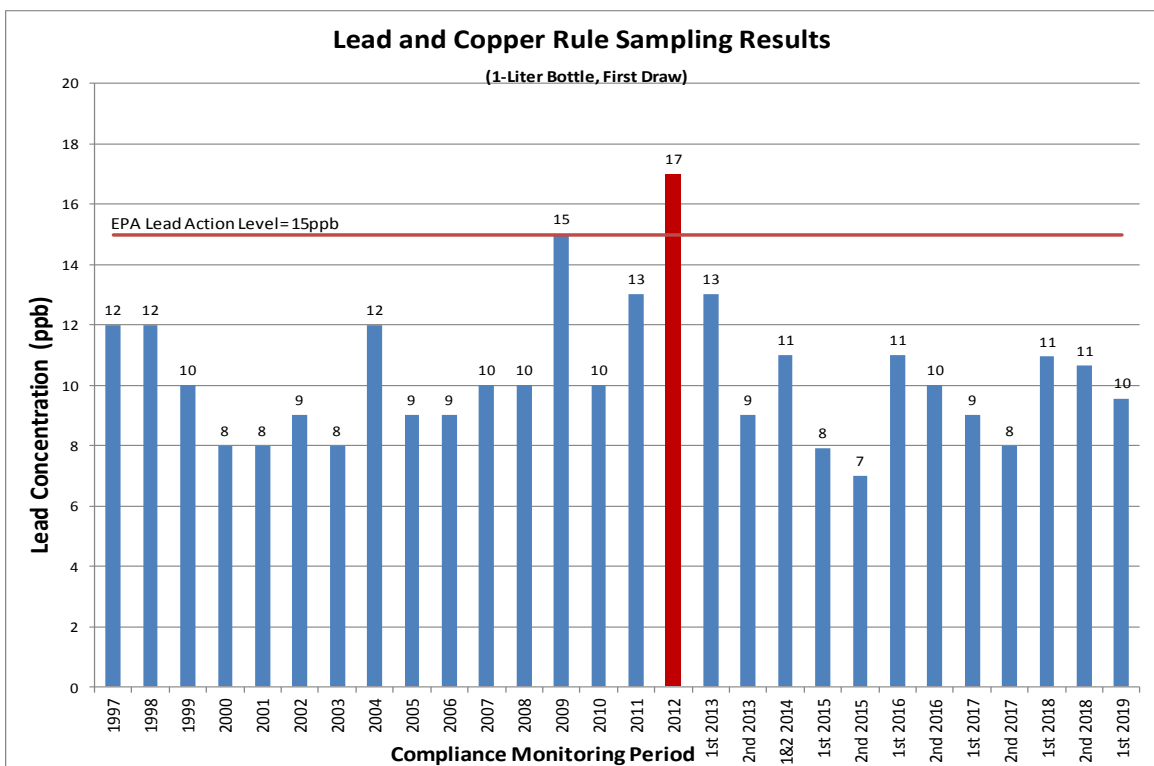


A corrosion control study completed in 1994 recommended that Denver Water adjust the pH of the water produced from its treatment plants to a range of 7.5 to 8.3 standard units. CDPHE issued a letter following the study indicating that to comply with the Lead and Copper Rule,

Denver Water must produce water with a minimum pH of 7.5 and minimum total alkalinity of 15 mg/L as CaCO<sub>3</sub> 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 90<sup>th</sup> 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: 90<sup>TH</sup> 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:

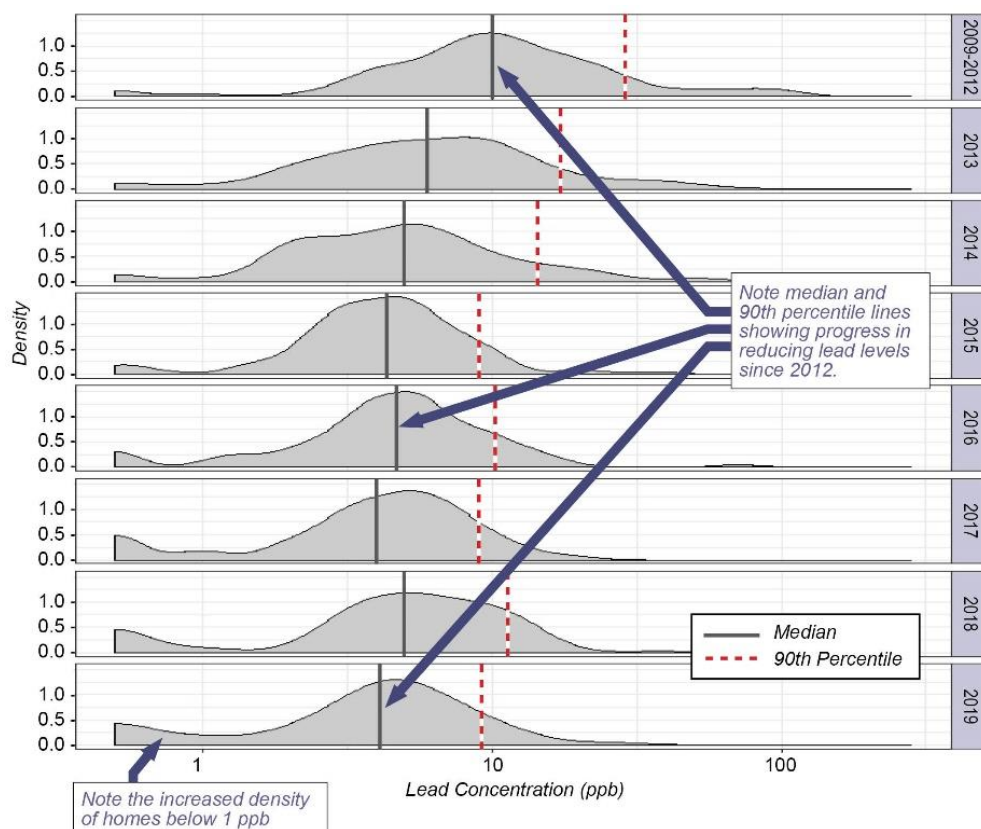


- Adoption of proactive and ever-adapting communications strategies that included direct customer mailings, bill inserts, sharing information at community gatherings, working with traditional media on coverage of lead issues and social media, including educational and call-to-action posts on Denver Water’s 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<sub>3</sub> 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
<b>Marston Treatment Plant (representing 80% of Denver Water’s supply)</b>	Median Reduction: 35% to 51%*	Median Reduction: 66% to 72%*
<b>Moffat Treatment Plant (representing 20% of Denver Water’s supply)</b>	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.<sup>2</sup>

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<sup>2</sup> 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 90<sup>th</sup> 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.<sup>3</sup>

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

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<sup>3</sup> 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.

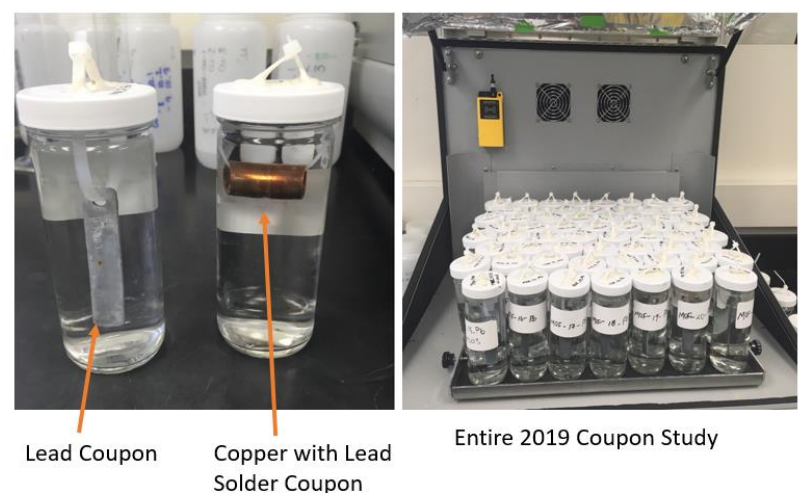
For its part in the alternatives analysis, Denver Water investigated the effects of the following alternative corrosion control strategies:

- 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<sup>4</sup> and initiated coupon studies to measure the effectiveness of different corrosion control strategies on lead release.<sup>5</sup> 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.

<sup>4</sup> See Appendix II.B for pilot testing results with the lead pipe racks.

<sup>5</sup> See Appendix III.E.2 for coupon testing results.

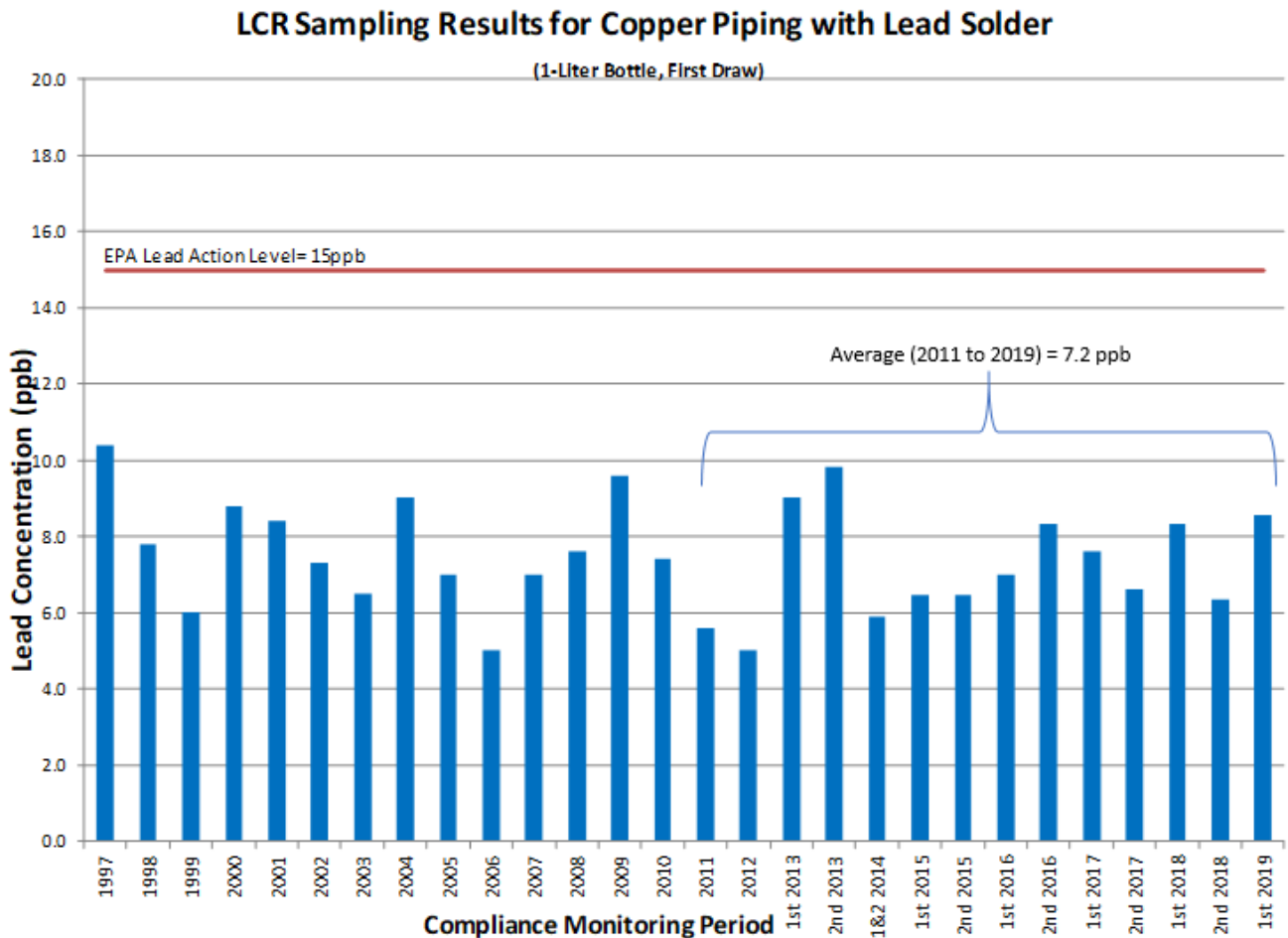
The results from a combined approach, using a high pH (8.8) and a low dose of orthophosphate (0.5 mg/L) also proved to be less effective than orthophosphate alone and was removed from further study. Of all the pH and orthophosphate doses tested, only the 2 mg/L dose proved to be as effective as the previously 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 90<sup>th</sup> 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.<sup>6</sup>

