

**Studies Identified by EPA Office of Water for the
SAB Drinking Water Committee Lead Review Panel Meeting
(as of March 23, 2011)**

TABLE OF CONTENTS

1. Full List of Studies Identified by EPA Office of Water.....	2
2. Studies Available on Public Webpages.....	4
3. Studies Included in this Compilation Document.....	5
Boyd et al., 2010.....	6
DeSantis et al., 2009.....	34
Gittelman et al., 1992.....	48
Muylyk et al., 2009.....	69
Swertfeger et al., 2006.....	81
USEPA, 1991b.....	91

1. Full List of Studies Identified by EPA Office of Water

Boyd, G. et al, 2004. Pb in Tap Water Following Simulated Partial Lead Pipe Replacements. *Journal of Environmental Engineering*. Vol. 130. Number 10. pp. 1188 – 1197.

Boyd, G., Reiber, S., and Korshin, G., 2010. Galvanic Couples: Effects of Changing Water Quality on Lead and Copper Release and Open-Circuit Potential Profiles. *Proceedings of the 2010 AWWA Water Quality Technology Conference*. Savannah, GA.

Brown, M.J., et al., 2011. Association between children's blood lead levels, lead service lines, and water disinfection, Washington, DC 1998-2006. *Environmental Research*, 111(1):67-74.

Britton, A. and Richards, W.N., 1981. Factors Influencing Plumbosolvency in Scotland. *Journal of the Institute for Water Engineers and Scientists*. Vol. 35, No. 5, pp. 349 - 364.

DeSantis, M. et al., 2009. Mineralogical Evidence of Galvanic Corrosion in Domestic Drinking Water Pipes. *Proceedings of the 2009 AWWA Water Quality Technology Conference*. Seattle, WA.

Deshommes, E. et al., 2010. Source and Occurrence of Particulate Lead in Tap Water. *Water Research*. pp. 3734 – 3744.

Gittelman, T.S. et al., 1992. Evaluation of Lead Corrosion Control Measures for a Multi-source Water Utility. *Proceedings of the 1992 AWWA Water Quality Technology Conference*. Toronto, Ontario, Canada. pp. 777 - 797.

HDR Engineering, 2009. An Analysis of the Correlation between Lead Released from Galvanized Iron Piping and the Contents of Lead in Drinking Water. Prepared for the District of Columbia Water and Sewer Authority. September 2009.

Kirmeyer, G. et al, 2006. Lead Pipe Rehabilitation and Replacement Techniques. Prepared for the American Water Works Research Foundation, Report 90789.

Muylywyk, Q. et al., 2009. Lead Occurrence and the Impact of LSL Replacement in a Well Buffered Groundwater. *Proceedings of the 2009 AWWA Water Quality Technology Conference*. Seattle, WA.

Reiber, S., and Dufresne, L., 2006. Effects of External Currents and Dissimilar Metal Contact on Corrosion of Lead from Lead Service Lines. Prepared for USEPA Region III.

Sandvig, A et al., 2008. Contribution of Service Line and Plumbing Fixtures to Lead and Copper Compliance Issues. Prepared for the American Water Works Research Foundation, Report 91229.

Swertfeger, J. et al., 2006. Water Quality Effects of Partial Lead Service Line Replacement. *Proceedings of the 2006 AWWA Annual Conference*. San Antonio, TX.

Triantafyllidou, S. and Edwards, M., 2010. Contribution of Galvanic Corrosion to Lead in Water After Partial Lead Service Line Replacements. Prepared for the Water Research Foundation, Report 4088b.

USEPA., 1991a. "Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper; Final Rule." Federal Register. Vol. 56, No. 110, p. 26505. June 7, 1991.

USEPA., 1991b. "Summary: Peach Orchard Monitoring, Lead Service Line Replacement Study." Prepared by Barbara Wysock. Office of Drinking Water Technical Support Division. April 1991.

Weston and EES, 1990. Lead Service Line Replacement: A Benefit-to-Cost Analysis. American Water Works Association, Denver, CO. p. 4-46.

Wujek, J.J. 2004. Minimizing Peak Lead Concentrations after Partial Lead Service Line Replacements. Proceedings AWWA Water Quality Technology Conference. San Antonio, TX.

2. Studies Available on Public Webpages

HDR Engineering, 2009 (PDF, 1.9 MB, 56 pages)

<http://www.dcwater.com/waterquality/plumbing/Galvanized%20Project%20Report.pdf>

Kirmeyer et al, 2006 (PDF, 4.6 MB, 266 pages)

http://waterrf.org/ProjectsReports/PublicReportLibrary/RFR90789_2000_465.pdf

Reiber et al., 2006 (PDF, 877 KB, 26 pages)

http://www.epa.gov/dclead/Grounding_Effects_Study_Final_November_2006.pdf

Sandvig et al., 2008 (PDF, 5.7 MB, 523 pages)

<http://waterrf.org/ProjectsReports/PublicReportLibrary/91229.pdf>

Triantafyllidou et al., 2010 (PDF, 2.9 MB, 46 pages)

<http://www.waterrf.org/ProjectsReports/PublicReportLibrary/4088b.pdf>

USEPA, 1991a

<http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=826917d693a1a7b09af78ac84aed1b6d&rgn=div6&view=text&node=40:22.0.1.1.3.9&idno=40>

3. Studies Included in this Compilation Document

(Some studies may not be in this compilation document, pending copyright release.)

Galvanic Couples: Effects of Changing Water Quality on Lead and Copper Release and Open-Circuit Potential Profiles

November 17, 2010

*AWWA Water Quality Technology Conference
Savannah, GA*



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Acknowledgements

- WaterRF #3107 – Traci Case, Project Manager
 - PAC – P Greiner, M Smith, & W Maier
 - Participating Utilities - DC Water (Rich Giani), Seattle Public Utilities, WA, Washington Aqueduct, DC, Marin Metro WD, CA, Newport News WW, VA
 - Project Team – M McFadden, A Vetrovs, K Dewis, A Sandvig, and S Hendrickson
 - Expert Panel - R Hunsinger, J DeMarco, and G Kirmeyer
-

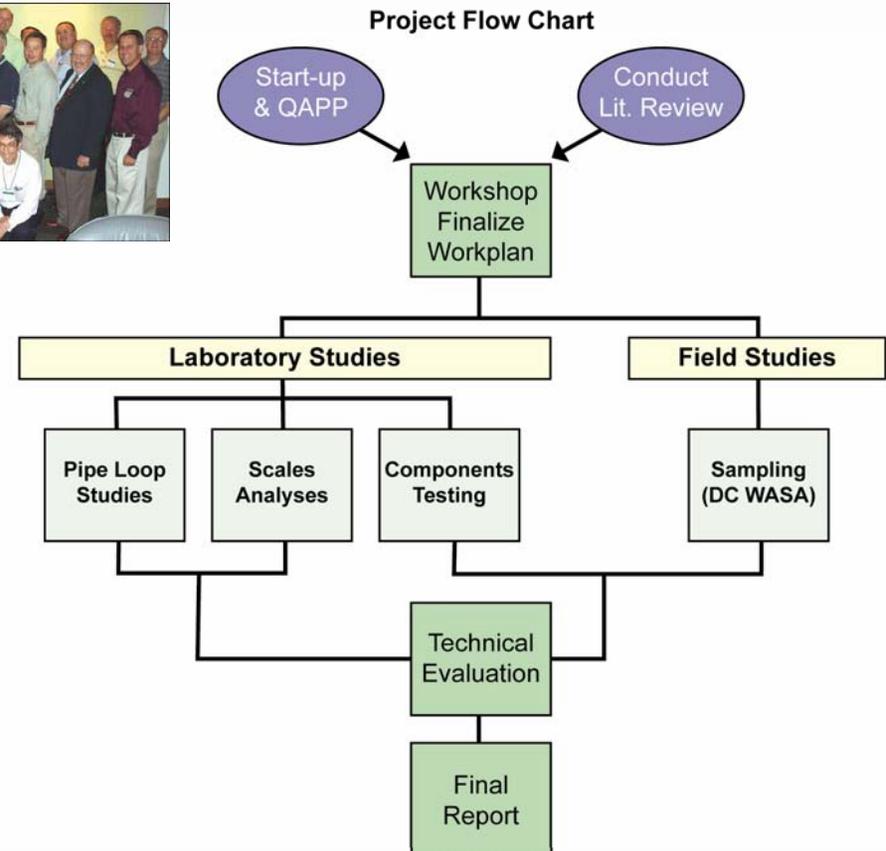
Outline

- Objectives & Approach
 - Methods
 - Galvanic pipe loops
 - Single-metal pipe loops
 - Controlled water quality conditions
 - Results
 - Grab sampling
 - Open-circuit potential profiles
 - Ongoing Studies – Preliminary Findings
 - Conclusions
-

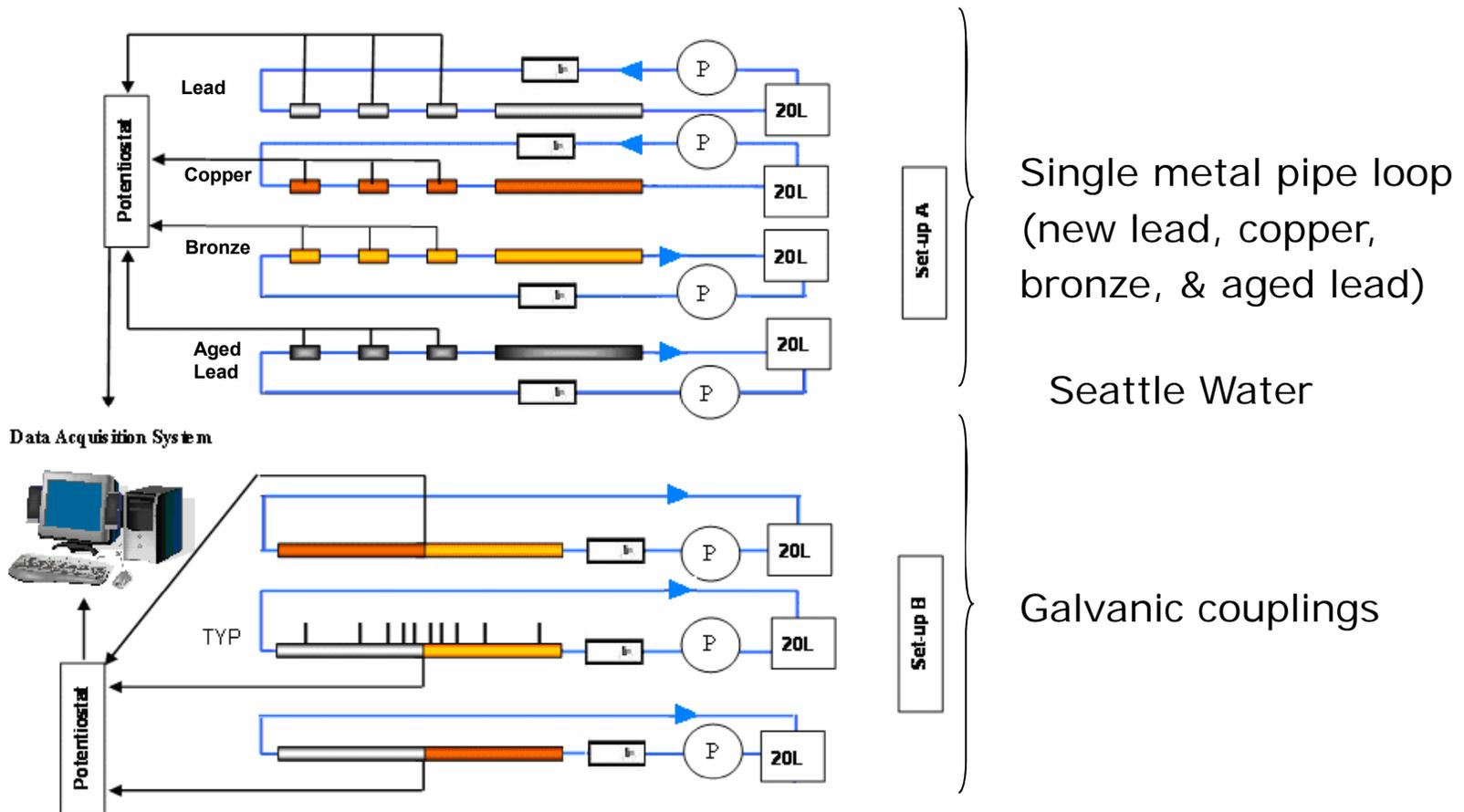
Project Objectives & Approach

Project Objectives

- Determine effects of changing disinfectants (Cl_2 vs. NH_2Cl) on lead and copper corrosion rates and release
- Study effects of
 - Galvanic coupling
 - Existing scales



Methods Pipe Loop Testing



Single metal pipe loop
(new lead, copper,
bronze, & aged lead)

Seattle Water

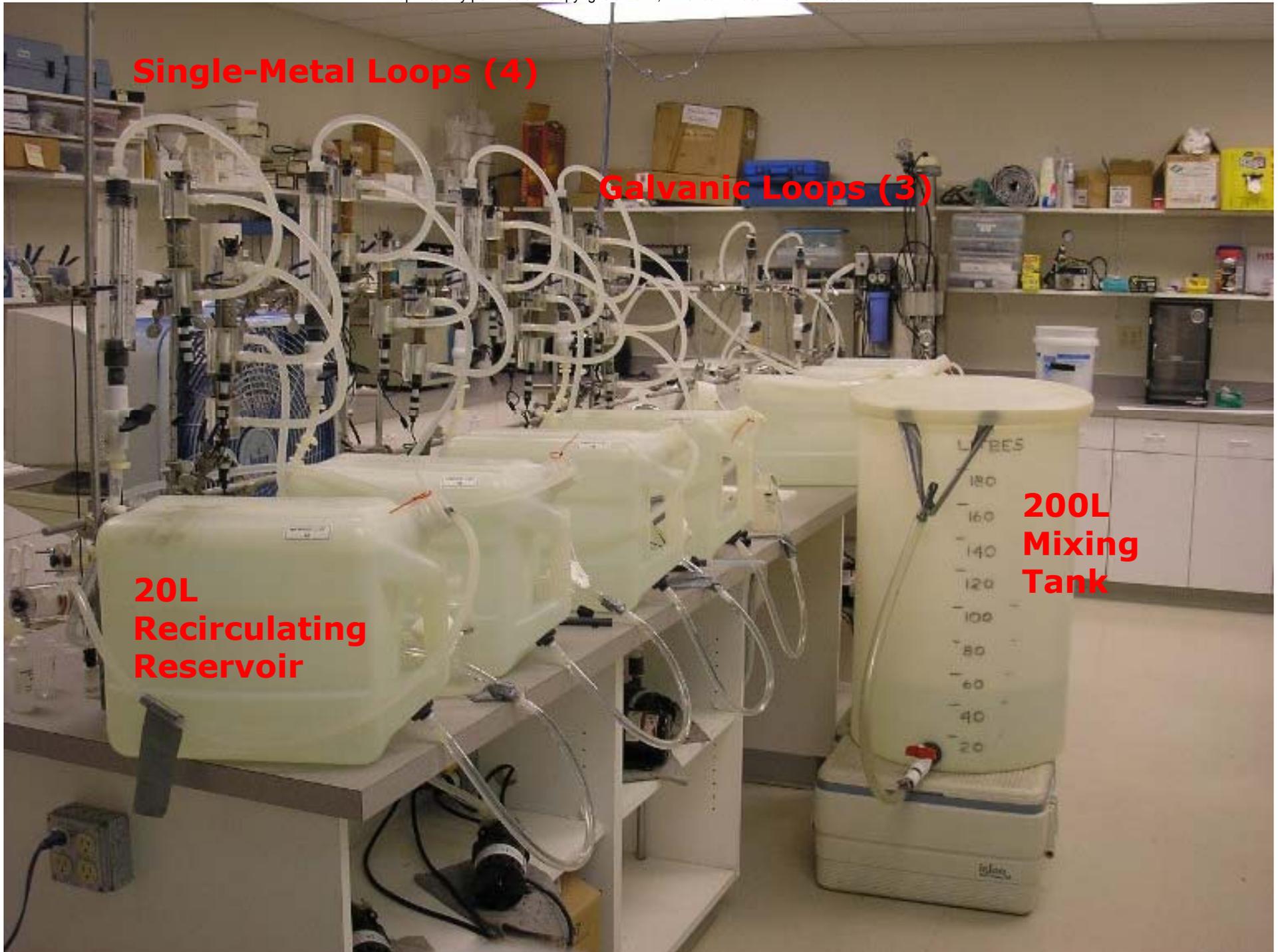
Galvanic couplings

Single-Metal Loops (4)