**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 <sub>4</sub> )
<b>Marston Treatment Plant (representing 80% of Denver Water’s supply)</b>	41% (32% - 61%)	70% (66% - 80%)
<b>Moffat Treatment Plant (representing 20% of Denver Water’s supply)</b>	43% (29% - 71%)	68% (54% - 84%)

Using the percent reductions from Table 5 above, Denver Water calculated the following ranges of 90<sup>th</sup> percentile lead concentrations based on the initial average 90<sup>th</sup> 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.

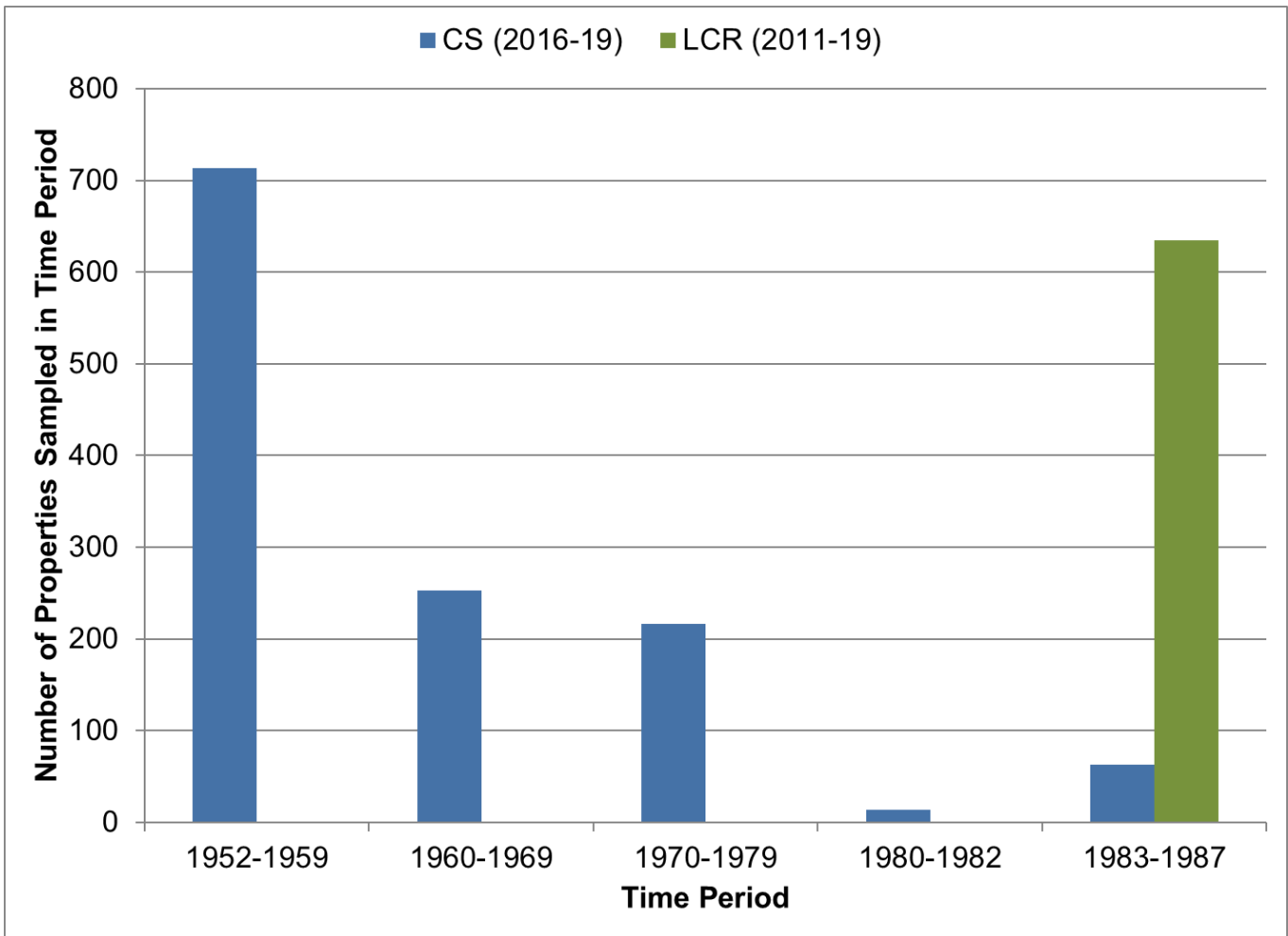
Although orthophosphate demonstrated better lead reduction than pH/alkalinity adjustment, the relative difference in reduction is small when applied to already low levels of lead coming from copper piping with lead solder (an approximately 2 ppb difference).

**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.

<sup>6</sup> 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.

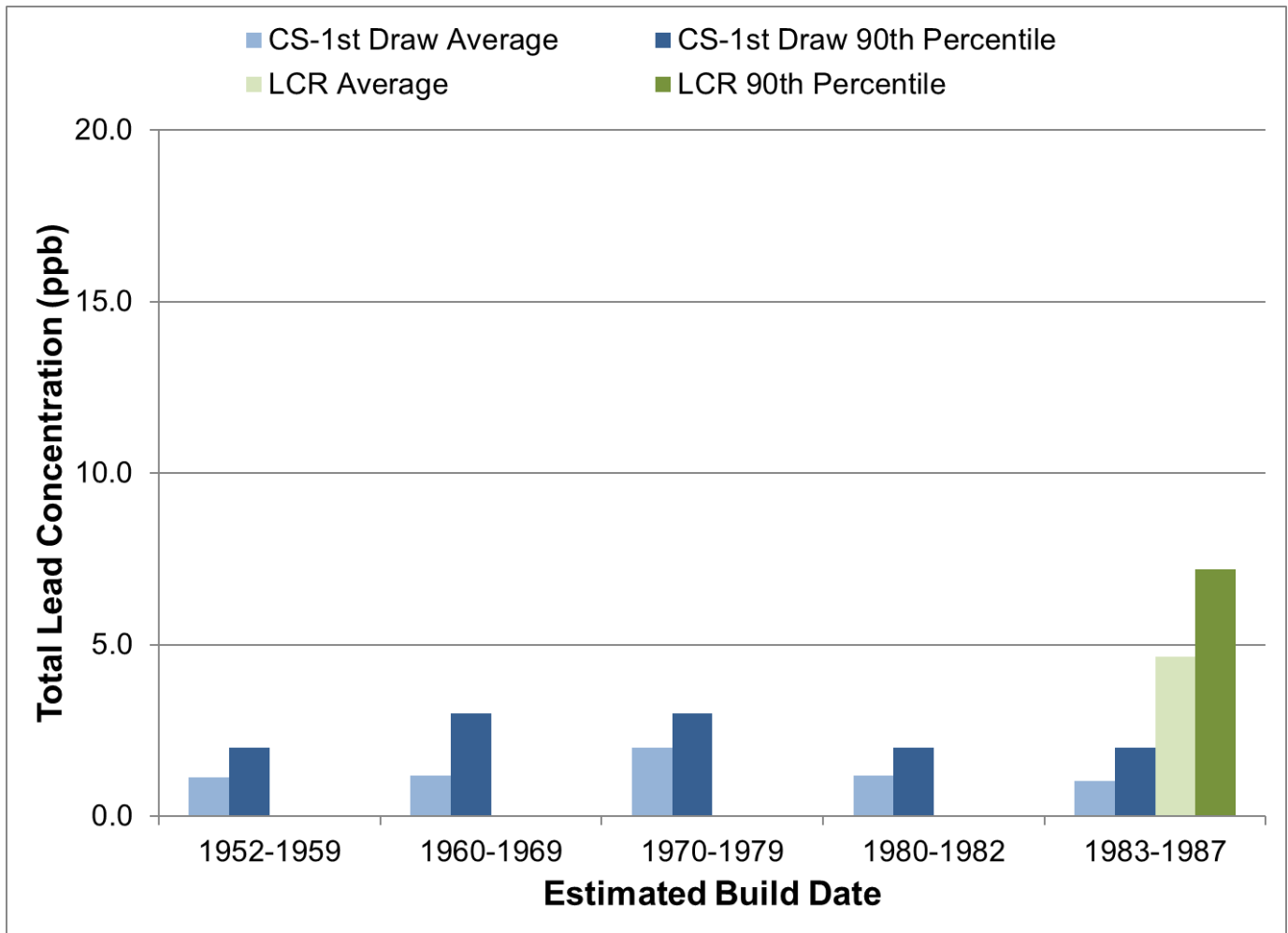
**FIGURE 10: DISTRIBUTION OF AVAILABLE WATER QUALITY SAMPLES BY DECADE OF BUILD DATE (COPPER PIPING WITH LEAD SOLDER)**



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 least one sample.<sup>7</sup> 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).

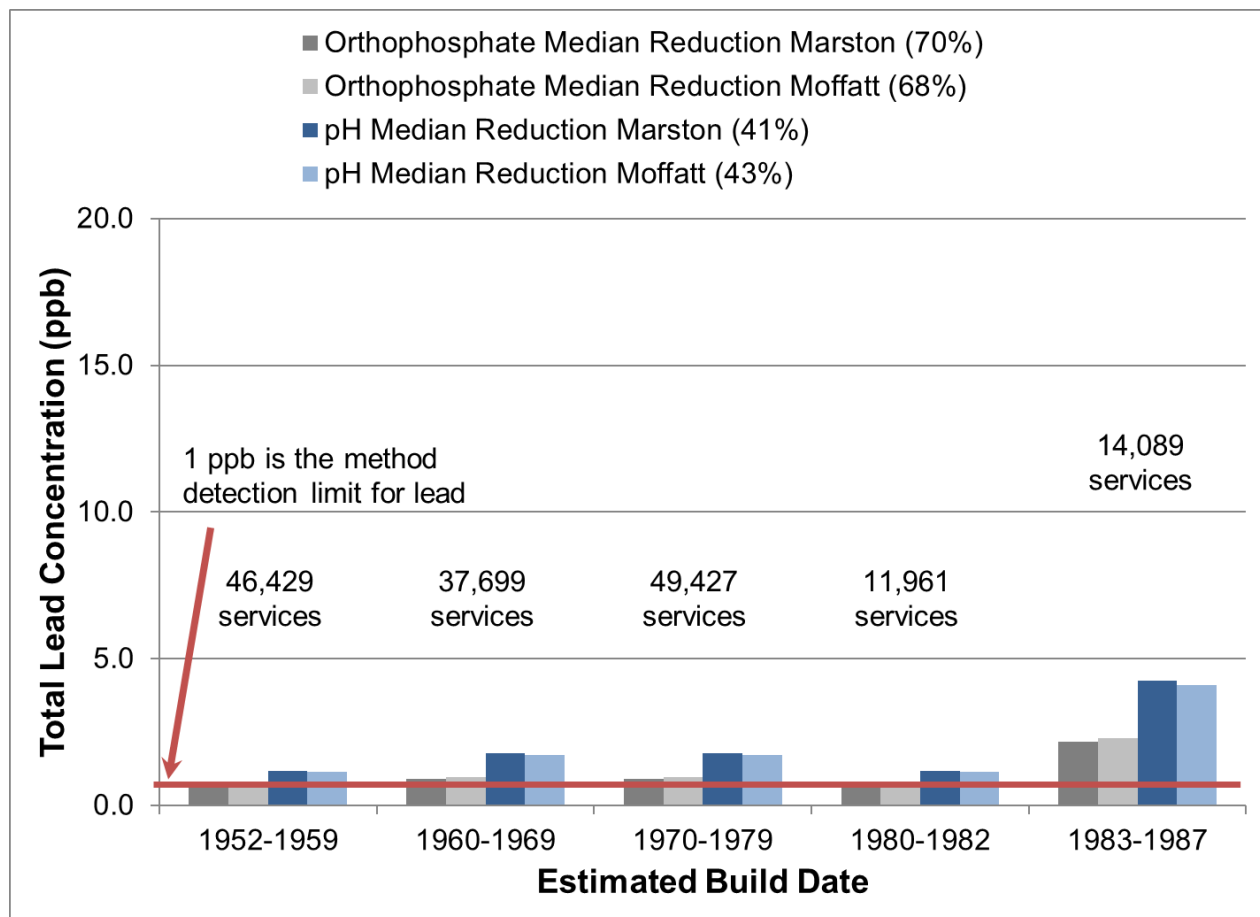
<sup>7</sup> See Appendix II.C for details.



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,<sup>8</sup> a difference of 2 ppb in lead concentration corresponds to a change in

<sup>8</sup> 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](http://HumanImpact.org/LeadPolicyEquity)



blood lead level<sup>9</sup> 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.

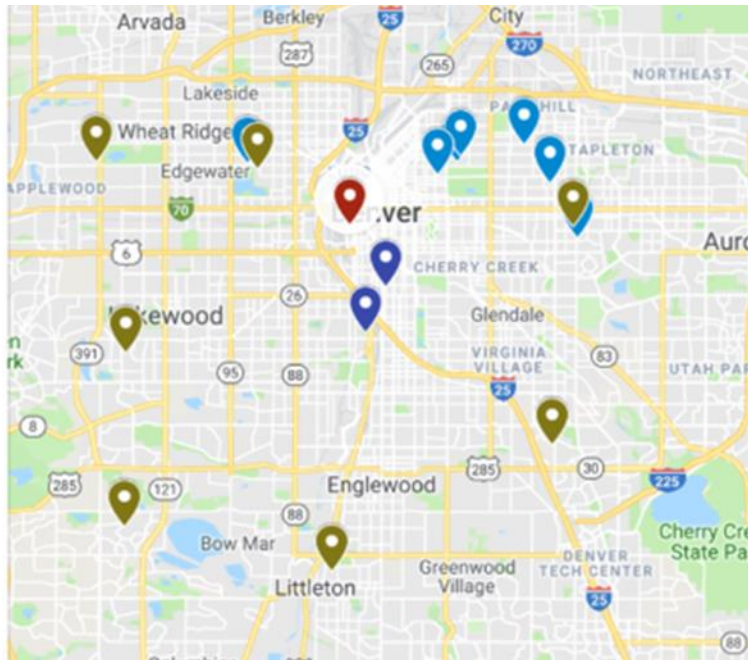
In the initial round of sampling, Denver Water collected data from ten homes with known lead service lines; seven of these were sampled in subsequent rounds (see Figure 13). For comparison, lead profiles were also generated for eight homes with known copper piping with lead solder, with six homes being 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.

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<sup>9</sup> The concentration of lead (in micrograms) in blood (deciliters), ug/dL, is used to quantify blood lead level.

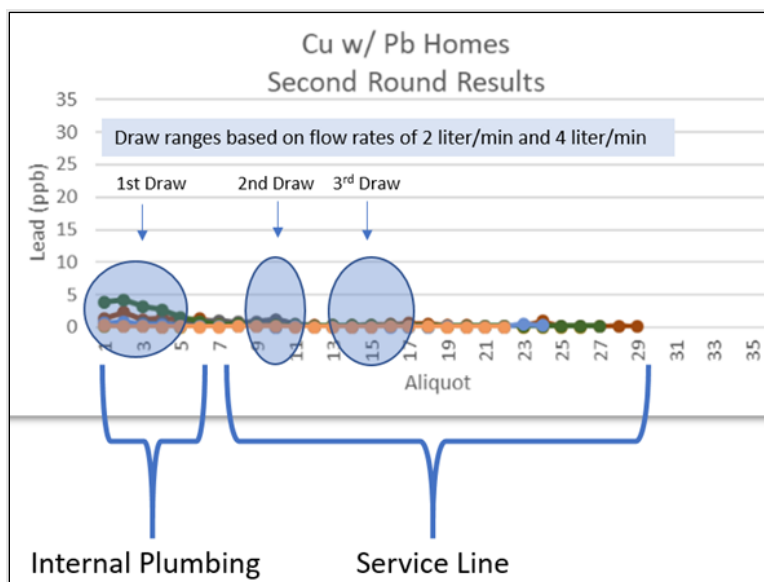
**FIGURE 13: HOUSEHOLDS FROM ACROSS THE DENVER WATER SYSTEM INCLUDED IN PROFILE SAMPLING**

(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)



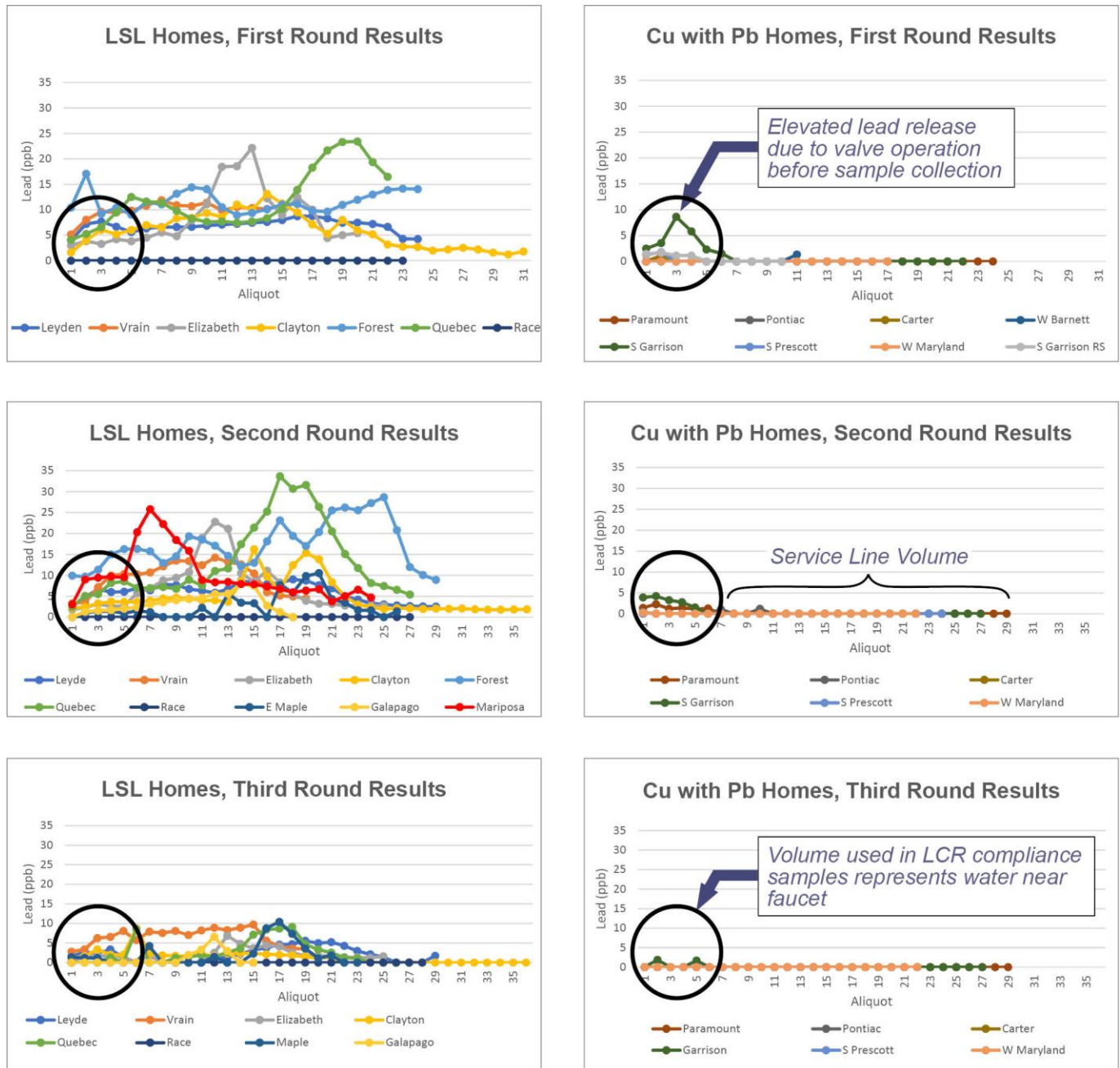
Results of this analysis show a higher concentration of lead in homes with lead service lines across the length of the profile (sink to water main). At households with verified copper piping with lead solder, lead release is typically characterized by a small increase in lead concentrations closest to 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.<sup>10</sup>