Galvanic Loops (3)

**20L
Recirculating
Reservoir**

**200L
Mixing
Tank**



Methods Galvanic Pipe Loop Testing

Galvanic coupled pipe loops
(Cu:brnz, Pb:brnz, or Pb:Cu)

Scales Analyses
(SEM, XAS)

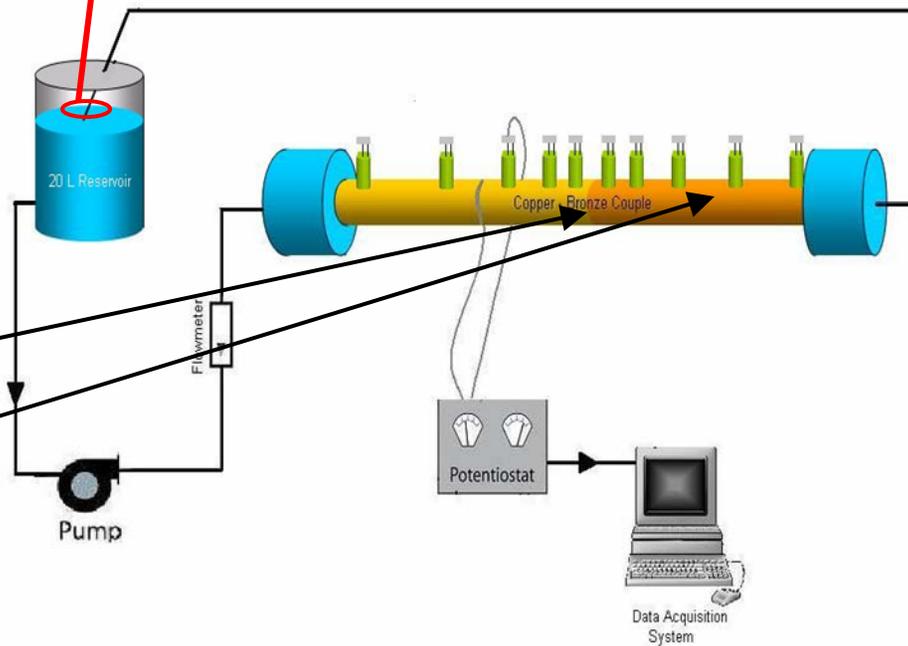
Grab Samples
(Pb, Cu, pH, ORP,
T, total Cl₂, PO₄)

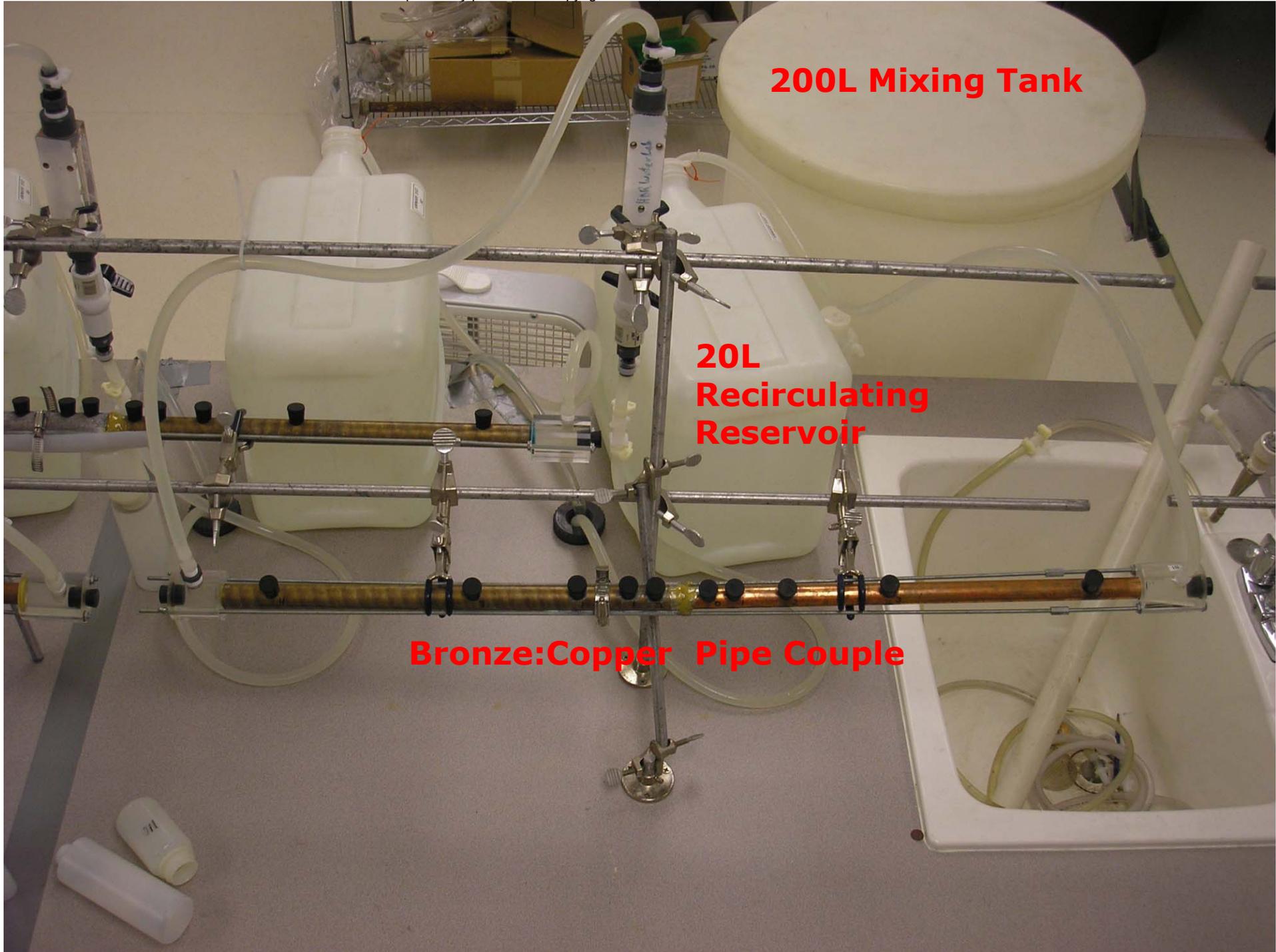
Metals Release
Sources

EC Testing
(E, d)



Coupon Holder
for Sampling &
Scales Analysis





200L Mixing Tank

**20L
Recirculating
Reservoir**

Bronze:Copper Pipe Couple

Methods

Single-Metal Pipe Loop Testing

New lead, copper, bronze,
or aged lead pipe

Scales Analyses
(SEM, XAS)

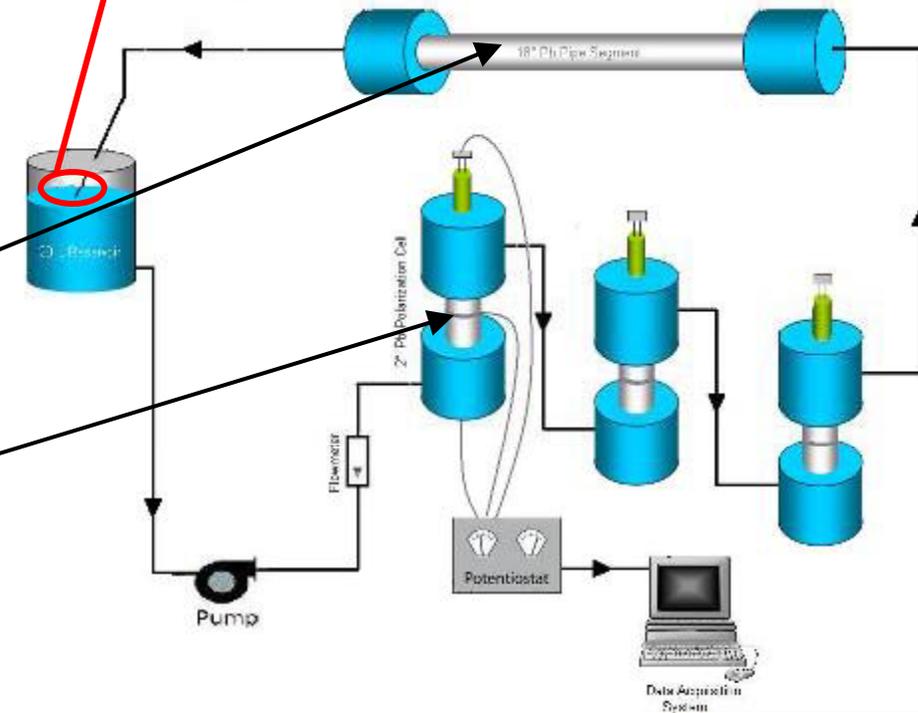
Grab Samples
(Pb, Cu, pH, ORP,
T, total Cl₂, PO₄)

Metal Release
Source

EC Testing
(E, E_{corr}, I_{corr}, CR)

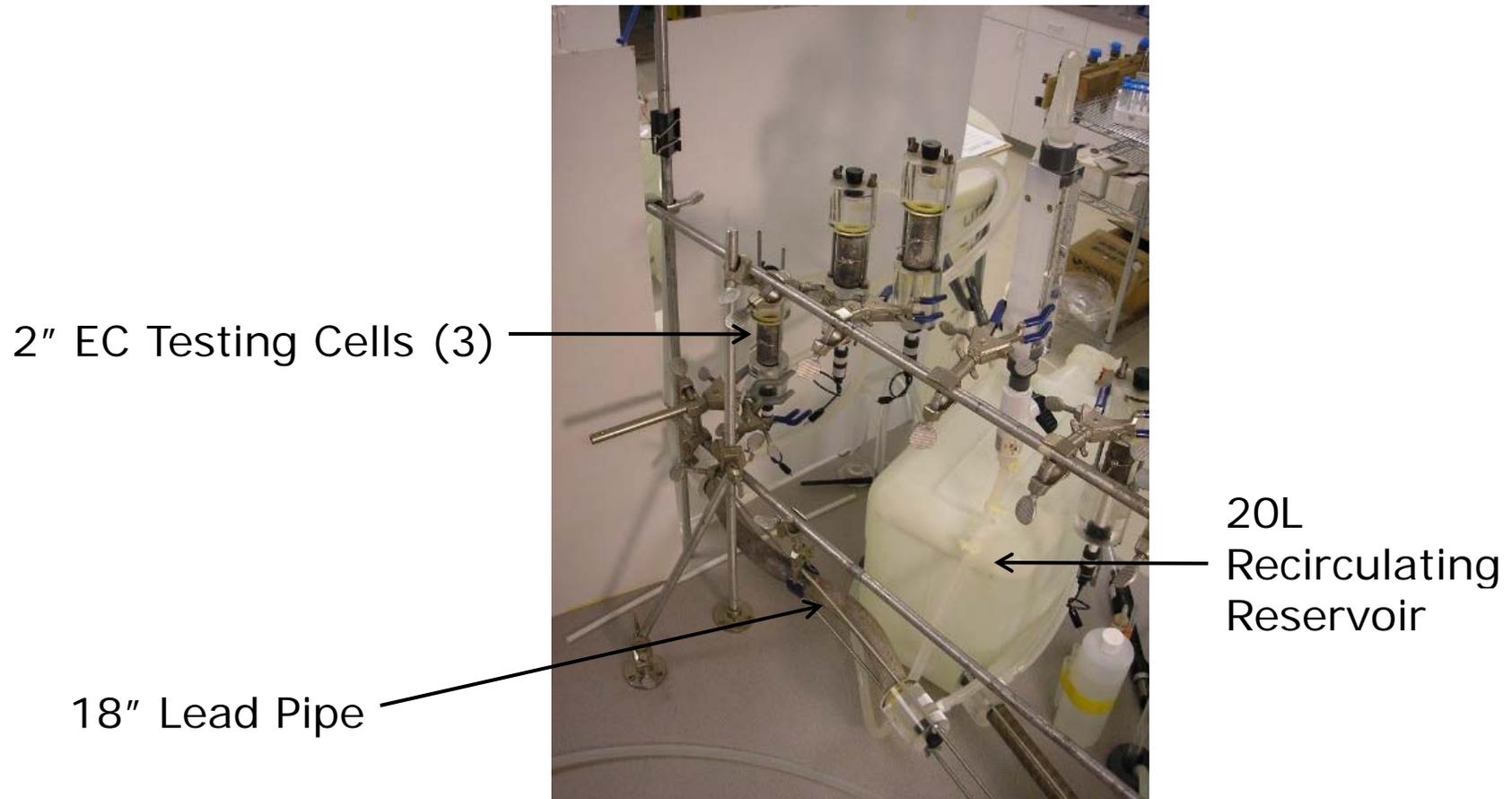


Coupon Holder for Sampling & Scales Analysis



Methods

Single-Metal Pipe Loop Testing



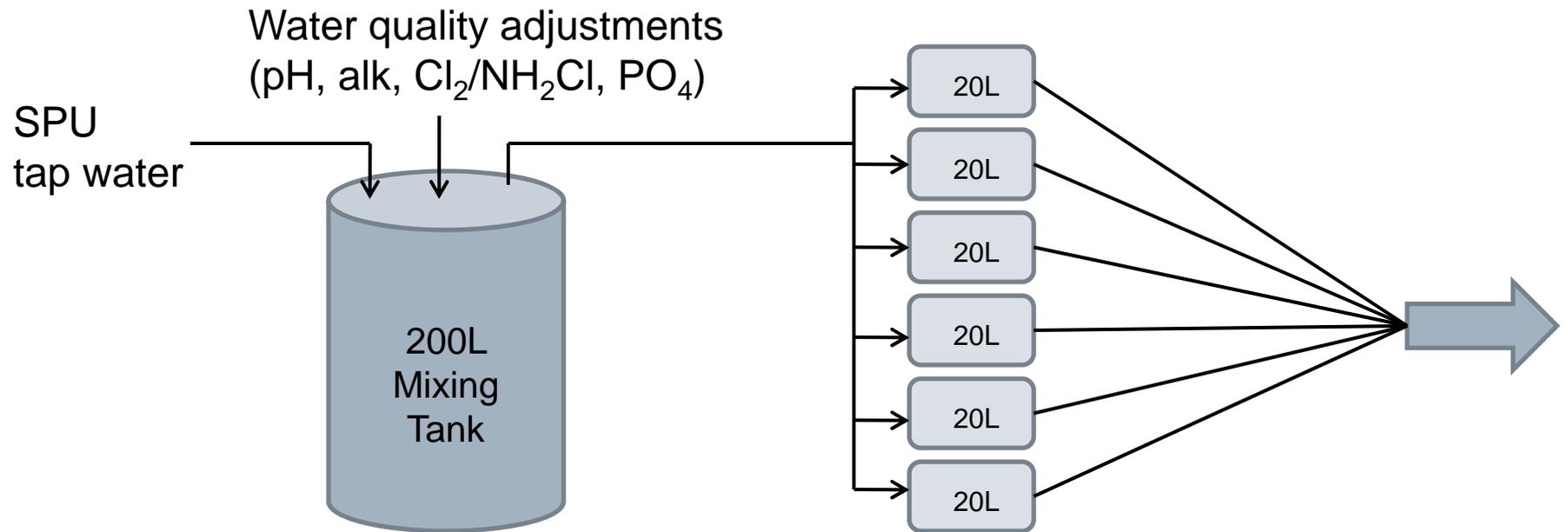
Methods

Controlled Water Quality

Test No.	2007	Sequence of Water Quality Change						
1	1 st Qtr	Dechld Tap	Dechld Tap	Cl ₂	NH ₂ Cl	Cl ₂	Dechld Tap	Dechld Tap
2	2 nd Qtr	Dechld Tap	Alk↑	Cl ₂	NH ₂ Cl	Cl ₂	Alk↓	Dechld Tap
3	3 rd Qtr	Dechld Tap	pH ↓	Cl ₂	NH ₂ Cl	Cl ₂	pH ↑	Dechld Tap
4	4 th Qtr	Dechld Tap	PO₄↑	Cl ₂	NH ₂ Cl	Cl ₂	PO₄↓	Dechld Tap