### 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](http://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

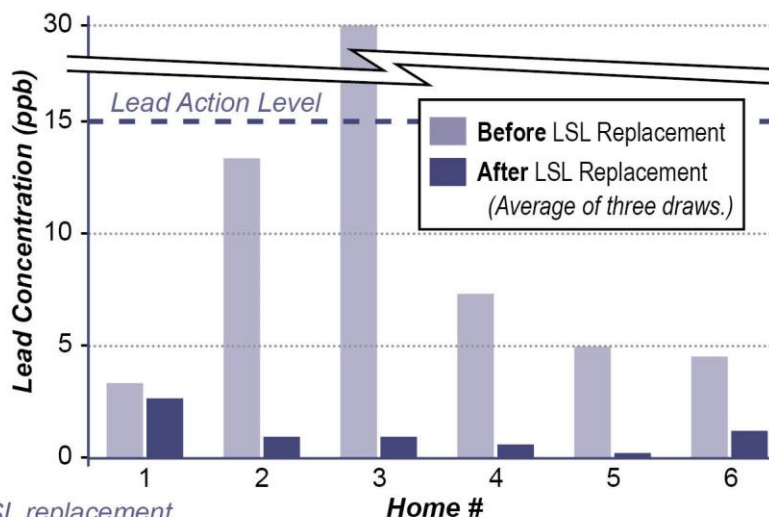
<sup>10</sup> Information on the profiling study can be found in Appendix III.E.1.



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
<b>Avg.</b>	<b>9.4</b>	<b>10.7</b>	<b>14.0</b>	<b>2.4</b>	<b>0.7</b>	<b>0.2</b>



*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.<sup>11</sup> 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.

<sup>11</sup> 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.<sup>12</sup> 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.

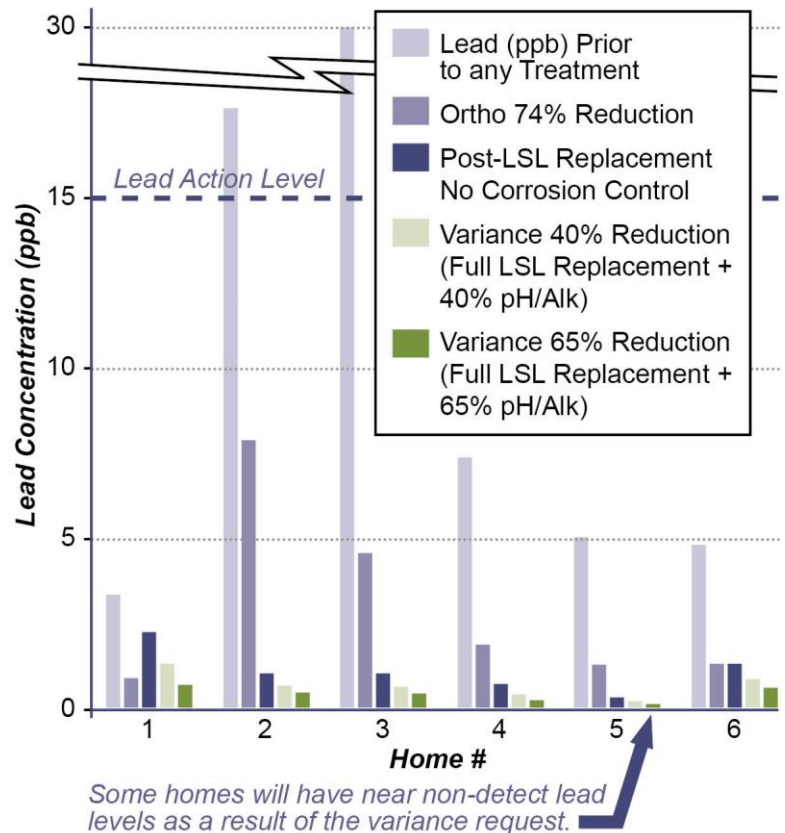
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<sup>12</sup> The Filter Pilot and survey are described in Appendix III.C.2

**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
<b>Avg.</b>	<b>11.4</b>	<b>5.0</b>	<b>1.1</b>	<b>0.7</b>	<b>0.4</b>

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 <u>no filter/no LSLR</u>	Variance 65% Reduction <u>no filter/no LSLR</u>
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
<b>Average</b>	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.<sup>13</sup> The model does not do any averaging, but in order to display the model results in a digestible way, Figure 19 shows the 95<sup>th</sup> percentile lead concentration for all service lines in the Denver Water service area, including lead, copper and non-lead materials.<sup>14</sup> 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.<sup>15</sup>

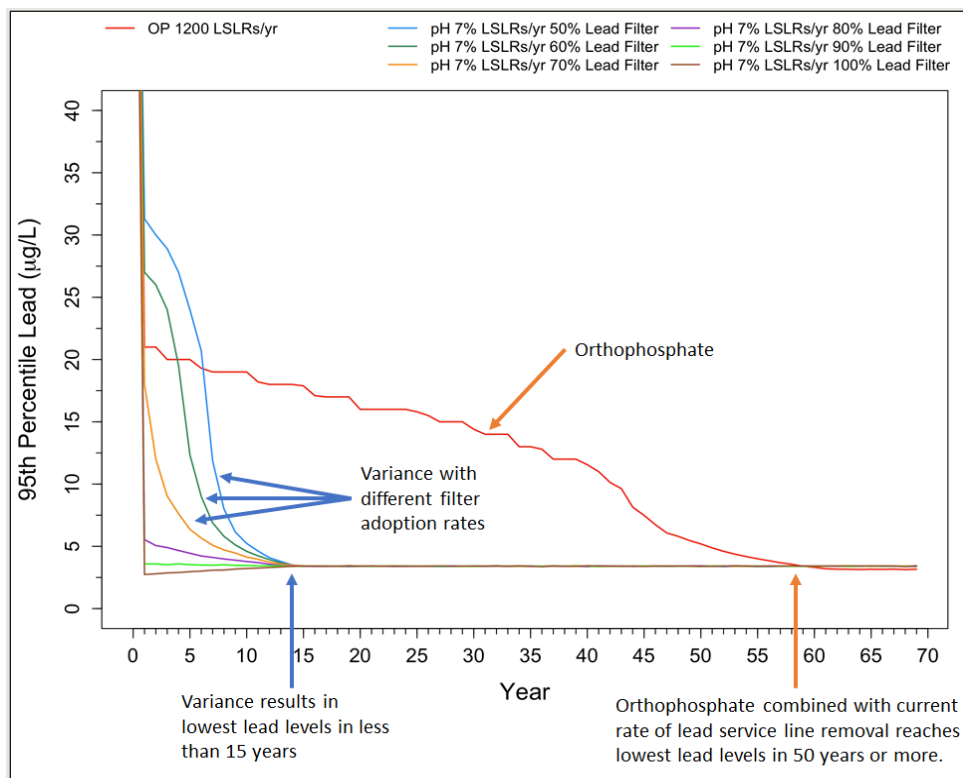
<sup>13</sup> For a description of the equivalency model see Appendix II.A.

<sup>14</sup> Full results are available in Appendix II.A.

<sup>15</sup> 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 90<sup>th</sup> 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 90<sup>th</sup> percentile lead concentrations to 7 ppb.

**TABLE 7: ESTIMATED 90<sup>TH</sup> PERCENTILE LCR LEAD CONCENTRATIONS AS A FUNCTION OF SERVICE LINE TYPE**

Scenario	Estimated 90 <sup>th</sup> 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

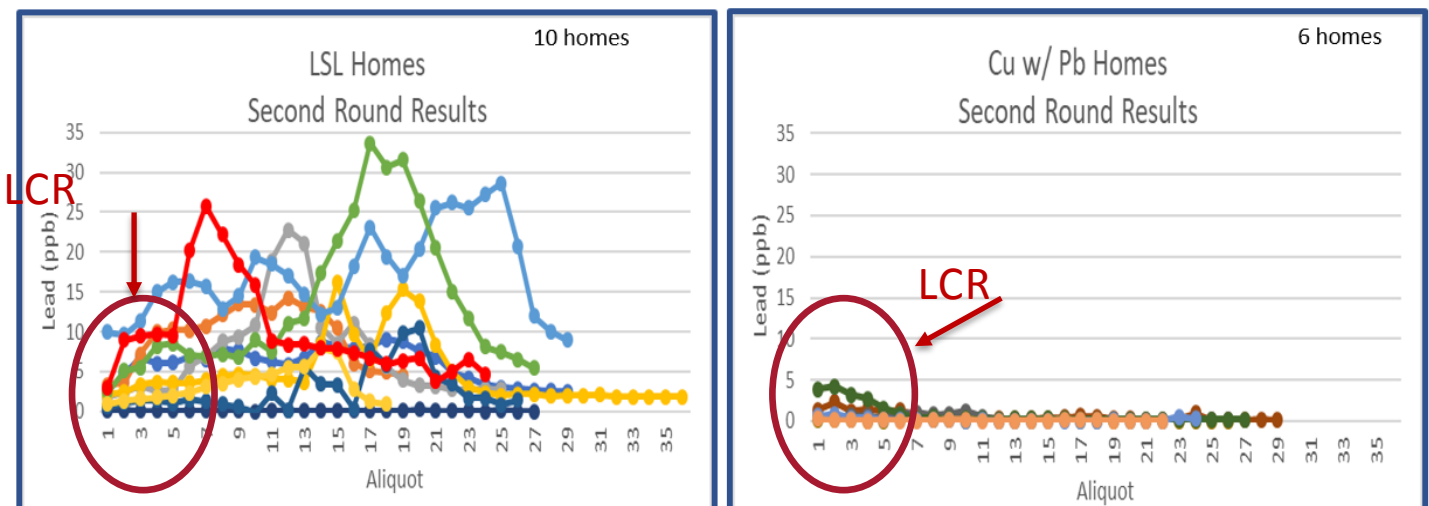
\*Based on percent lead reduction observed from pipe rack testing of 50% for pH/alkalinity adjustment and 74% for orthophosphate (per March 2018 designation for optimal corrosion control treatment by CDPHE).

\*\*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, 90<sup>th</sup> 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		
	90 <sup>th</sup> Percentile Lead (ppb)		
	1 <sup>st</sup> Draw	2 <sup>nd</sup> Draw	3 <sup>rd</sup> 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:<sup>16</sup>

- 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.

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<sup>16</sup> 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.

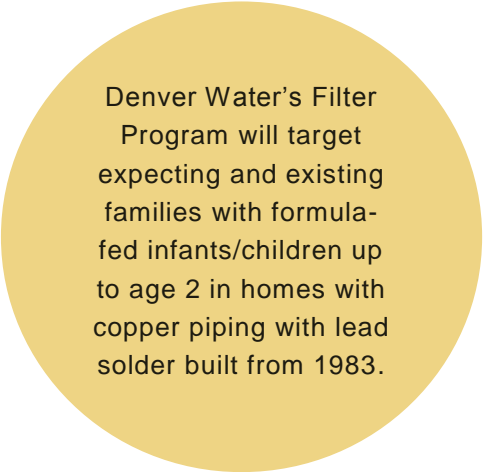
#### Filter Program objectives and strategies:

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.<sup>17</sup>

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.

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<sup>17</sup> 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.

- 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	<b>84,546 service lines assumed to be included as candidate properties for the Filter Program and further investigation.</b>
Suspected LSL	61,374	
Possible LSL	22,106	
Unlikely LSL	89,388	
Non-Lead	145,766	
<b>Total</b>	<b>319,700</b>	

\*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
<b>Census</b>	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
<b>Estimate</b>	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
	<b>Totals</b>	<b>63,955</b>	<b>255,745</b>	<b>319,700</b>

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.<sup>18</sup> 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<sup>19</sup> 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:

<sup>18</sup> As discussed in later in Section III.B.

<sup>19</sup> Please see Appendix III.B.3 for details.

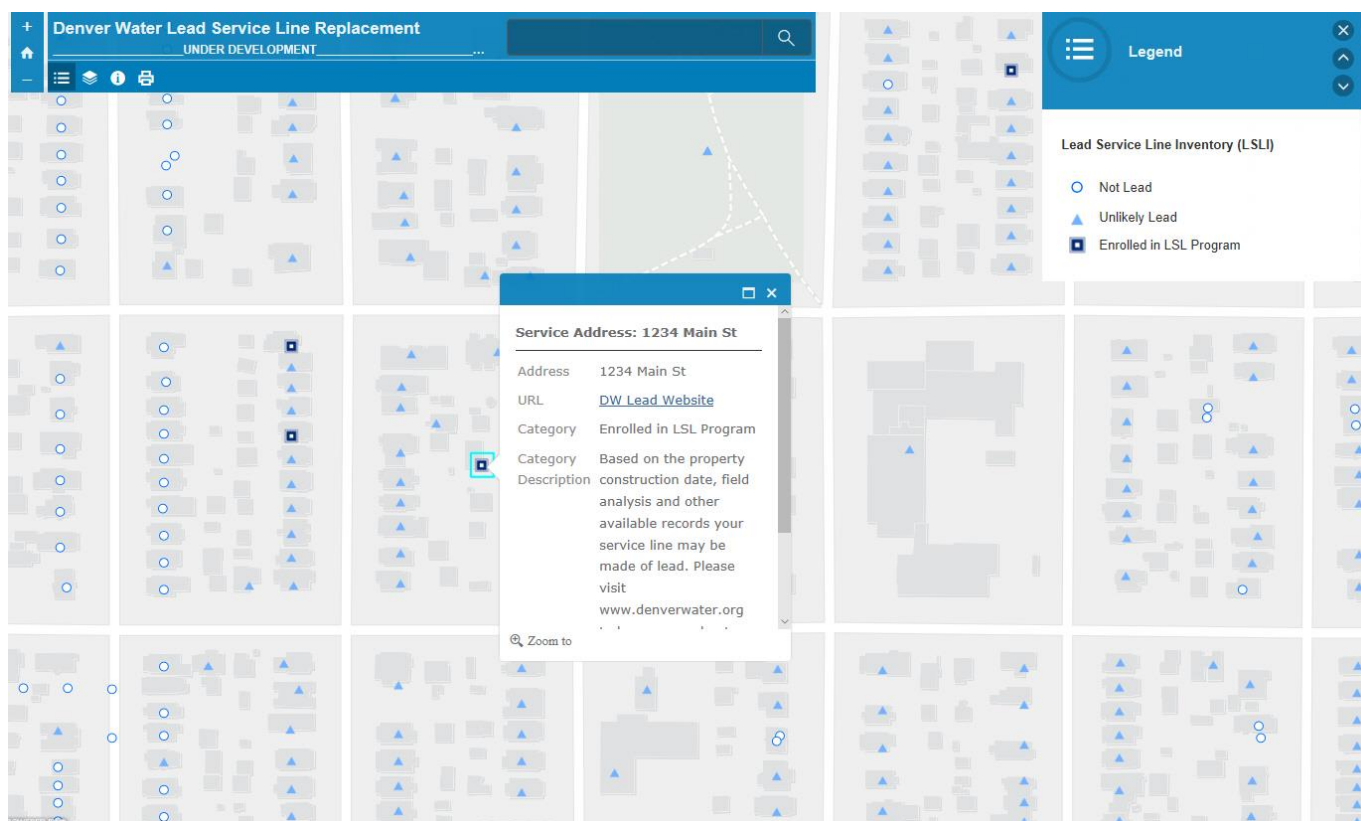


- Water quality sampling using the 3-bottle test to establish the service line profile. Denver Water’s research shows that water quality assessed from the second and third bottles is indicative of the service line material, especially lead.
- Historical data review to improve the knowledge of a given 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.<sup>20</sup>

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.

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<sup>20</sup> 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.<sup>21</sup> As part of the Filter Program, households with known, suspected or possible LSLs, whether owner-occupied or tenanted, will receive a filter and replacement

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<sup>21</sup> 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'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 canvassing (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.<sup>22</sup>

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.

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<sup>22</sup> 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.<sup>23</sup>

#### 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.

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<sup>23</sup> 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.<sup>24</sup>
- 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.

<sup>24</sup> 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
<b>GROUP A – LSLR by GEOGRAPHIC AREA</b>	Water main Replacement	400	3,850*
	Block by Block or Street by Street	3,000*	
	Municipal Pavement and Road Improvement Programs	450	
<b>GROUP A – LSLR by INDIVIDUAL</b>	Leaks	300	1,400*
	Individual & High Priority LSLR	600*	
	Scrape Off and Redevelopment Properties	500	
<b>GROUP B - INVESTIGATION</b>	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.<sup>25</sup>

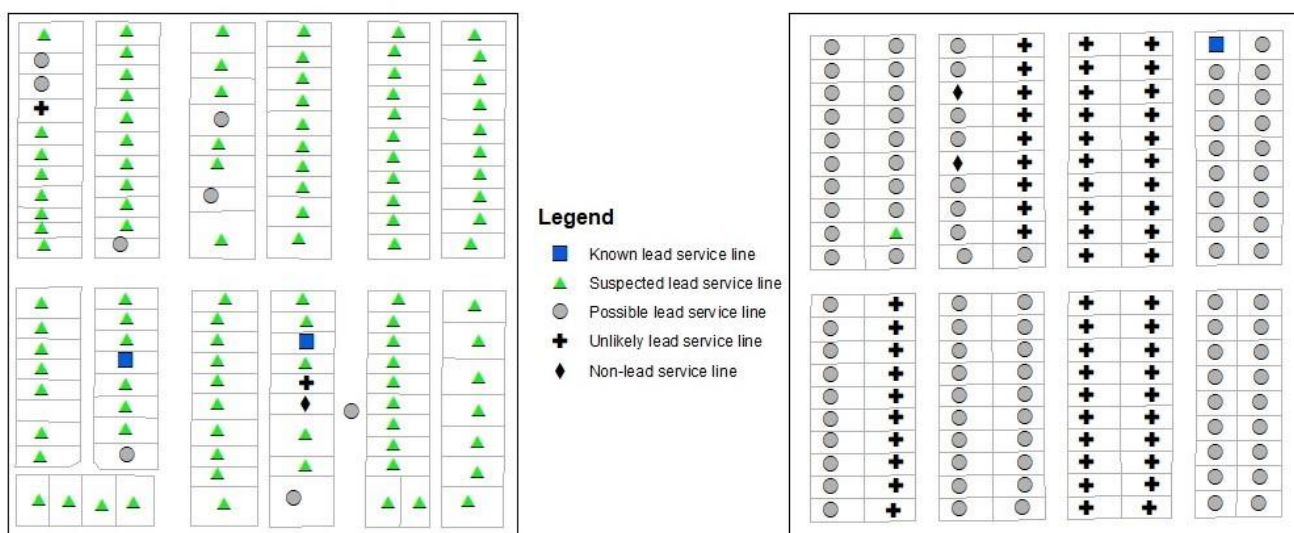
Properties types targeted for Individual lead service line replacement include:

- 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)**



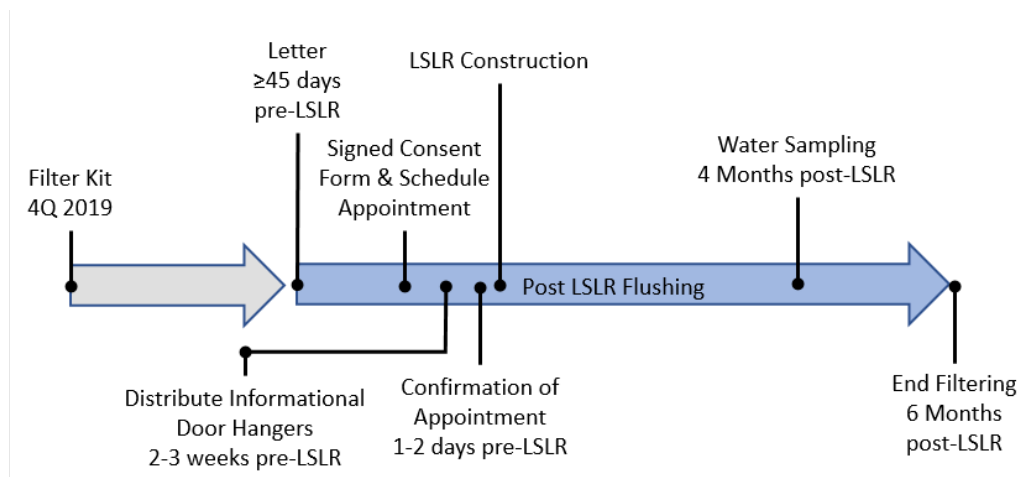
### What can customers expect during a lead service line replacement?