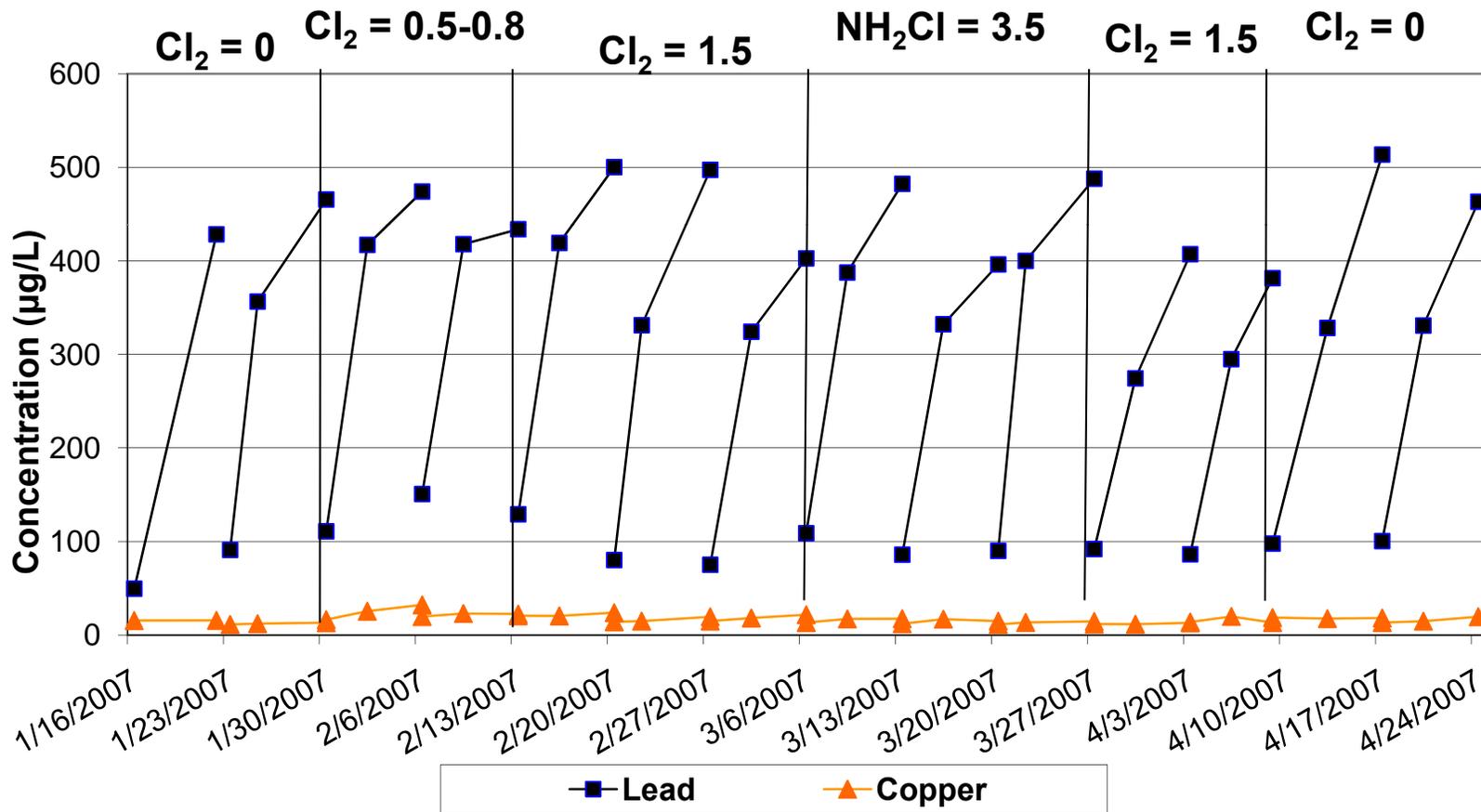
pH 7.8-8.3; Alk = 20 mg/L CaCO₃; T = 23-25C; TOC = 1 mg/L; Cl/SO₄ = 2-3; 0.8 mg/L Cl₂; no PO₄

Methods Controlled Water Quality



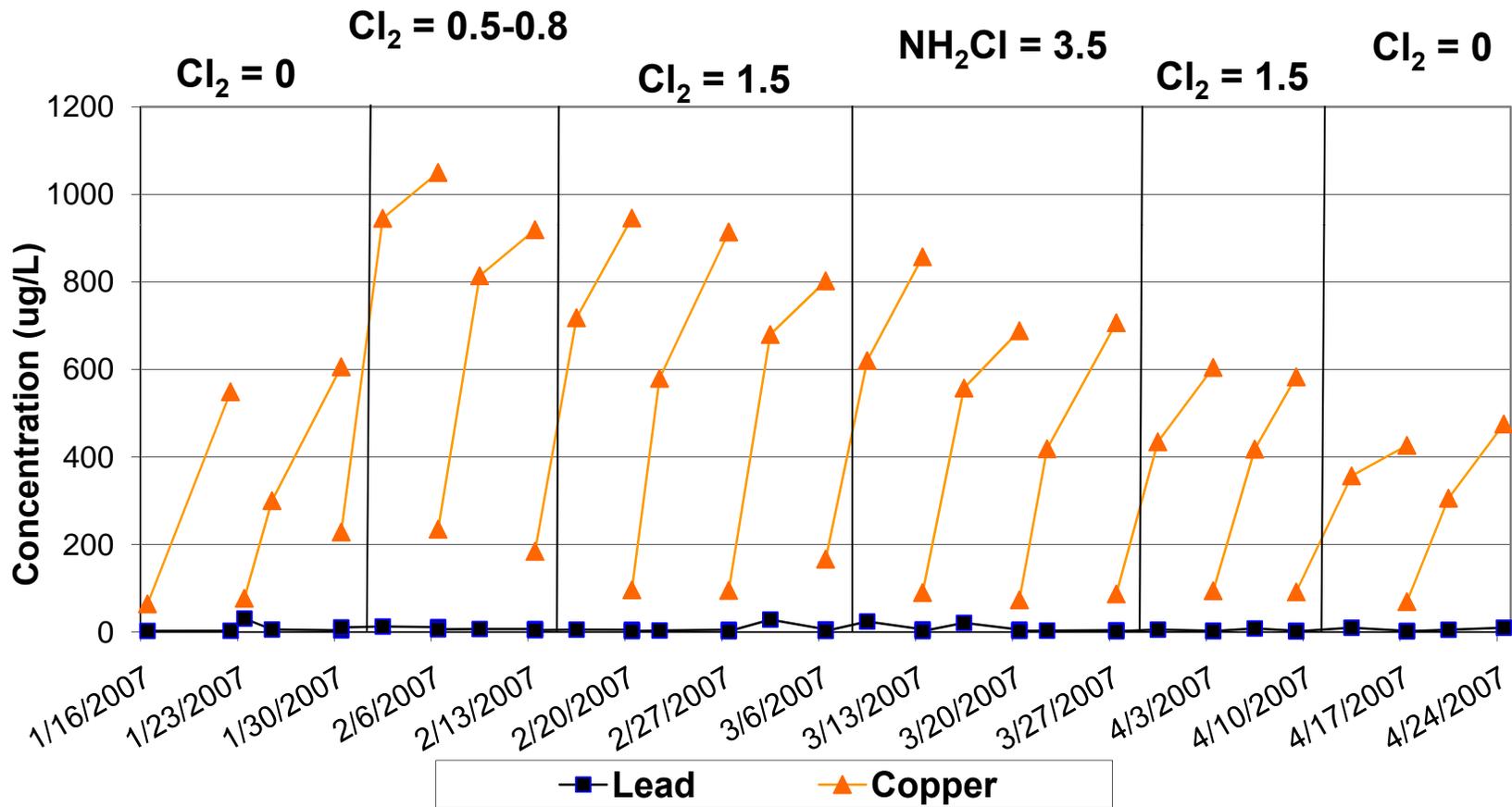
Activity	Prepare fresh batch of targeted water quality	Adjust water quality in 20L reservoirs	Dispose of test water
Frequency	Weekly	Daily	Weekly

Methods - Weekly Sampling Single-Metal Lead Pipe Loop



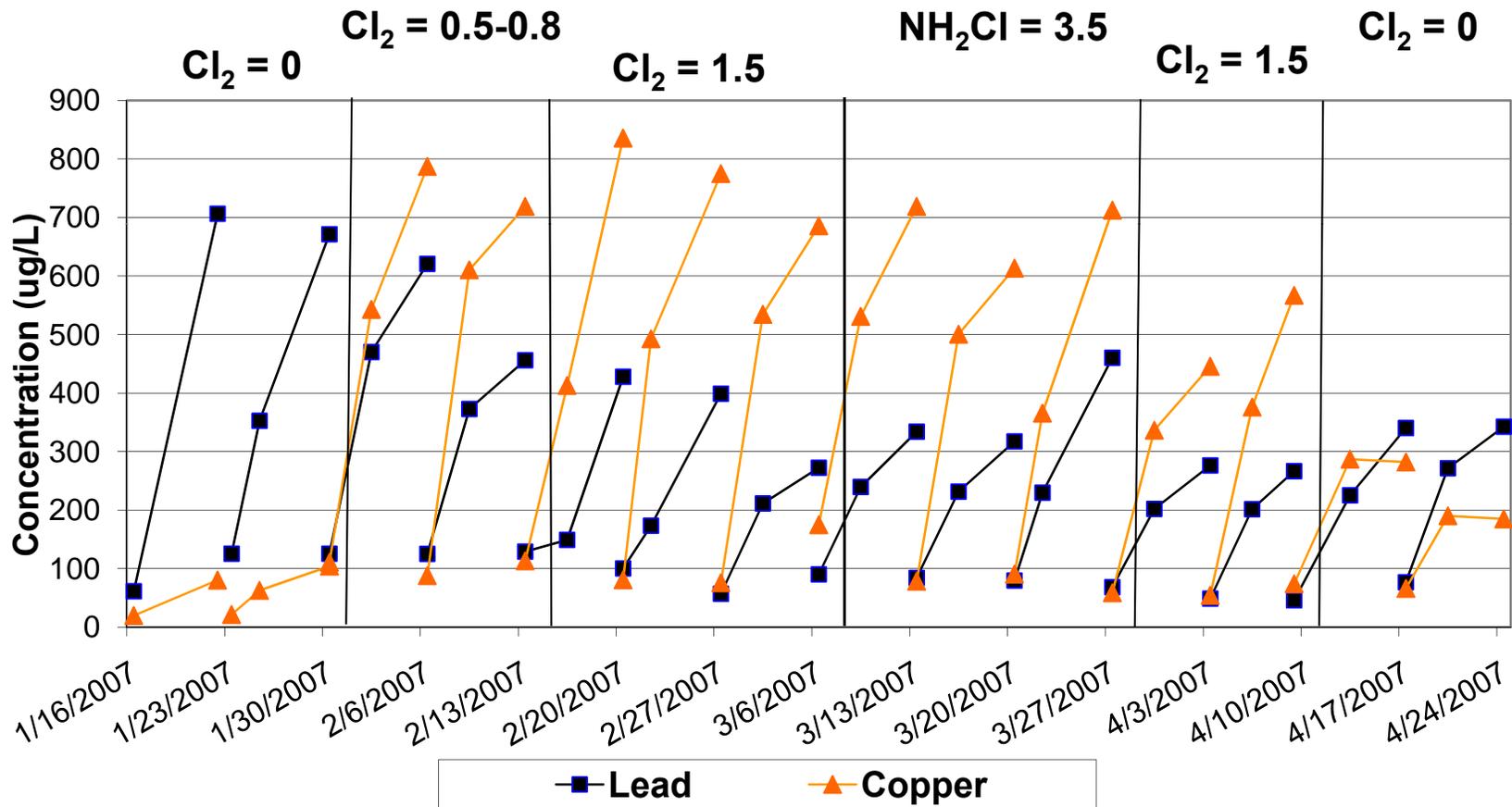
Test 1 – Change in Disinfectant

Methods - Weekly Sampling Single-Metal Copper Pipe Loop



Test 1 – Change in Disinfectant

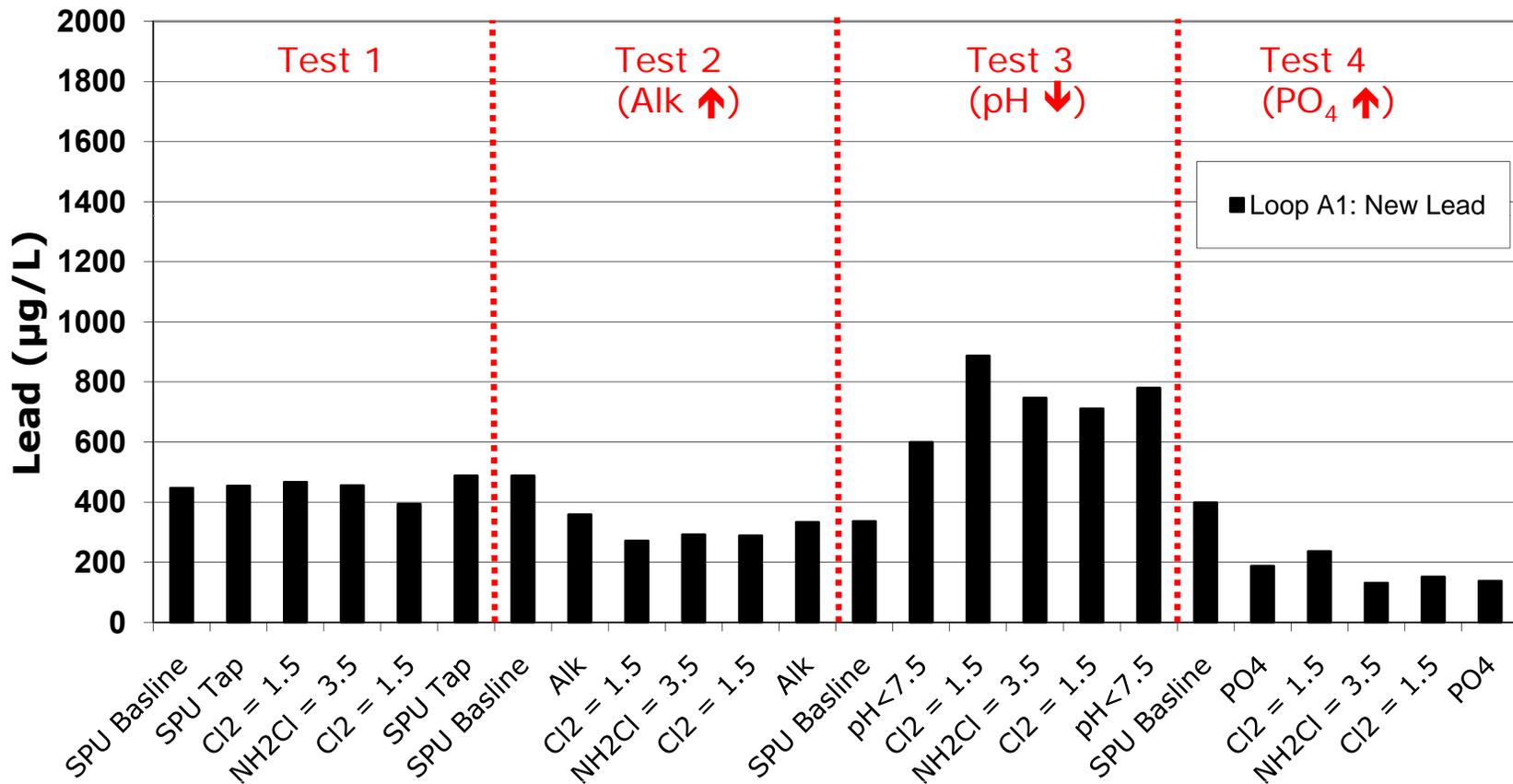
Methods - Weekly Sampling Galvanic-Couple Pb-Cu Pipe Loop



Test 1 – Change in Disinfectant

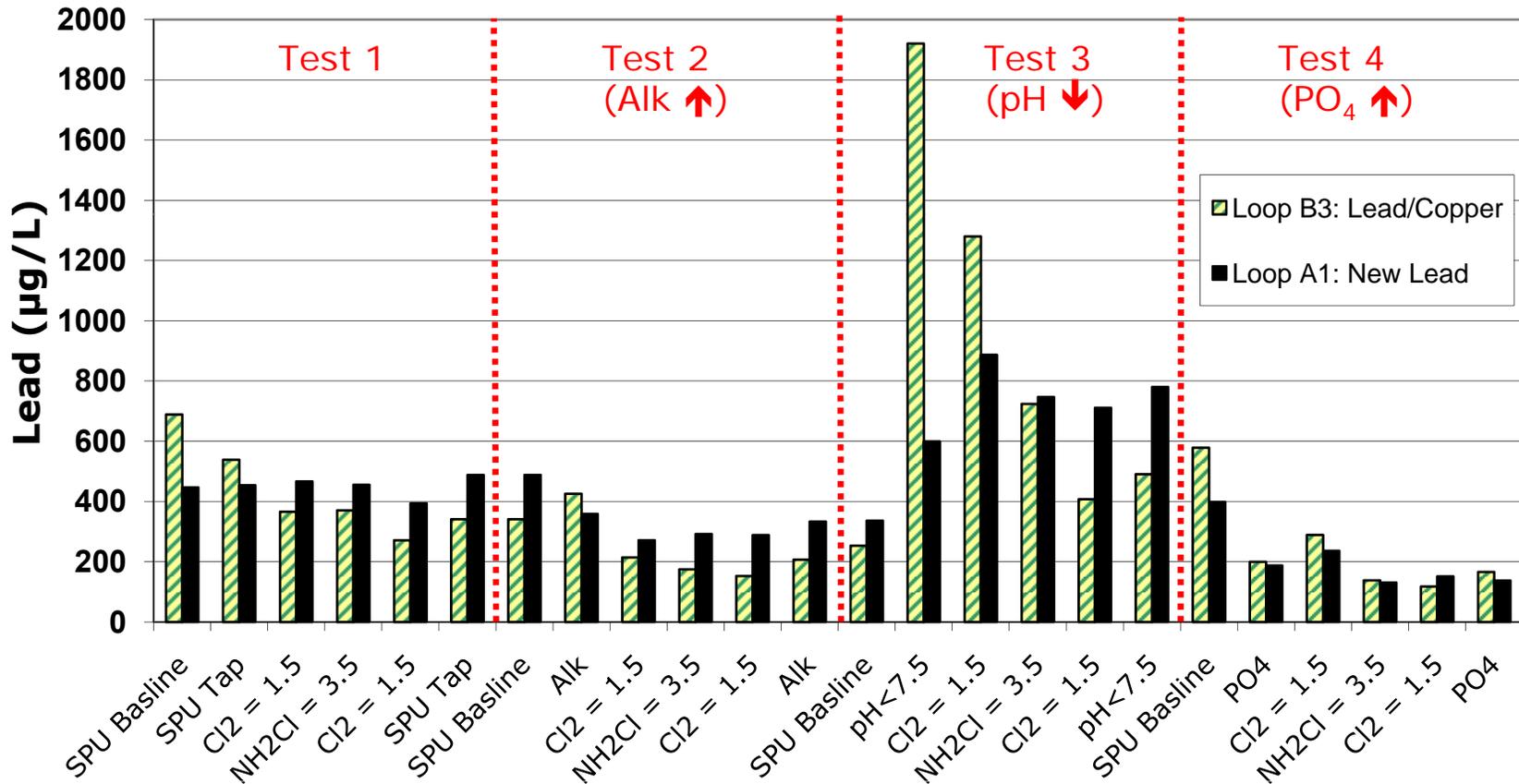
Results

Single-Metal Lead Pipe



Average seventh-day lead measured in samples collected from new lead pipe loop (A1)

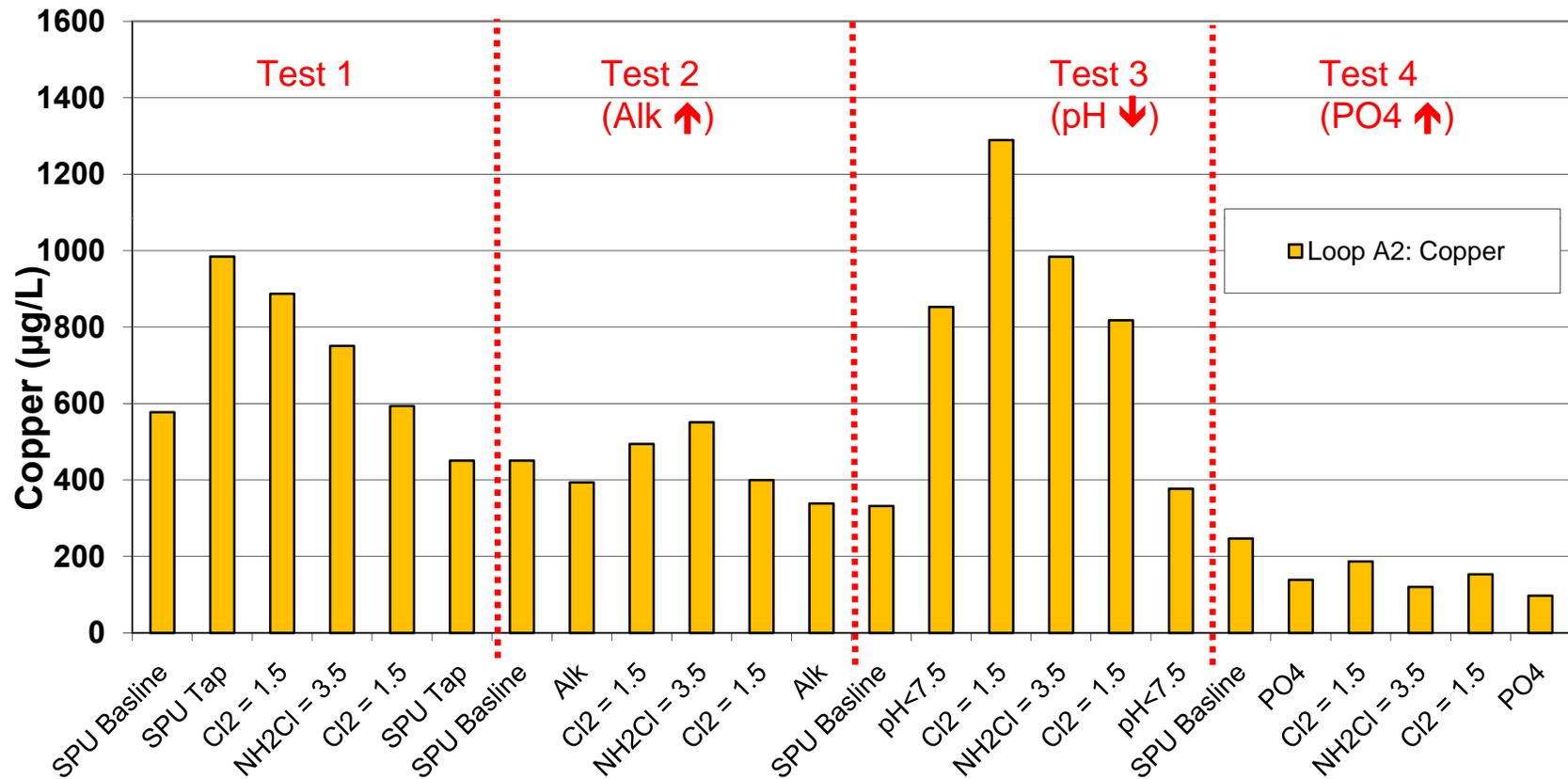
Results – Galvanic-Couple Pb-Cu vs. Single-Metal Lead Pipe



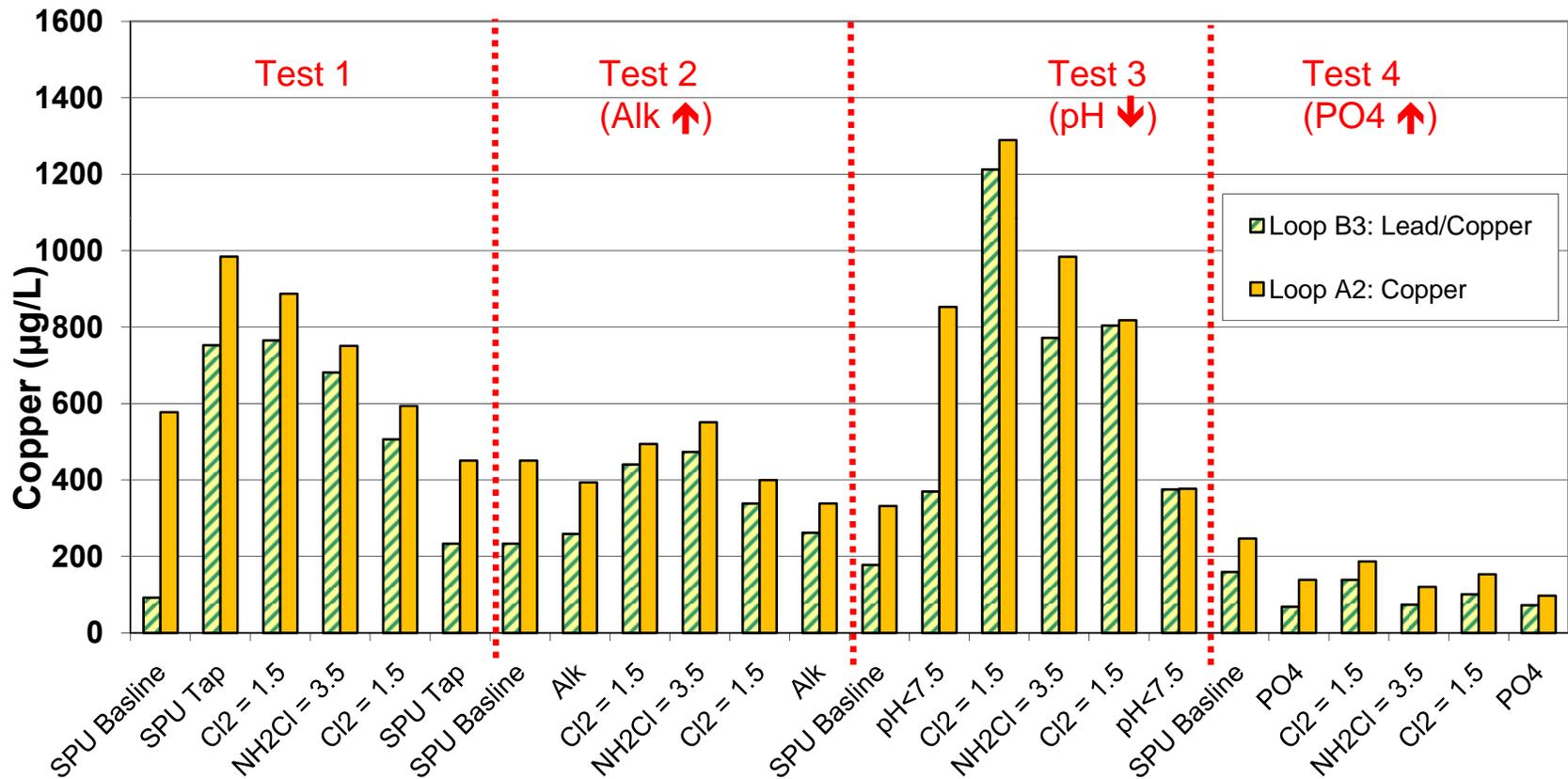
Comparison of average seventh-day lead samples

Results

Single-Metal Copper Pipe

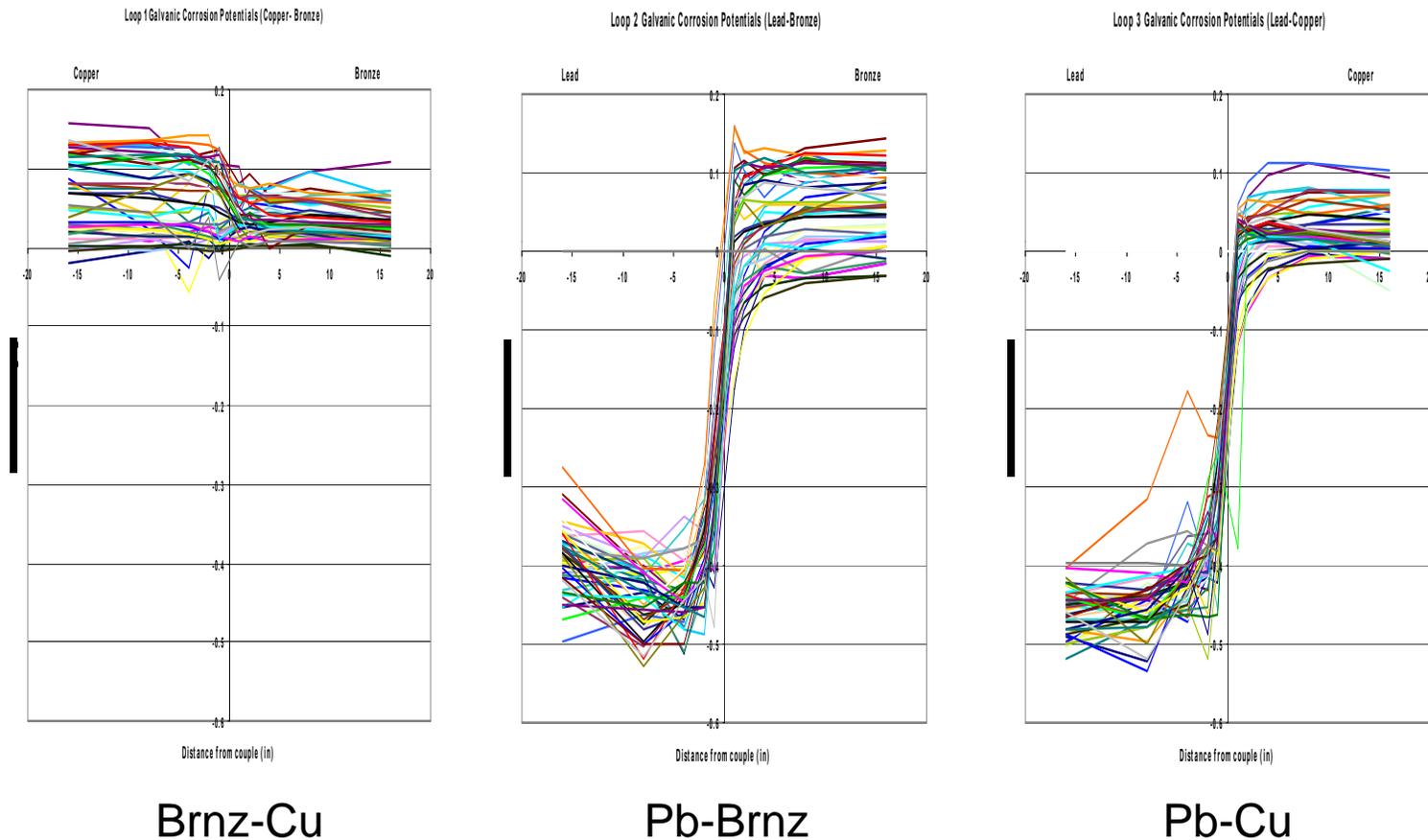


Results – Galvanic-Couple Pb-Cu vs. Single-Metal Copper Pipe



Results

Open Circuit Potential Profiles



Notable galvanic effect (up to 600 mV) ; limited galvanic reach (<3") from juncture