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

<sup>25</sup> How these properties are prioritized and grouped is described in Appendix III.B.3

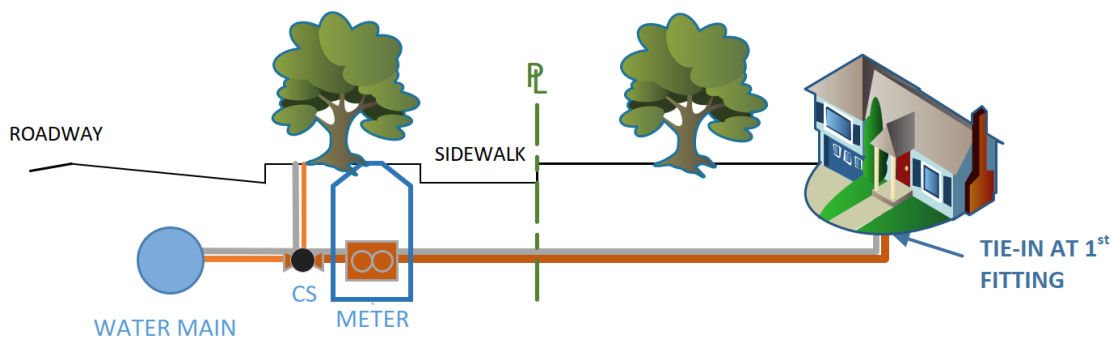
construction for their property as well as sign a consent form allowing the replacement of their lead service lines, (3) reminded via signage placed at the limits (ends of streets) within geographic work areas four to five weeks in advance of construction and (4) provided a door hanger two to three weeks 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)
<b>No adjustment:</b> property owner declines replacement after multiple attempts by Denver Water to encourage replacement.	<b>Adjust down:</b> known or suspected lead service line confirmed to be non-lead during investigation phase.
<b>Adjust up:</b> entire lead service line replaced or existing partial lead service line replaced such that entire line is non-lead after replacement.	<b>Adjust up:</b> lead service line confirmed after customer sampling reveals high lead concentrations in all three bottles.
<b>Counts as more than one:</b> 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.<sup>26</sup>

### 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.

<sup>26</sup> See Appendix III.D.1 for example calculations for the cumulative program year replacement rate.

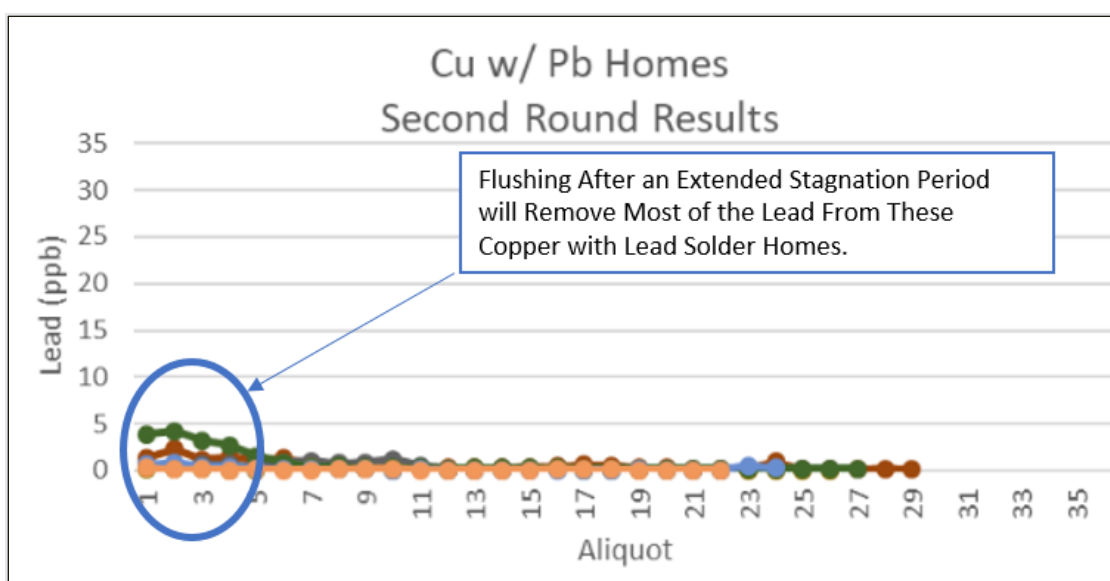


## How will pH/alkalinity adjustment protect customers with copper piping with lead solder?

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.<sup>27</sup> 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 24<sup>th</sup> month of age.

<sup>27</sup> 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%.<sup>28</sup> Applying this 50% reduction to the average of all 90<sup>th</sup> 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)	90 <sup>th</sup> Percentile Lead Concentration (ppb)
<b>Pre-Variance: 1997 to 2019 (average)</b>	6.7	14.0*
<b>Projected Post-Variance: 2021 &amp; Beyond</b>	3.4	7.0

\*Based average of all 90<sup>th</sup> percentile lead concentration reported for each monitoring period from 1997 to 2019.

### How will Denver Water verify corrosion control is working?

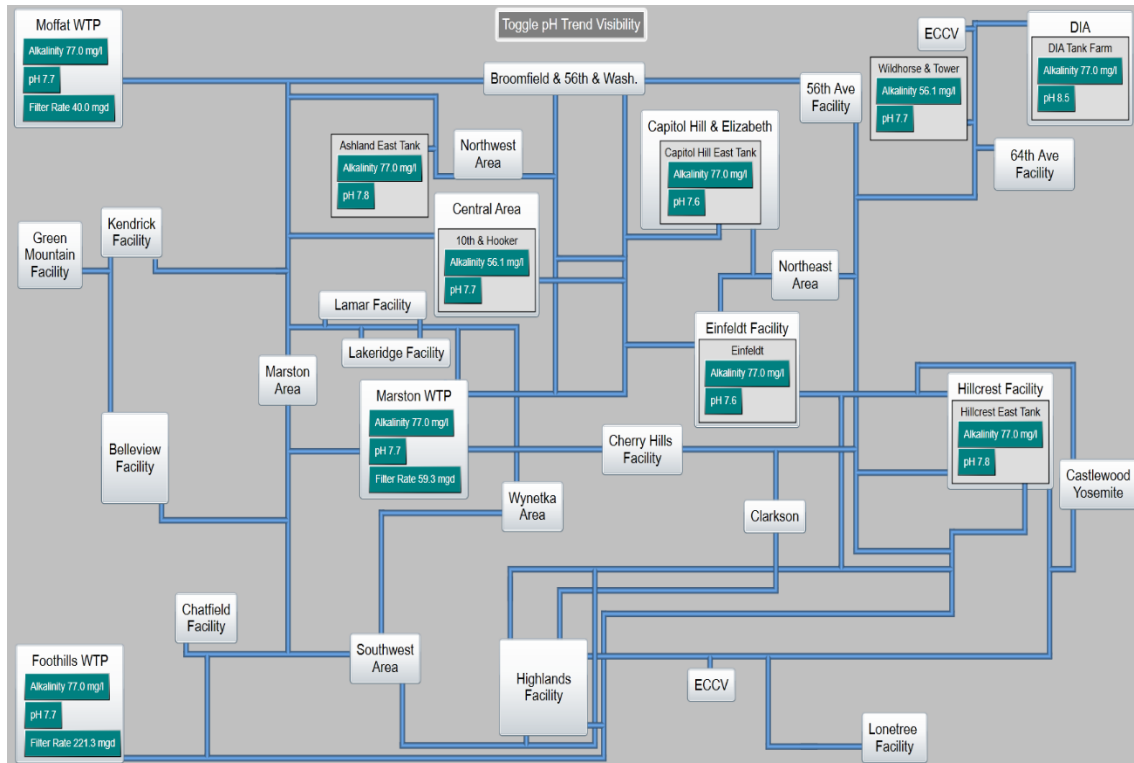
Under the LRP, Denver Water will continue to sample at Tier 1 homes with a) lead service lines and b) copper pipes with lead solder constructed between 1983 and 1987. Samples will be collected from an unfiltered tap (by-passing the filter if used to remove lead). Samples will be collected twice a year 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  $\pm 0.2$  standard units in water leaving the treatment plants and  $\pm 0.3$  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.

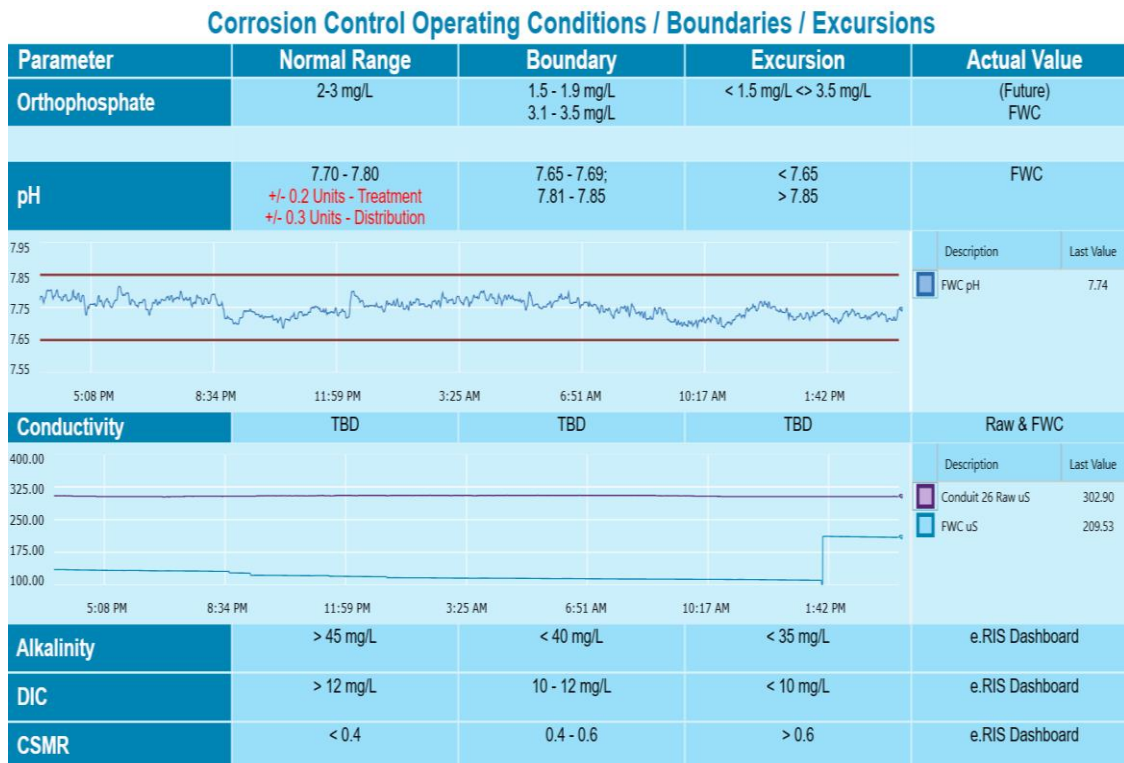
Denver Water will use its real-time monitoring system to track and trend pH, alkalinity and conductivity (where on-line instrumentation is available) at the treatment plants and in the distribution system. Figures 27 and 28 display the existing monitoring screens, one for the overall distribution system and the other for one of the treatment plants, respectively.

<sup>28</sup> 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**

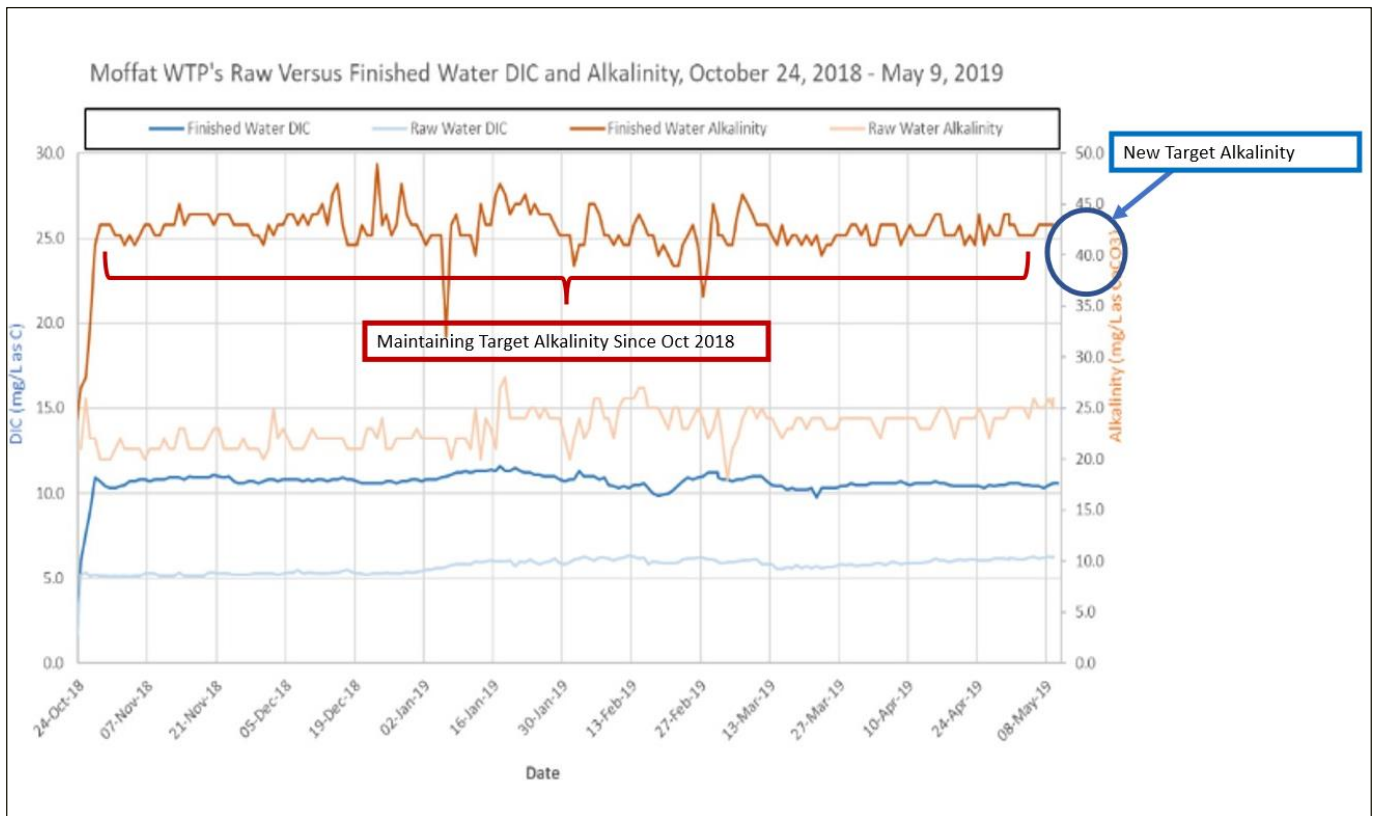


## Will Denver Water have to make modifications to the treatment plants to support pH/alkalinity adjustment for corrosion control?

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<sub>3</sub> 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<sub>3</sub> most of the year. The alkalinity in the South Platte River can drop to levels between 20 and 35 mg/L as CaCO<sub>3</sub> 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	
<b>Treatment Plants at Point of Entry*</b>	<ul style="list-style-type: none"> <li>• pH = monthly average 8.8 standard units, with an operating range of 8.6 to 9.0</li> <li>• Alkalinity = minimum monthly average of 30 mg/L as CaCO<sub>3</sub></li> </ul>
<b>Distribution System*</b>	<ul style="list-style-type: none"> <li>• pH = monthly average 8.8 standard units, with an operating range of 8.5 to 9.1</li> </ul>

\*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.<sup>29</sup>

<sup>29</sup> 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<sup>30</sup>, 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.

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<sup>30</sup> 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.<sup>31</sup> If the variance is granted, nitrification should not be a concern at the proposed pH target of 8.8 standard units.<sup>32</sup> 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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<sup>31</sup> AWWA M56 Nitrification Prevention and Control in Drinking Water (2<sup>nd</sup> Edition), 2013.

<sup>32</sup> 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.<sup>33</sup> 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
<b>Lead Service Line Inventory</b>	Must investigate a minimum of 1.4% of total LSLs in inventory per year.	<ul style="list-style-type: none"> <li>Achieve compliance by following year.</li> <li>Provide notice of corrective action to customers with filters.</li> </ul>	If less than 1.4% investigations occur for three program years: <ul style="list-style-type: none"> <li>Notice to all customers.</li> </ul>
<b>Filter COE</b>	Outreach and education materials provided each year to at least 95% of households enrolled in the Filter Program.	<ul style="list-style-type: none"> <li>Must achieve compliance by following year.</li> <li>Notice to customers with filters.</li> </ul>	If Denver Water fails to provide outreach and education materials to at least 95% of households enrolled in the Filter Program for three years: <ul style="list-style-type: none"> <li>Notice to all customers.</li> </ul>
<b>Filter Program</b>	Achieve minimum filter adoption rate of 65% per year.	<ul style="list-style-type: none"> <li>If filter adoption rate is less than 65% in a year, increase outreach and education efforts to improve filter use.</li> <li>Notice of corrective action to customers with filters.</li> </ul>	If failure to achieve 65% adoption rate for three years: <ul style="list-style-type: none"> <li>Termination of variance.</li> <li>Notice to all customers.</li> </ul>
<b>Accelerated Lead Service Line Replacement</b>	Must achieve 7.0% cumulative annual average replacement rate each year.	<ul style="list-style-type: none"> <li>Achieve compliance by following year.</li> <li>Notice to customers with filters.</li> </ul>	If less than 7.0% of lead service lines are replaced for three years: <ul style="list-style-type: none"> <li>Termination of variance.</li> <li>Notice to all customers.</li> </ul>
<b>Corrosion Control Treatment</b>	Lead and Copper Rule sampling results remain below action level for lead.	<ul style="list-style-type: none"> <li>Must adjust corrosion control and distribution management.</li> <li>Customer education and notice.</li> </ul>	If action level exceeded for two monitoring periods: <ul style="list-style-type: none"> <li>Must provide customer notice.</li> <li>Termination of variance unless CDPHE requires otherwise.</li> </ul>

<sup>33</sup> 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.<sup>34</sup>

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.

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<sup>34</sup> 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.

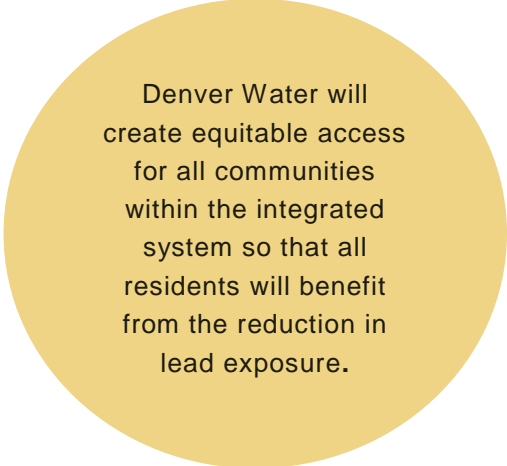
Denver Water will continue to consult and collaborate with the organizations listed above and other HE&EJ experts, stakeholders, community members and customers to continually improve upon integration of the HE&EJ principles with the LRP.

## 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.<sup>35</sup> 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.

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<sup>35</sup> 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<sup>36</sup>**

- **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.

<sup>36</sup> 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](https://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**

<b>Phase I – Submission</b>	
<b>September 2019</b>	Denver Water submits Final Variance Request, Lead Reduction Program Plan and Treatment Modification Request to EPA and CDPHE and awaits decision.
<b>Phase II — Implementation</b>	
<b>Late 2019/Early 2020</b>	<p><b>Upon approval of the variance:</b></p> <ul style="list-style-type: none"> <li>• Begin region wide Communications, Outreach and Education including:               <ul style="list-style-type: none"> <li>- Tier II Notification to all customers with known, suspected and possible lead service lines.</li> <li>- Publications of service line inventory map.</li> <li>- Community meetings.</li> </ul> </li> <li>• Begin distribution of filters.</li> <li>• Notify customers that are identified for LSL replacement in first the year of the LRP and ALSLR Program.</li> <li>• Begin corrosion control treatment per CDPHE's approved schedule.</li> </ul> <p><b>First Program Year Begins</b></p> <ul style="list-style-type: none"> <li>• 91 days after approval of the variance, Lead Reduction Program begins accelerated lead service line replacement and the 15-year program begins.</li> </ul>
<b>Phase III — Maintenance</b>	
<b>Annually</b>	<b>Annual compliance meetings with EPA and CDPHE:</b> 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.
<b>15 Years After First Program Year</b>	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.<sup>37</sup> 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.

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<sup>37</sup> 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.<sup>38</sup> 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.