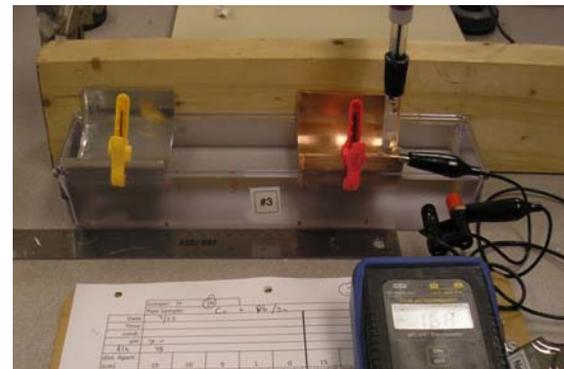
Ongoing Studies



Objective

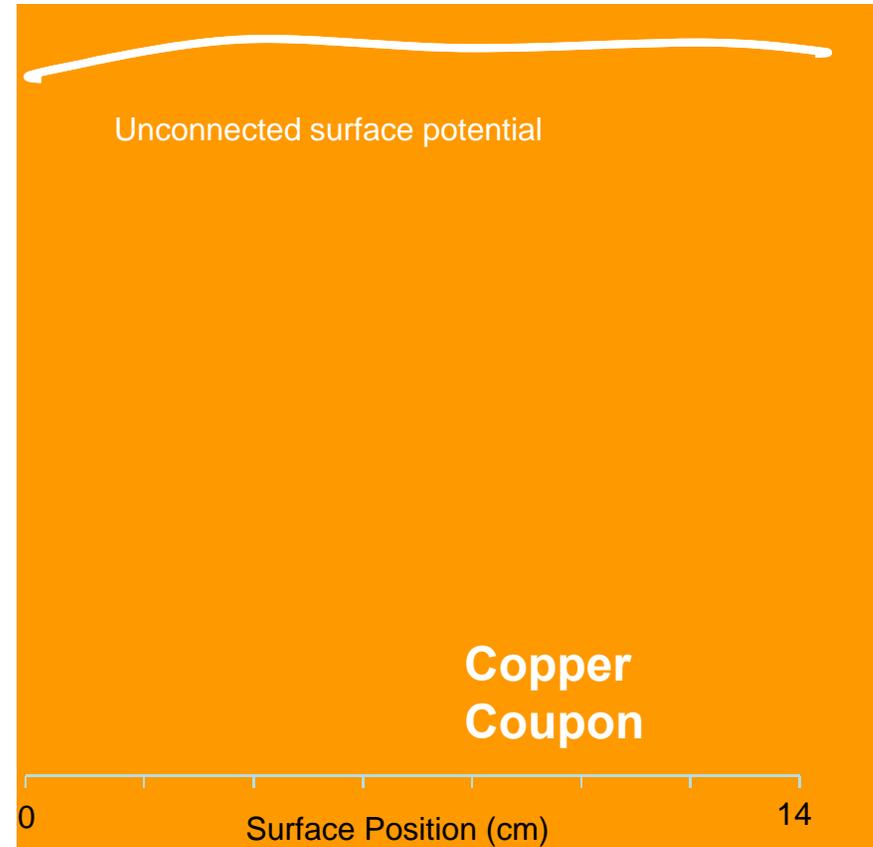
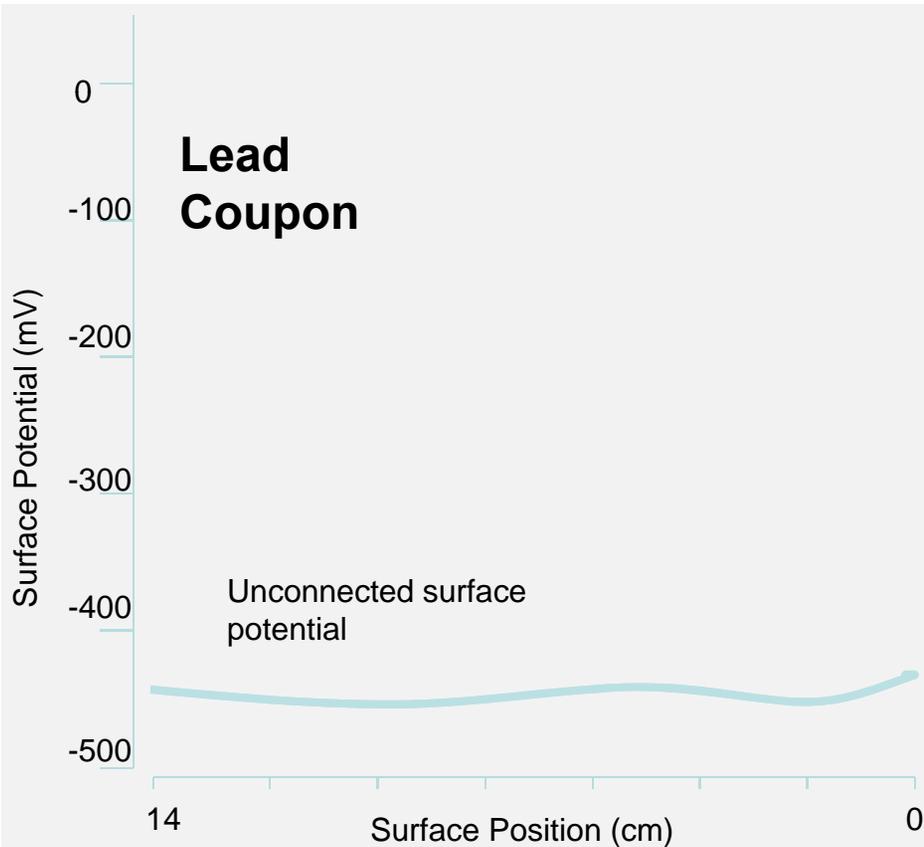
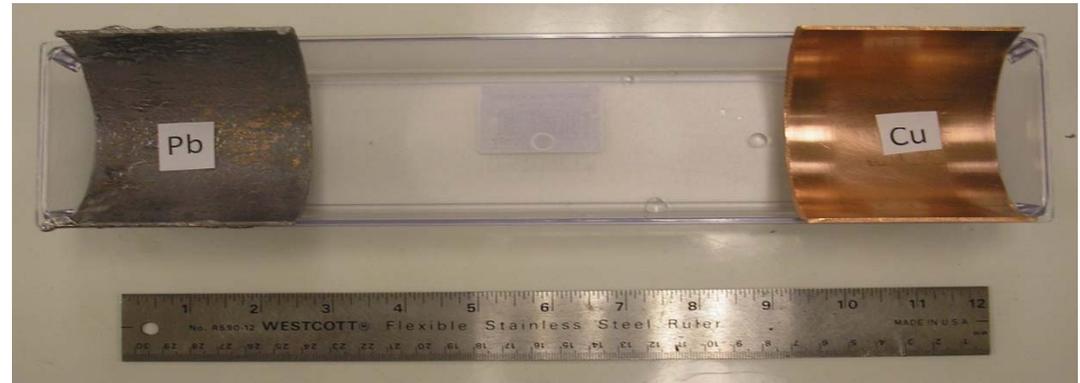
Compare potential profiles for lead and copper surfaces

1. Independent metals
2. Jointed (end-to-end) metals
3. Jumpered (wired) metals



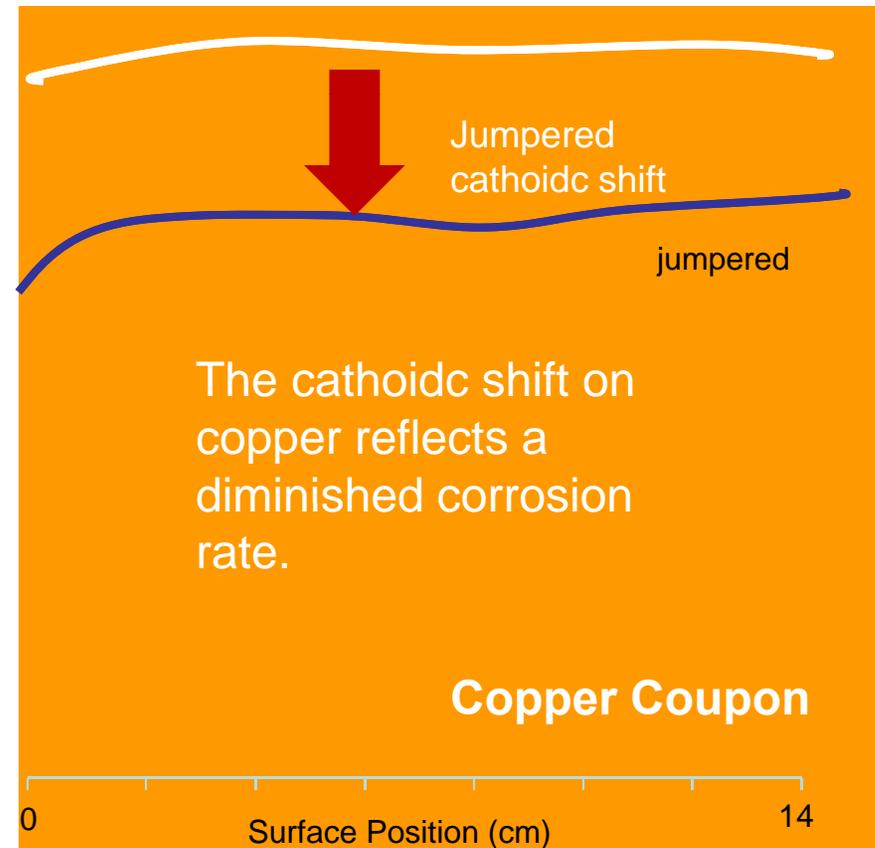
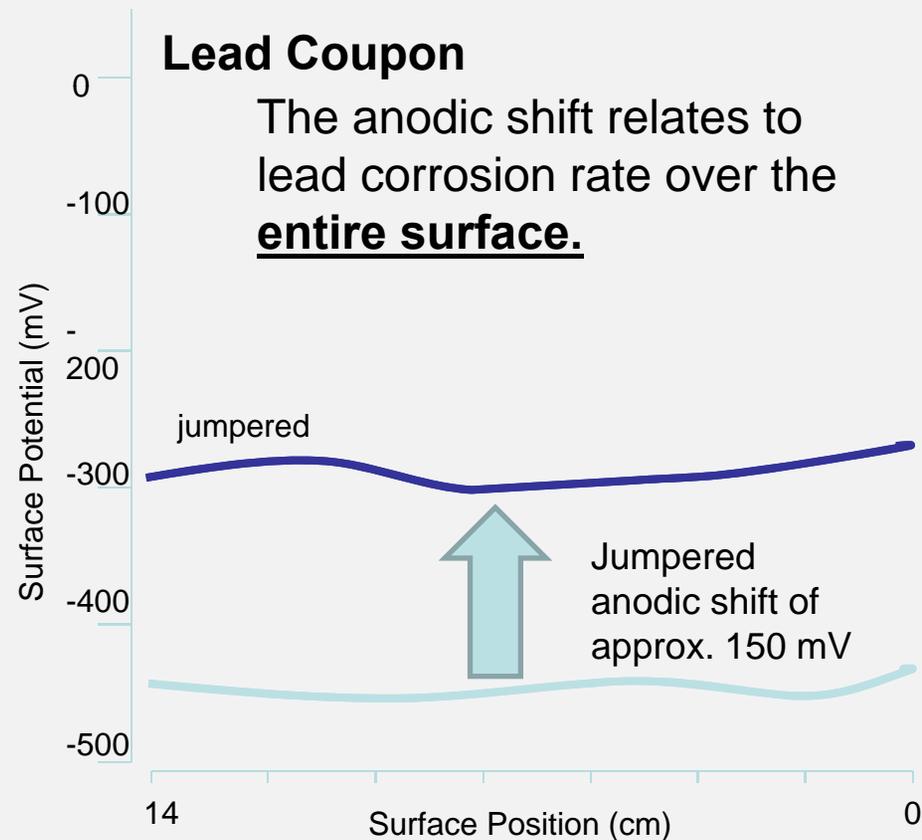
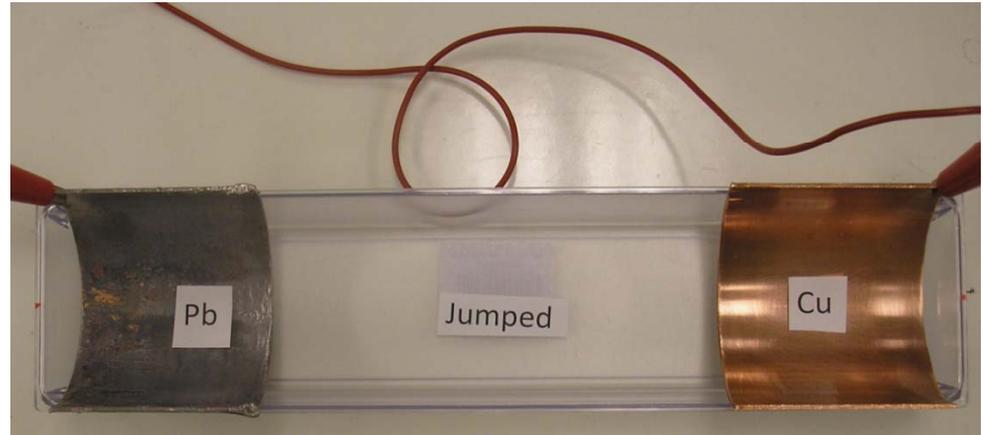
Independent Coupons

- Well defined and stable electrochemical surface potentials



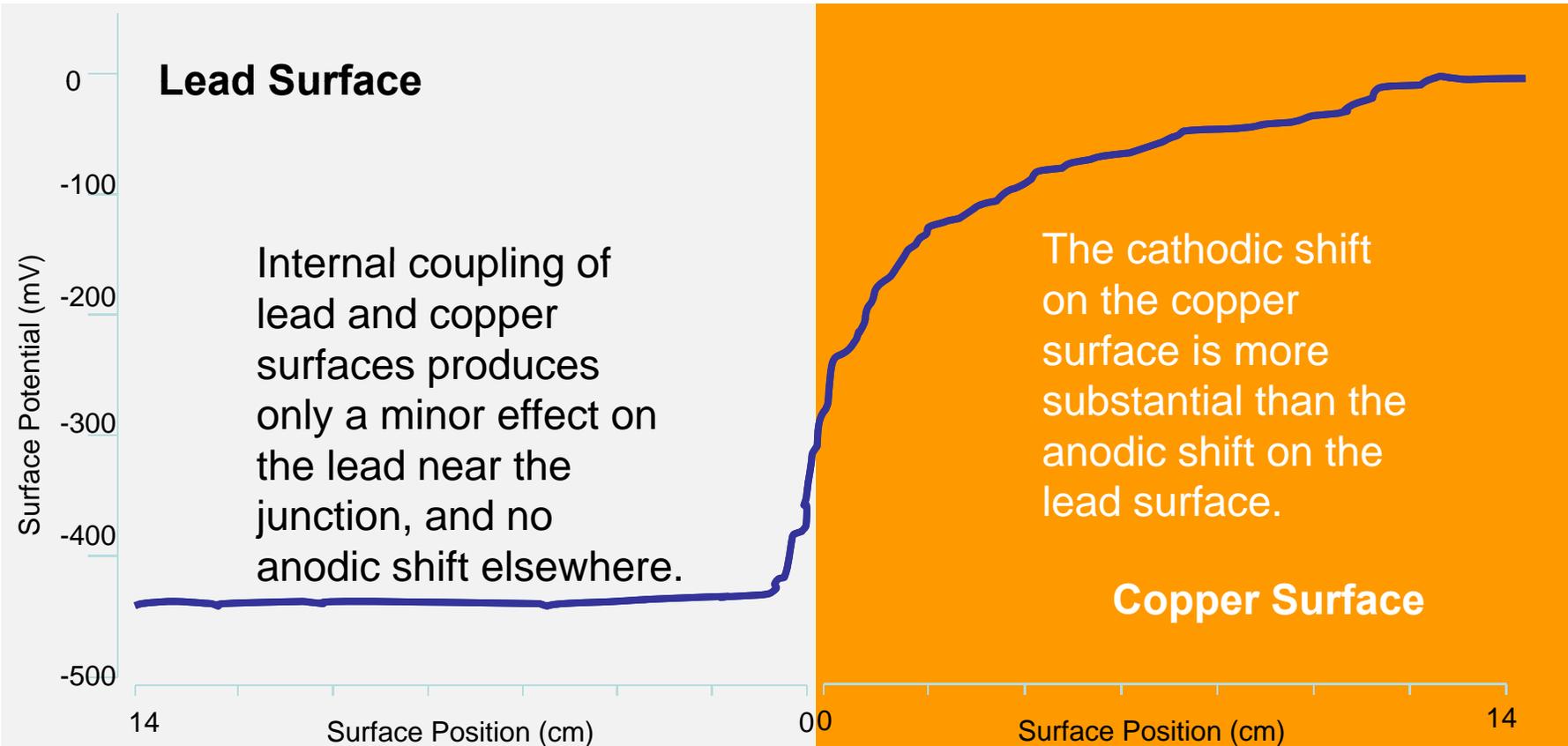
Jumpered (Wired) Coupons

- Anodic/cathodic shifts extend over the entire surfaces
- Shifts are substantial and reflect a meaningful lead corrosion increase



Jointed (End-to-End) Coupons

- Produces a minor increase in corrosion on the lead surface



Conclusions

- Pipe loop methods developed to evaluate effects of changing water quality on galvanic couples
 - Lead and copper release
 - Open-circuit potential profiles
 - Changes in water quality caused
 - Transient \uparrow lead (and corresponding \downarrow copper)
 - Effect was short-lived (<3-4 weeks)
-

Conclusions (cont'd)

- Open-circuit potential measurements revealed
 - Galvanic effect substantial (~600 mV)
 - Galvanic reach is limited (<3")
- Ongoing Studies – Preliminary Findings
 - Galvanic contact configuration (end-to-end vs. jumpered) potentially can impact corrosion and metals release

Conclusions (cont'd)

- More research needed
 - Nature of transient lead & copper releases
 - Significance of open-circuit potential profiles
-

Galvanic Couples: Effects of Changing Water Quality on Lead and Copper Release and Open-Circuit Potential Profiles



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Mineralogical Evidence of Galvanic Corrosion in Domestic Drinking Water Pipes

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Introduction

Drinking water distribution system (DWDS) piping contains numerous examples of galvanically-coupled metals (e.g., soldered copper pipe joints, copper-lead pipes joined during partial replacements of lead service lines). The possible role of galvanic corrosion in the release of lead or other metals has been a subject of debate for more than 25 years.

Previously, the effects of galvanic corrosion on drinking water pipe materials have been studied by measuring electro-potentials across the galvanic couple¹⁻³ or by examination of dissolved metal concentrations⁴⁻⁶. These studies have generally been short-term, prohibiting the significant development of corrosion solids.

This study presents the results of a visual and mineralogical characterization of scales developed over long time periods (up to 115 years) at galvanically-connected lead-brass and lead copper joints from several different drinking water distribution systems. The long-term exposure aspect of these samples allows: (1) a direct view as to which metal in the galvanic couple actually behaved anodically (i.e., corroded) over time, and (2) evaluation of mineral phases produced at these sites. Although beyond the scope of the current study, the latter observations, coupled with knowledge of the bulk water chemistry, may be used to model the conditions under which the deposits formed.

Methods

Sample preparation: Prior to processing, the ends of each pipe were plugged with rubber stoppers and all loose material was washed from the outer surface, and then cut longitudinally using a band-saw. Representative archival segments were set aside for photography, stereomicroscopic observations, and mineralogical descriptions. Scale material was harvested from pipe sections in layers. Harvested scale layers were manually ground with an agate mortar and pestle until able to pass through a 200-mesh (<75 μm grain size) stainless steel sieve.

Photography/Morphological description: Digital macro-photographs were taken with a Canon G3 digital camera attached to a copy stand. Micro-photographs were obtained using the Canon digital camera attached to the Zeiss stereomicroscope or with a Keyence VHX-600 digital microscope/camera.

Powder X-ray Diffraction (PXRD): Powder samples were analyzed using a Scintag or PANalytical diffractometer, both equipped with Cu X-ray tubes. Operating conditions were 40 kV, 40 mA, 0.02° 2 θ step size, and a 1-3s count time for the Scintag diffractometer and 45 kV, 40 mA, 0.02° 2 θ step size, and a 40s count time for the PANalytical diffractometer. Pattern analysis was performed using Jade software (Versions 7-9, Materials Data Inc.) and the 1995-2002 ICDD PDF-2 database.

Results

This study presents the characterization of corrosion scale deposits developed on fifteen pipe joint samples harvested from four DWDSs with differing bulk water chemistry (Tables 1 and 2). Thirteen of the samples were lead service lines or goosenecks connected to brass fittings with Pb:Sn solder, two were copper pipe sections soldered to lead, and one consisted of copper and lead pipe joined by a brass compression fitting. In-service periods for the samples ranged from 81 to 114 years.

Visual characterization of scale solids, combined with powder X-ray diffraction showed three different motifs defined by what is occurring in the galvanic zone. Motif 1 is characterized by deep corrosion of the copper or brass pipe and little evidence of lead corrosion. Motif 2 displays enhanced lead corrosion and little effect to the brass. Motif 3 is defined by minimal difference in galvanic zone scales relative to the mineralogy of either adjacent pipe.

Table 1. Pipe sample information

Utility	Sample	Pipe Materials	Joint Type	Installed	Extracted	Years in service
A	A_1	lead-brass	solder	1924	27-Apr-06	82
	A_2	lead-brass	solder	1913	11-Jul-06	93
B	B_1	lead-copper	solder	1926	15-Apr-07	81
	B_2	lead-copper	solder	1926	15-Apr-07	81
C	C_1	lead-brass	solder	1891	8-Dec-05	114
	C_2	lead-brass	solder	1916	19-Jul-05	89
	C_3	lead-brass	solder	1912	27-Jan-05	93
	C_4	lead-brass	solder	1934	2004	70
	C_5	lead-brass	solder	1910	21-Jul-05	95
	C_6	lead-brass	solder	1932	Apr-08	76
	C_7	lead-brass	solder	1922	22-Sep-08	86
	C_8	lead-brass	solder	1911	8-Oct-08	97
	C_9	lead-brass	solder	1910	14-Nov-08	98
	C_10	lead-brass	solder	1911	30-Apr-09	98
D	D_1	lead-brass	compression	1915	2006	91

Table 2. Approximate Water Qualities, last 5 years before samples

<i>all units mg/L</i>									
	pH	Alkal.	Ca	Cl	SO₄	Ortho-phos. (as PO₄)	Poly-phos. (as PO₄)	Type of Disinfect.	Approx. Residual
Utility A	7.2- 8.1	35-98 (62 avg)	44	16-85	34- 81	1.8-3.0	0	mono- chloramine	3-3.4
Utility B	8.4- 8.7	60-80	30- 40	20-50	57- 119	0.1-0.2	0.3-0.5	free Cl ₂	1
Utility C	8.2- 9.4	24-27	11	?	?	0	0	free Cl ₂	0.7
Utility D	7.6	300	69	15	17	0	0	free Cl ₂	0.2-0.4

Motif 1 (Galvanic corrosion of brass or copper pipe): Samples from two utilities fall into this motif. Figures 1 and 2 show representative photographs and powder X-ray diffraction patterns for Utility A. Figures 3 and 4 show a representative sample from Utility B.

Utility A samples (n=2), brass pipe fitting solder to lead pipe, exhibited dealloying of the brass pipe for 1 cm immediately adjacent to the pipe joint as well and pitting of the pipe wall in a zone up to 6 cm back from the joint (Figure 1A, B). Minerals present in the dealloyed brass included cuprite, posnjakite, and anglesite. The overlying copper scale deposit occluded much of the cross-sectional area of the pipe at the joint and extended onto the surface of the adjacent lead pipe. This deposit was comprised primarily of brochantite, malachite, and nakauriite (Figure 2). This differed from the scale mineralogy of the non-galvanic portion of the brass pipe, which was characterized by mushistonite (Figure 2). Porous copper scales extended onto the lead pipe (Figure 1C) surface had a similar mineralogy those occurring on the brass pipe, with the addition of small spherical crystal clusters of the mineral antlerite (Figures 1D, 2). These deposits also differed significantly to the lead pipe scales developed away from the galvanic zone, which consisted of plattnerite, pyromorphite, hydrocerussite and litharge.

Utility B samples (n=2) consisted of copper pipe solder to lead. These samples exhibited deep pitting of the copper pipe wall up to 4 cm from the joint (Figure 3A, B). The overlying porous copper solids had a similar mineralogy to that of Utility A, consisting of brochantite, malachite and nakauriite (Figure 4). These also extended onto the adjacent lead pipe, in this area anglesite and cerussite were also present in the deeper parts of the scale, out of direct contact with the bulk water (Figure 4). Typical mineralogy of the lead scale away for the galvanic zone consists of plattnerite, and hydrocerussite (Figure 4).

Table 3. Key to abbreviations for mineral phases in PXRD patterns

Abbrev.	Mineral/Phase name	Chemical Formula
L	Litharge	PbO
P	Plattnerite	PbO ₂
S	Scrutinyite	PbO ₂
C	Cerussite	PbCO ₃
Hc	Hydrocerussite	Pb ₃ (CO ₃) ₂ (OH) ₂
Pn	Plumbonacrite	Pb ₁₀ (CO ₃) ₆ (OH) ₆ O
Py	Pyromorphite-F	Pb ₅ (PO ₄) ₃ F
PS	Lead oxide sulfate	Pb ₃ O ₂ SO ₄
A	Anglesite	PbSO ₄
Lr	Laurionite	Pb(OH)Cl
Cp	Cuprite	Cu ₂ O
T	Tenorite	CuO
M	Malachite	Cu ₂ CO ₃ (OH) ₂
N	Nakauriite	Cu ₈ (SO ₄) ₄ (CO ₃)(OH) ₆ · 48H ₂ O
B	Brochantite	Cu ₄ SO ₄ (OH) ₆
Po	Posnjakite	Cu ₄ SO ₄ (OH) ₆ · H ₂ O
An	Antlerite	Cu ₃ SO ₄ (OH) ₄
Na	Nantokite	CuCl
At	Atacamite	Cu ₂ Cl(OH) ₃
Er	Eriochoalcite	CuCl ₂ · 2H ₂ O
Cs	Cassiterite	SnO ₂
Mu	Mushistonite	CuSn(OH) ₆
Ho	Hopeite	Zn ₃ (PO ₄) ₂ · 4H ₂ O
Sm	Smithsonite	ZnCO ₃
W	Willemite	Zn ₂ SiO ₄
Zi	Zincite	ZnO
Q	Quartz	SiO ₂
Ca	Calcite	CaCO ₃
<i>Cu</i>	Copper (metallic)	Cu
<i>Pb</i>	Lead (metallic)	Pb
<i>Sn</i>	Tin (metallic)	Sn
<i>Cu-Sn</i>	Copper-tin	Cu ₆ Sn ₅
<i>Cu-Zn</i>	Copper-zinc (brass)	varies

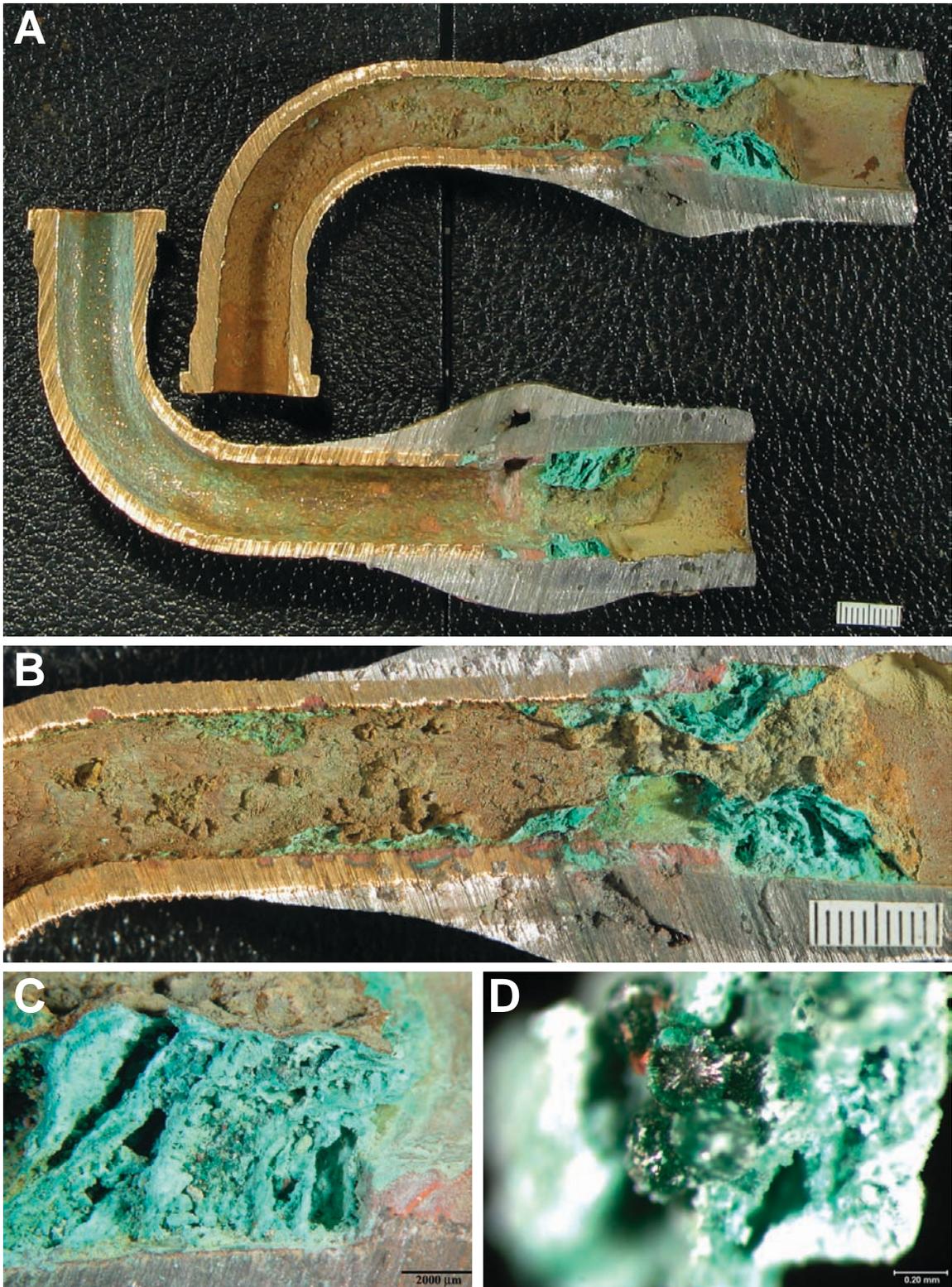


Figure 1. Photographs of pipe sample A_2. (A), (B): scale bar divisions are in mm. (C): scale bar = 2 mm. (D): scale bar = 200 μm.

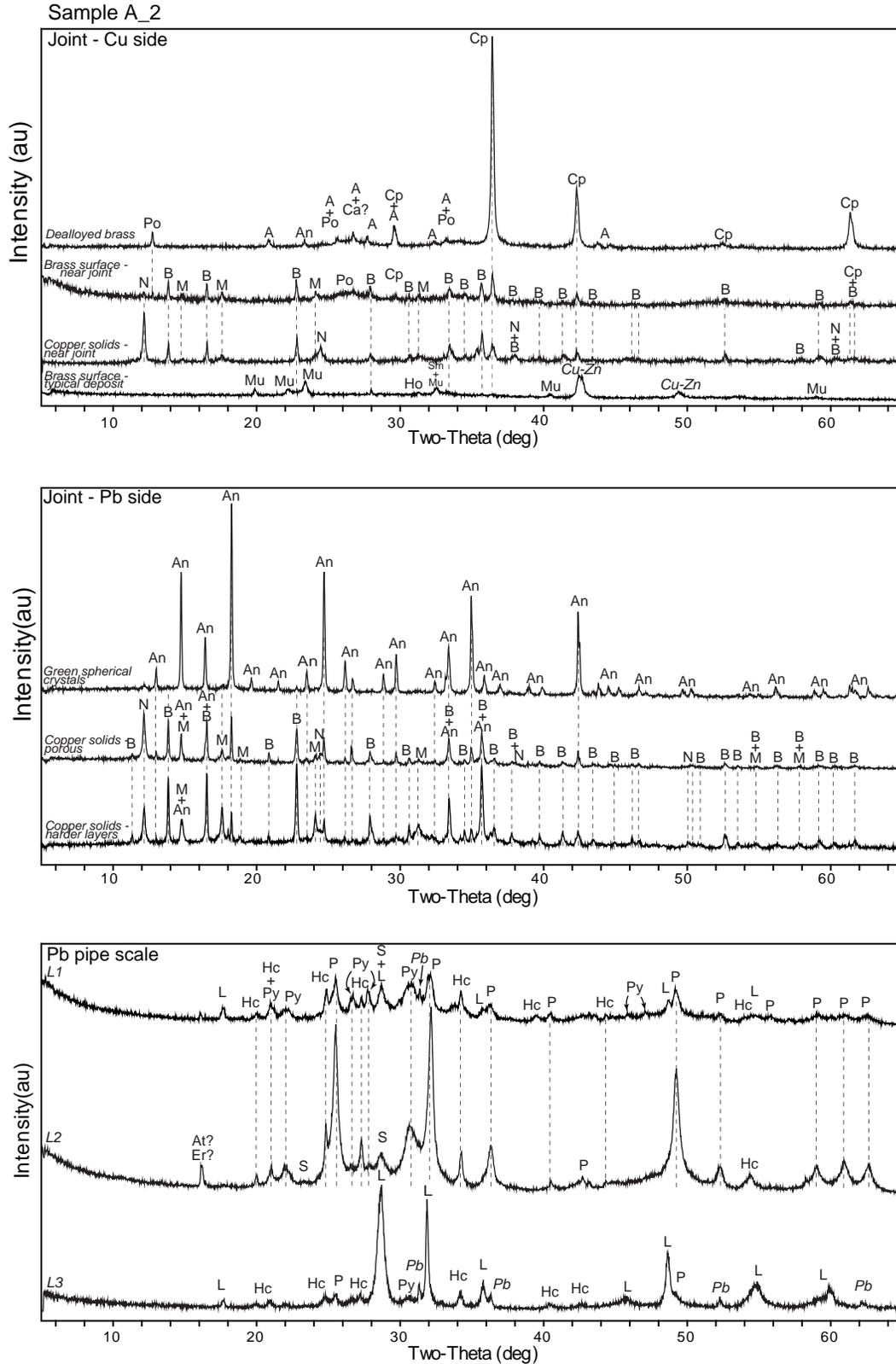


Figure 2. Sample A_2 powder X-ray diffraction patterns. Refer to Table 3 for key to mineral phase abbreviations.