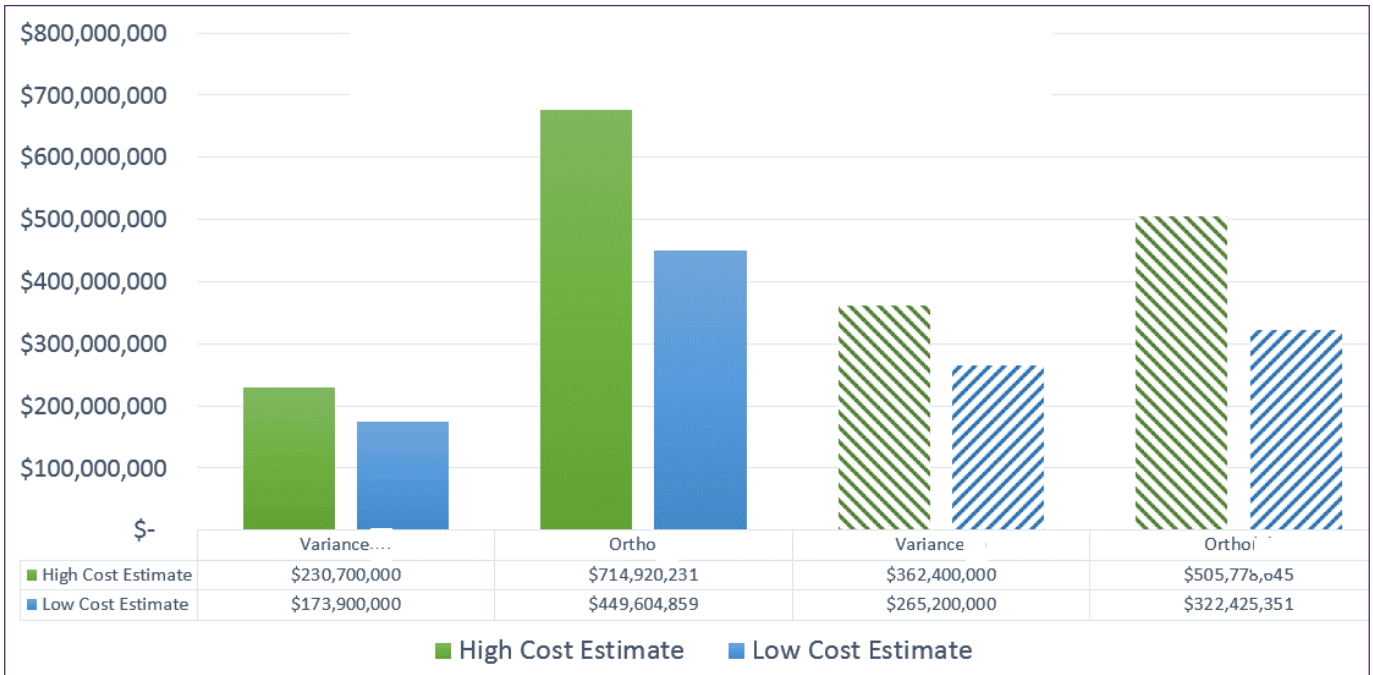
Denver Water replaces lead service lines at a rate of 700 per year based on existing operations, with an additional 500 per year replaced through redevelopment. To replace all lead services within 50, Denver Water would have to increase the rate of replacement from 700 per year to 780 per year. These 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.

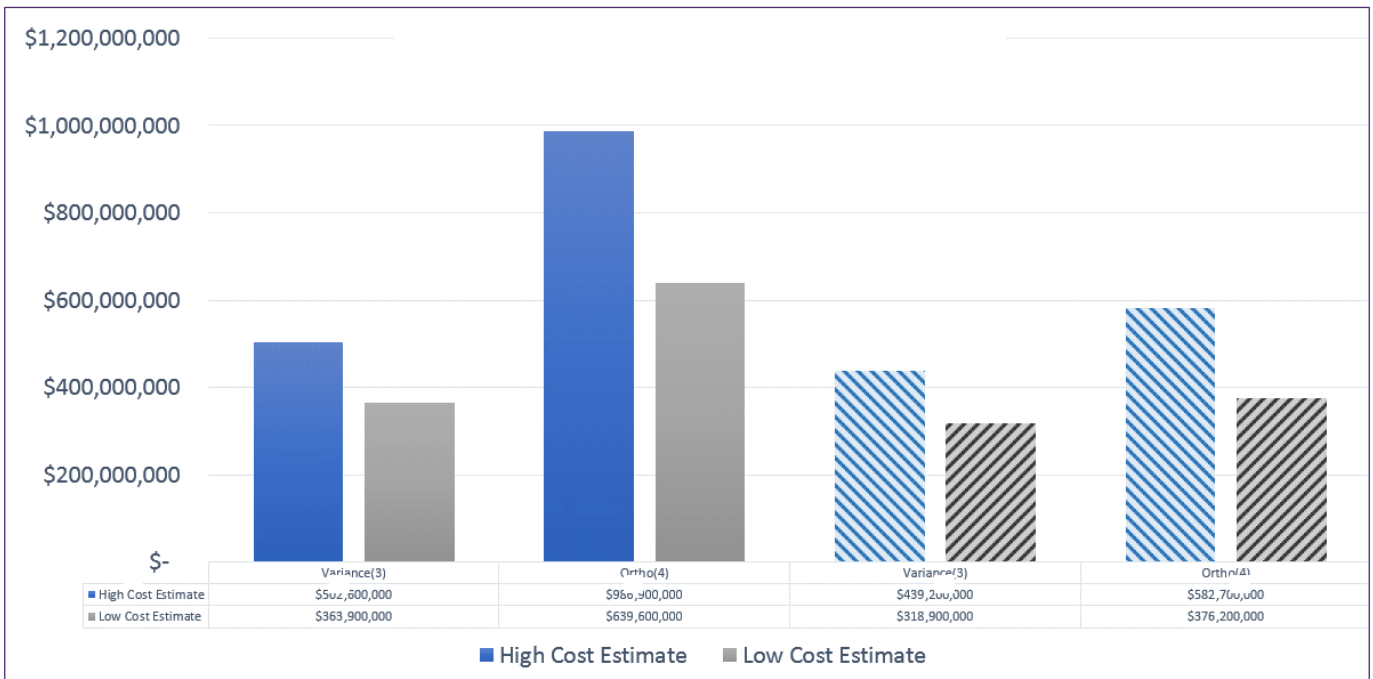
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<sup>38</sup> See Appendix VII.A for detailed cost information.

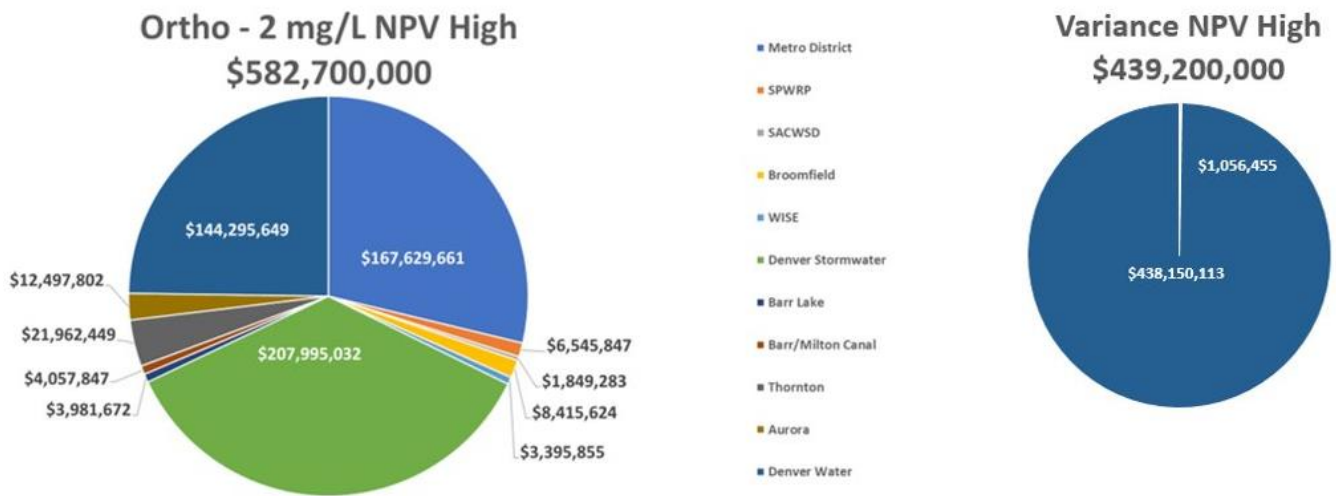
**FIGURE 30: COST COMPARISON BETWEEN VARIANCE AND ORTHOPHOSPHATE ALTERNATIVES, EXCLUDING CURRENT LEAD SERVICE LINE REPLACEMENT COSTS**



**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,<sup>39</sup> 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.

<sup>39</sup> Human Impact Partner’s “Achieving Equity in Lead Poisoning Prevention Policy Making: Proceedings from a Consensus Conference,” May 2019. See [HumanImpact.org/LeadPolicyEquity](http://HumanImpact.org/LeadPolicyEquity)

## VIII. GLOSSARY OF DEFINITIONS

Abbreviations, Acronyms or Terms	Abbreviations, Acronyms or Terms Descriptions
<b>90<sup>th</sup> Percentile</b>	The 90 <sup>th</sup> 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 90 <sup>th</sup> percentile.
<b>Action Level</b>	As used in the Lead and Cooper Rule, if the lead concentration exceeds the action level, additional actions are required to control corrosion. Also referred to as the AL.
<b>Adoption</b>	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.
<b>ALSLR Program</b>	Refers to the Accelerated Lead Service Line Replacement Program.
<b>Blood Lead Level (BLL)</b>	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).
<b>COE Plans</b>	Refers to the Communications, Outreach and Education Plans associated with the Lead Reduction Program.
<b>Contact</b>	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.
<b>Corrosion Control Treatment (CCT)</b>	Refers to corrosion control treatment, such as by orthophosphate addition or pH/alkalinity adjustment.
<b>Coupon Testing</b>	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.
<b>Filter Program</b>	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.
<b>Households</b>	Refers to any single family or multi-family unit in Denver Water's service area enrolled in the Filter Program.
<b>Integrated System</b>	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
<b>Known LSL</b>	100% direct evidence documenting that the material of the service line is lead.
<b>LCR</b>	Lead and Copper Rule.
<b>LSL</b>	Lead Service Line.
<b>Lead Service Line</b>	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.
<b>LSL Inventory</b>	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.
<b>LSL Replacement</b>	Lead Service Line Replacement.
<b>LRP</b>	Lead Reduction Program.
<b>Non-detect</b>	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.
<b>Non-Lead LSL</b>	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.
<b>OCCT</b>	Optimal Corrosion Control Treatment.
<b>Orthophosphate Treatment</b>	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.
<b>Possible LSL</b>	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.
<b>Program Year</b>	Has the same meaning as calendar year.
<b>Public Notice</b>	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.
<b>Suspected LSL</b>	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
<b>Threshold for Filter Adoption Rate</b>	Refers to the minimum percentage of households that use filters (i.e., filter adoption rate) such that the LRP is considered equivalent to orthophosphate.
<b>Tier 1 Site</b>	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.
<b>Tier II Public Notice</b>	Tier II public notice as described in section 11.33 of the Colorado Primary Drinking Water Regulations, 5 CCR 1002-11.
<b>Unlikely LSL</b>	Based on available data, there a very low likelihood (less than 10%) that the service line is made of lead.