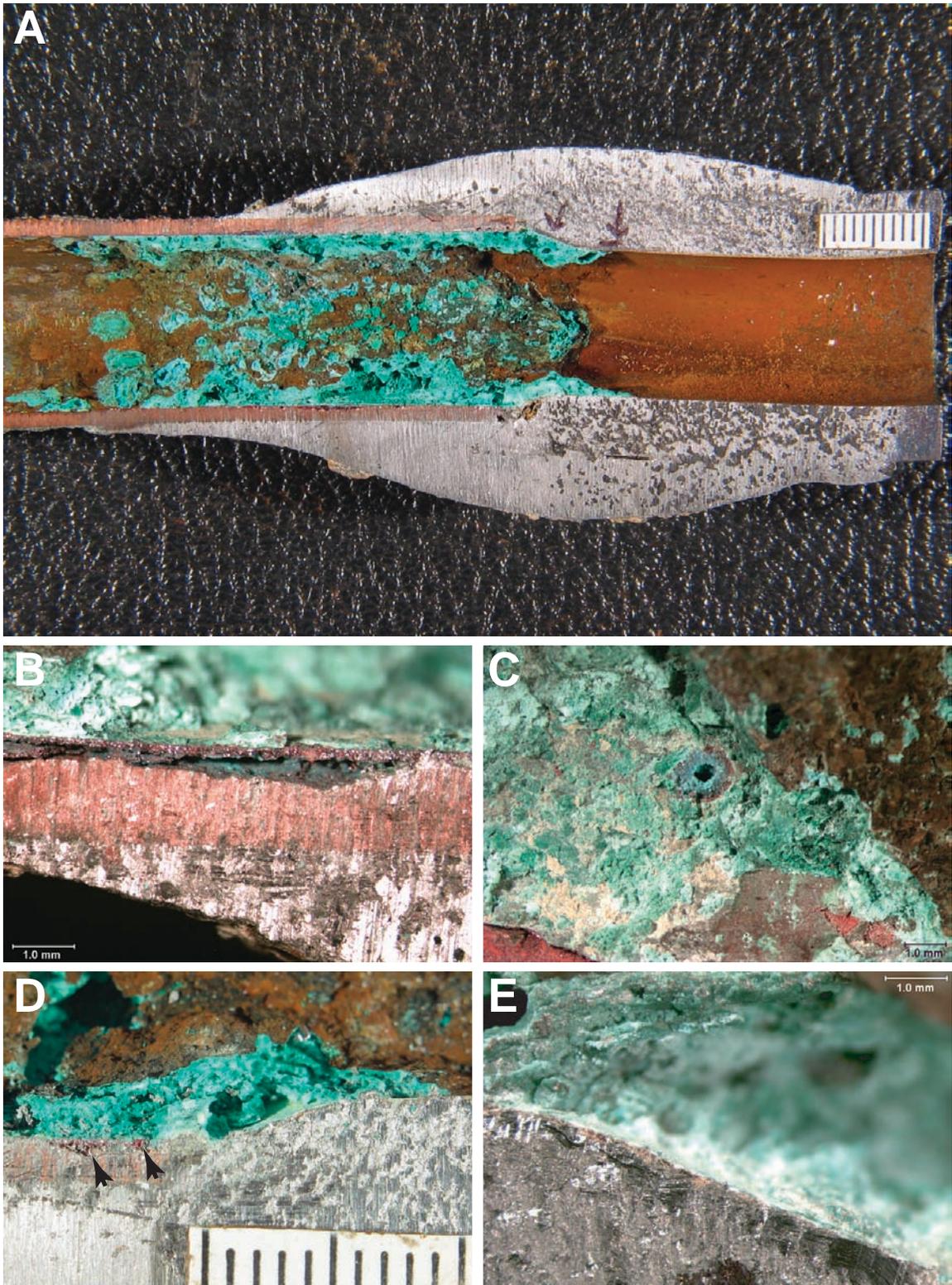


Figure 3. Photographs of pipe sample B_1. (A), (D) scale bar divisions are in mm. (B), (C), (E): scale bar = 1 mm.

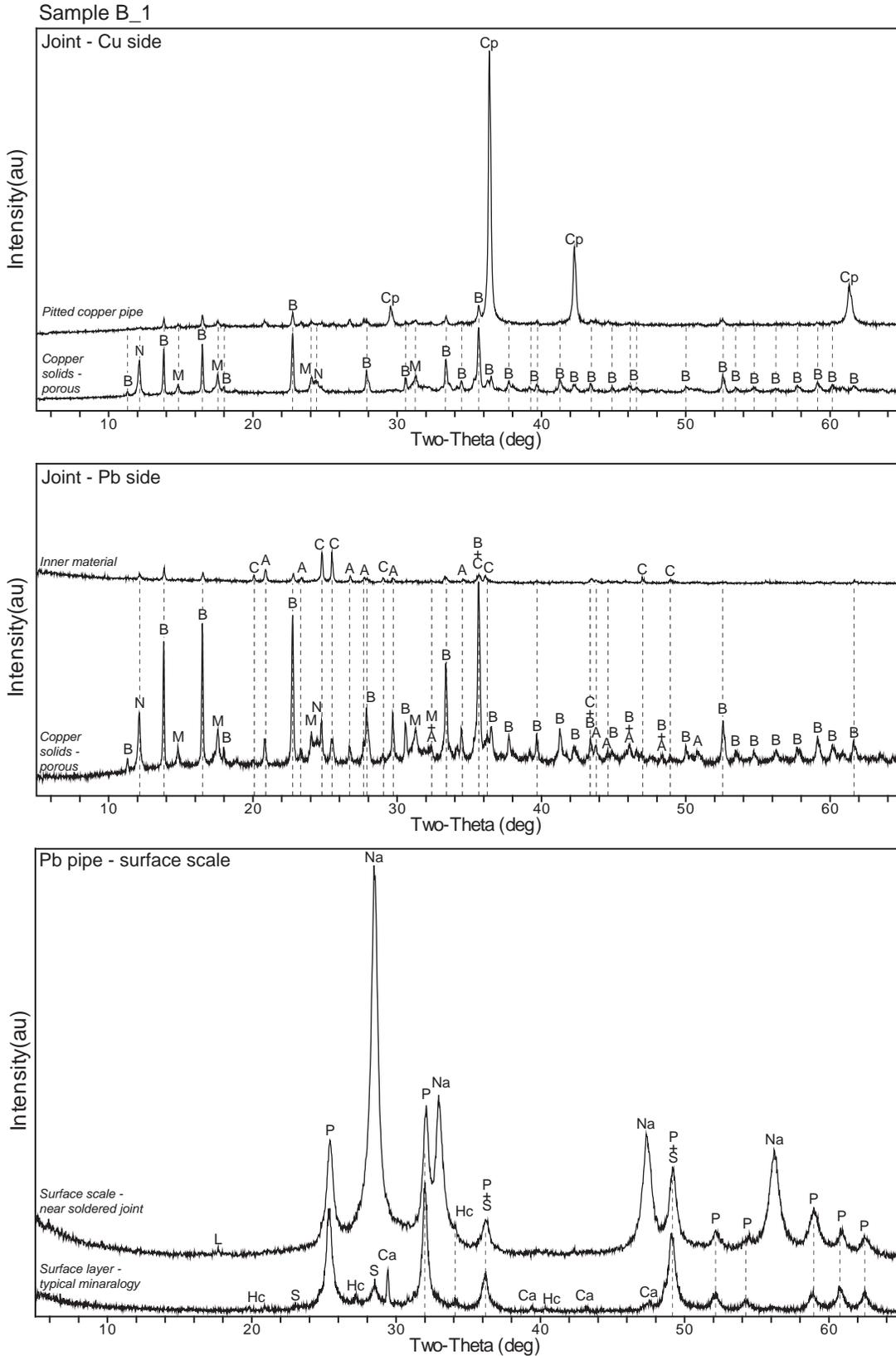


Figure 4. Sample B_1 powder X-ray diffraction patterns. Refer to Table 3 for key to mineral phase abbreviations.

Motif 2 (galvanic corrosion of lead pipe): Motif 2 is characterized ten samples from Utility C (Figure 5). The typical lead pipe scale mineralogy consists of an outer layer (L1) consisting of cerussite and hydrocerussite and a lower layer (L2) of litharge. (Figures 5B, 6). Lead scales, developed in the 1-3 mm wide galvanic zone immediately adjacent to the soldered joint, were structurally distinct from the typical background deposits. The lower, litharge layer, is not present (Figure 5B) and the scale consists of lead hydroxychlorides, hydrocerussite, and cerussite (Figure 6). The depth of corrosion of the lead pipe in this zone ranged from 1mm (Figure 5B) to as much as 3 mm (Figure 5C), with the latter case weakening the pipe wall enough to cause a failure at the joint. On the brass pipe the mineralogy of thin scales over different regions of the surface (Figures 5A,D,E, 6) is complicated by a thin layer of Pb:Sn solder over part of the interior, outlined by the color change in the scale about 4 cm from the end of the joint in Figure 5A, E). Importantly however, the brass shows little evidence of the deep pitting and dealloying exhibited by samples from Utility A.

Motif 3 (Minimal evidence of galvanic corrosion): One sample from Utility D falls into this motif. Figures 7 and 8 show representative photographs and powder X-ray diffraction patterns. The lead pipe mineralogy consists of a surface layer of cerussite, hydrocerussite, and plumbonacrite. Small residual patches of plattnerite are locally present in the surface layer. The lower layer is comprised of litharge (Figure 8). On the brass fitting the scale consists of malachite. Scales at the point of contact of these metals are mineralogically similar to those of the respective adjacent pipes. The lead pipe showed a thickened litharge (PbO) layer at the joint (Figure 7B, C).

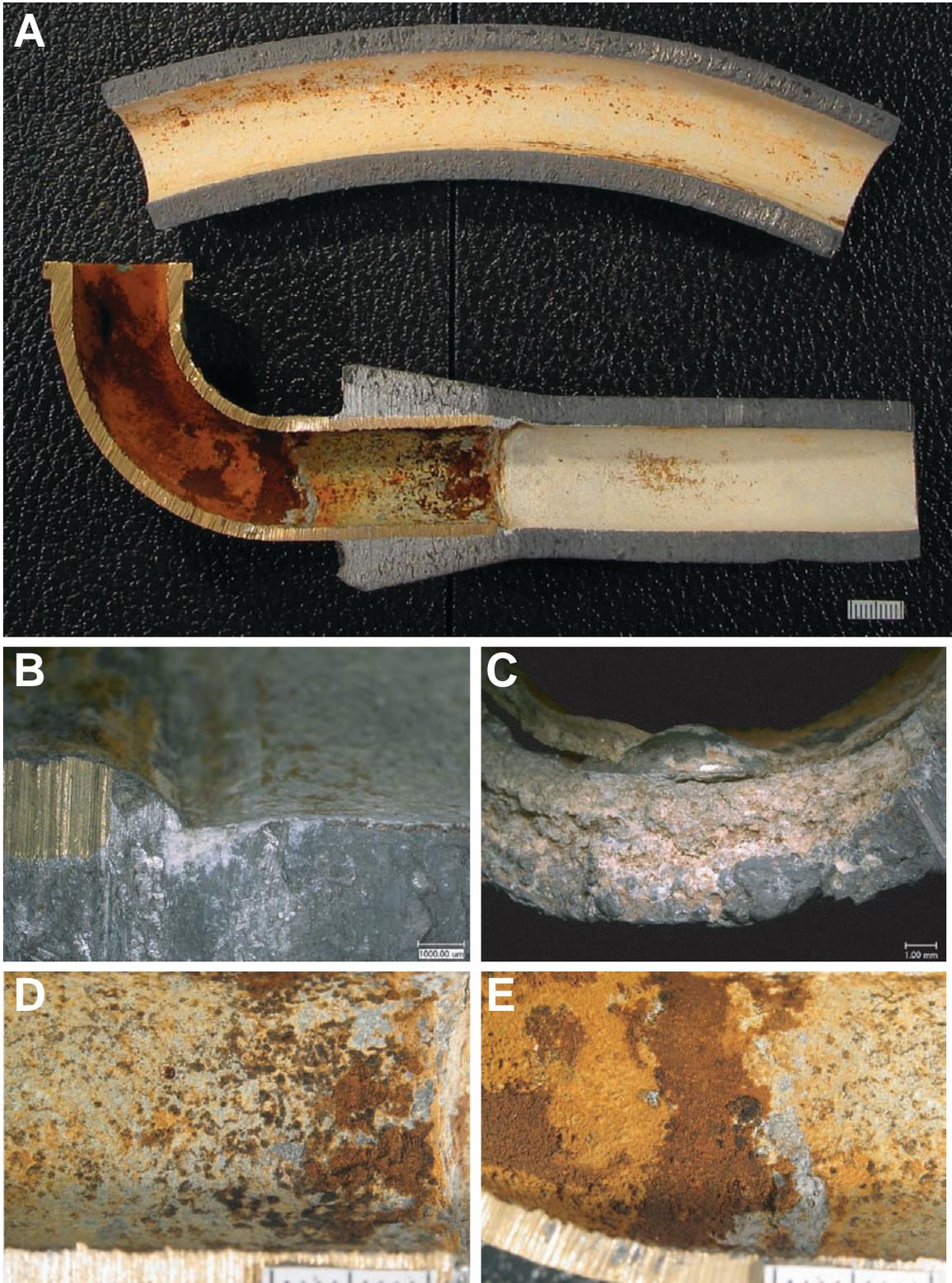


Figure 5. Photographs of pipe sample C_3. (A), (D), (E): scale bar divisions are in mm. (B), (C): scale bar = 1 mm

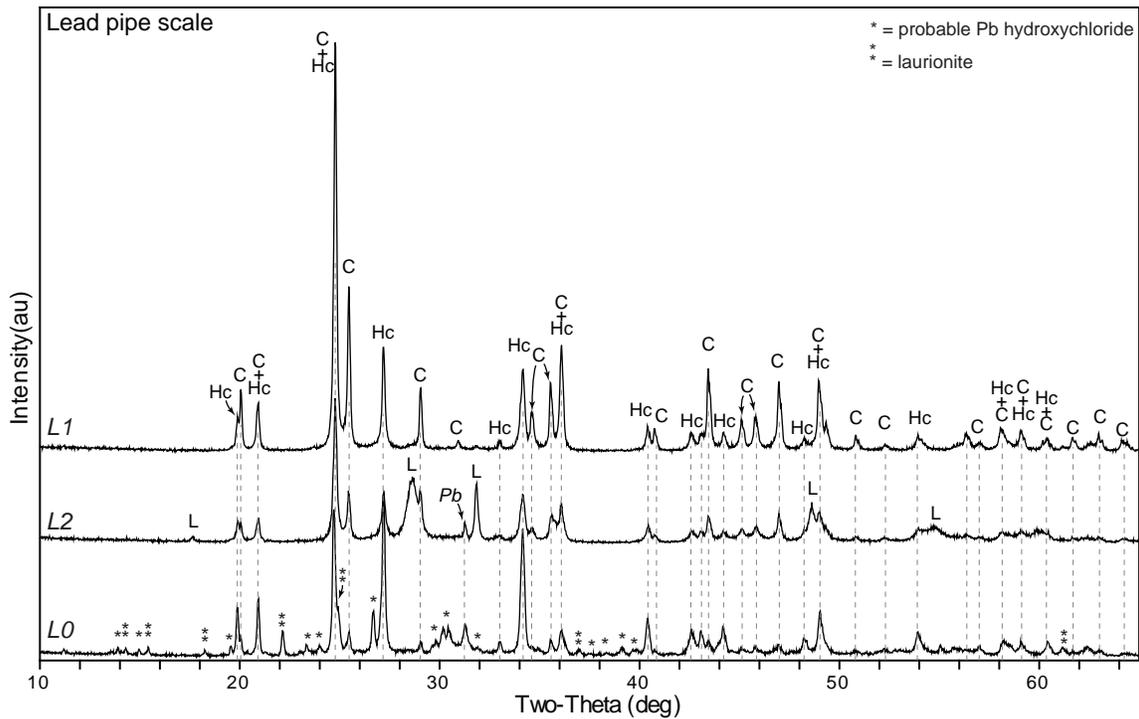
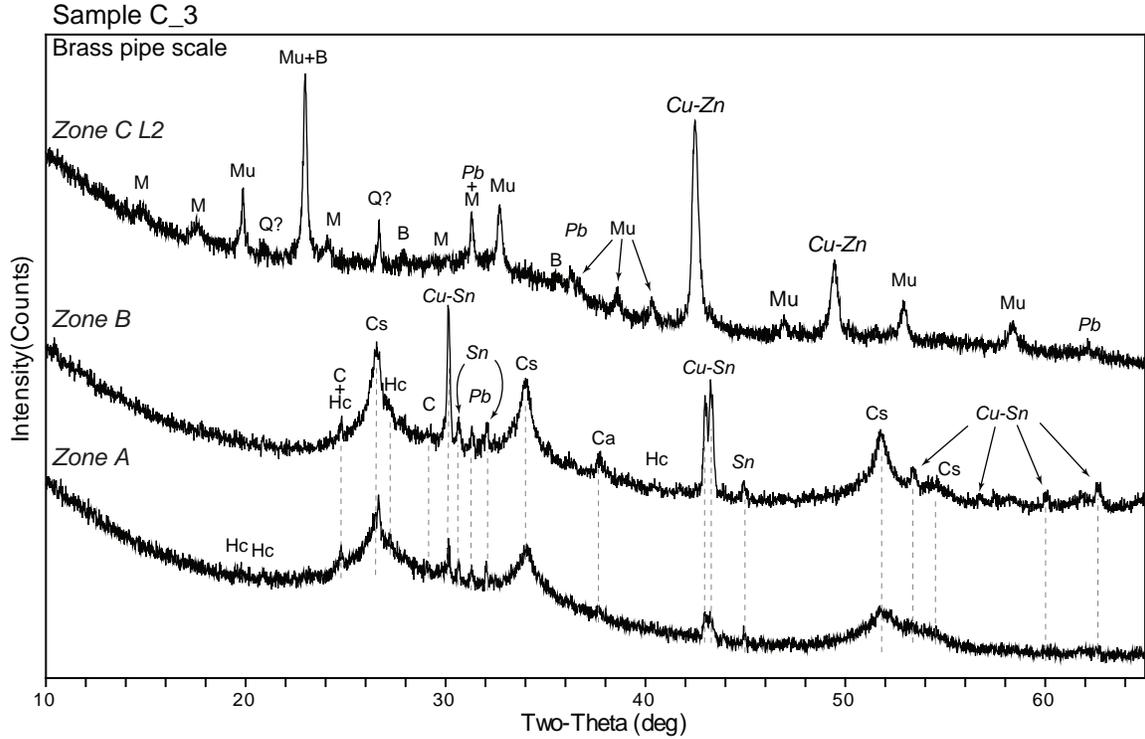


Figure 6. Sample C_3 powder X-ray diffraction patterns. Refer to Table 3 for key to mineral phase abbreviations. For brass pipe, Zones A and B are solder-coated brass located close to joint. For lead pipe L1 and L2 are typical mineralogy, L0 is galvanic zone scale deposit.

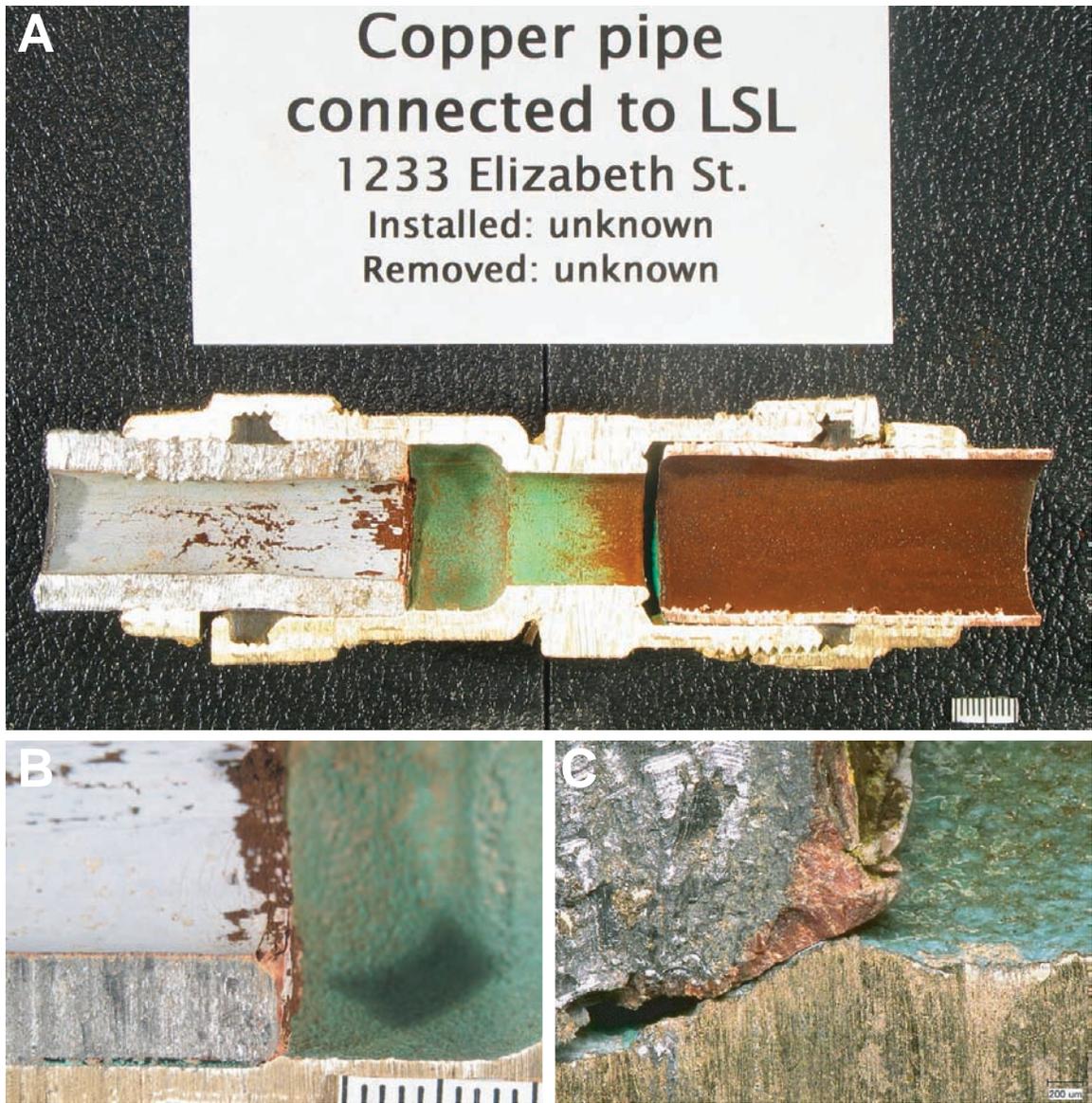


Figure 7. Photographs of pipe sample D_1. (A), (B): scale bar divisions in both images are in mm. (C): scale bar = 200 um.

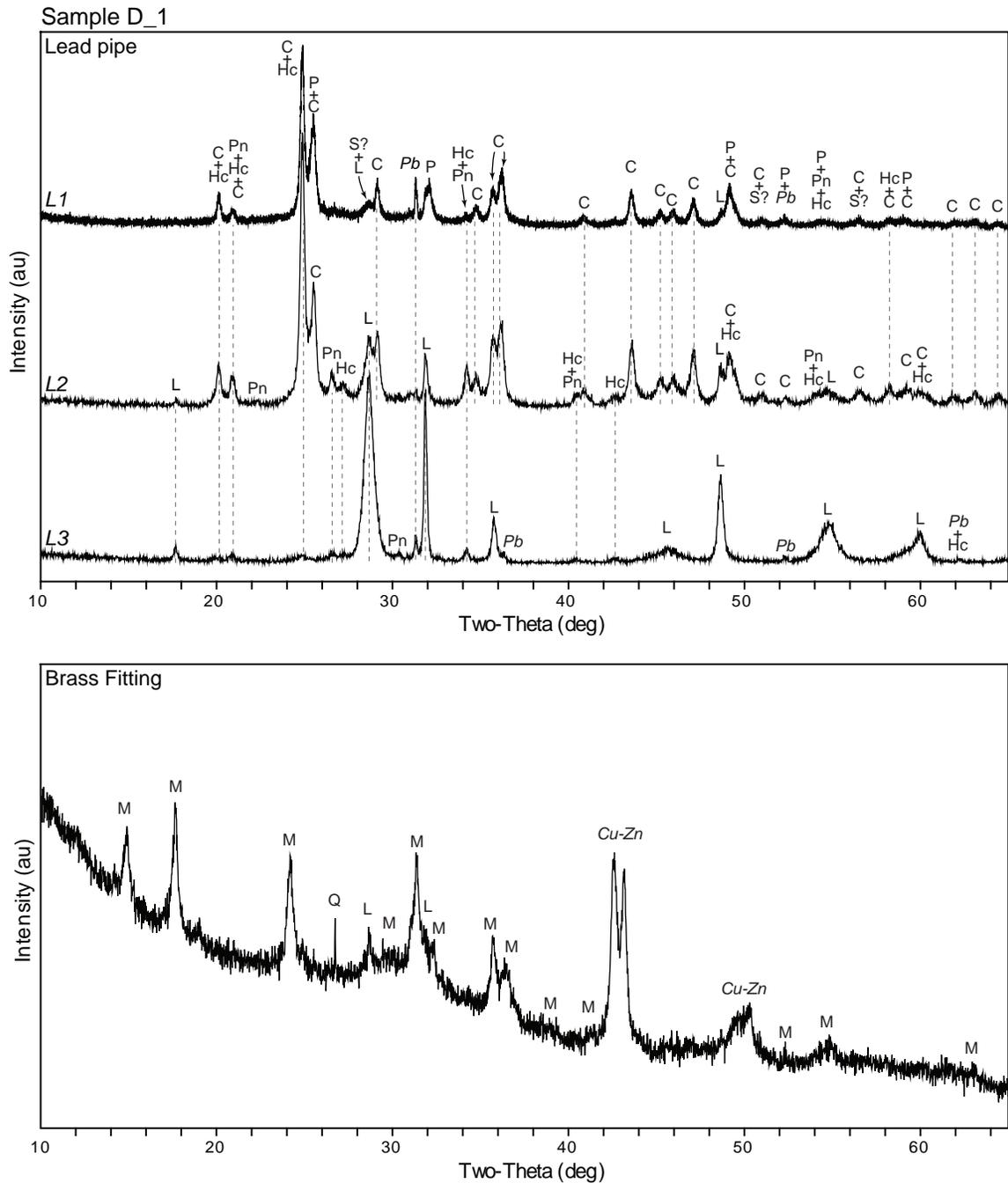


Figure 8. Sample D_1 powder X-ray diffraction patterns. Refer to Table 3 for key to mineral phase abbreviations.

Implications

Implications of the above observations include:

- (a) Deep corrosion localized in the area immediately adjacent to the pipe joints suggests a galvanic mechanism.
- (b) Examples from Utilities A and B, with evidence of brass or copper plumbing materials behaving anodically (corroding) when coupled to lead, run contrary to the conventional wisdom of commonly referenced galvanic series tables and standard electro-potential series⁷, which predict lead to be anodic. Distribution system water chemistry, reflected by the “background” scale mineralogy of the adjacent pipes, likely influenced the anodic/cathodic relationships of the coupled metals, but exact mechanisms are poorly understood at this time.
- (c) Mineralogy of scale deposits developed near the joints indicates areas of locally altered water chemistry, at a lower pH compared to that of the bulk distribution system water.

Acknowledgment

The authors would like to thank the representatives of each of the utilities for providing the pipe samples examined in this study.

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Evaluation of Lead Corrosion Control Measures

for a Multi-source Water Utility

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INTRODUCTION

The Philadelphia Suburban Water Company (PSW) is an investor-owned water utility serving an area of 339 square miles north and west of Philadelphia, Pennsylvania. PSW provides nearly 800,000 people in 64 municipalities with water from 4 surface water plants, one former quarry, and 40 wells. These diverse sources encompass a wide range of parameters related to corrosivity (Table 1).

PSW has long been concerned with corrosion control. Sodium hexametaphosphate was first introduced at one plant in 1948. Since 1972 Sodium Zinc Metaphosphate has proven to be a cost-effective means of addressing problems related to iron corrosion. A variety of corrosion control alternatives were investigated in pipe rack studies using mild steel pipes [1]. Studies done in the early 1980s with coupons attempted to evaluate effects of various treatments on both iron and copper corrosion. Only recently has the emphasis in corrosion control shifted to reducing lead levels at the consumer's tap [2,3].

In 1987, after the Safe Drinking Water Act amendments placed a ban on lead pipe and solder [4], PSW initiated a lead service line (LSL) replacement program. To date, 1844 services known or suspected to have some component of lead on the company side of the service were replaced or abandoned at a cost of about \$700 per service; however, LSLs probably were never a major source of elevated lead levels in the PSW system. As part of the service line replacement program, samples were taken at 21 sites before and after LSL replacement. Interestingly, the results actually showed a slight increase in lead levels after LSL replacement (Figure 1).

TIER 1 SITE SELECTION, SAMPLING, AND RESULTS

The contiguous PSW distribution system is divided into four divisions. Table 2 shows a comparison of the 1992 estimated percentage of water delivered to each division with the corresponding number of Tier 1 sites ultimately selected for sampling in each division. A target distribution of sites by division was proposed to ensure that each division and water quality type was fairly represented. Every effort was made to locate and include as many remaining LSLs as possible. A total of 30 such sites were identified and included in the sampling program.

Although potential Tier 1 sites, especially ones with lead services, tended to be clustered, the final selection of sites was fairly evenly distributed overall (Figure 2). Table 2 also shows the distribution of LSLs by division. The Great Valley Division, consisting of mostly newer homes, had no lead service lines. Out of 107 of the targeted Tier 1 sites, 103 actually participated in the first round of sampling. Results from this sampling were as follows:

90th percentile Lead	0.012 mg/L
90th percentile Copper	1.06 mg/L

Figure 3 shows a log-normal plot of the lead data accumulated for the first six month sampling period. Figure 4 shows a log-normal plot for the LSLs only. The similarity between the two plots is striking, indicating again that, in the PSW system, LSLs probably did not contribute significantly to elevated lead levels.

Figures 5 through 8 show log-normal plots of the Tier 1 lead data subsets by division. These show that the Southern division had the highest lead levels. Under the Lead and Copper Rule, large systems are required to complete corrosion control studies by July 1994 [4]. The log-normal plots confirm that evaluation of treatment alternatives for PSW's system should focus on the Crum Water Treatment Plant which provides 60% of the water supplied to the Southern division.

PIPE LOOP STUDIES

To meet the future requirements of the Lead and Copper Rule [6], a study was designed to evaluate present corrosion control treatment at PSW's Crum Creek Plant.

Previous studies

From 1979 to 1984, PSW conducted 21 corrosion control pipe rack studies, all at the Crum Creek Plant [1]. The primary focus of these studies was to minimize corrosion of iron and steel. A few of the later studies also looked at copper corrosion. Some coupon studies have also been conducted in the distribution system in the Southern Division.

Unfortunately, the results of the previous pipe rack studies were not

Reprinted by permission, Copyright © 2011, American Water Works Association. None gave any insight into the effectiveness of treatment for lead corrosion control. Only the latest coupon study involved lead coupons. However, results of lead coupon tests are of limited value because: 1) the lead corrosion rates are very low, 2) the coupons are easily damaged, and 3) the test conditions do not simulate those which affect lead levels in first-draw tap samples.

Study design

A recommended protocol for pipe loop testing for lead and copper corrosion studies has been developed by AWWARF [7]. For the Crum Creek Plant pipe loop study, the design was simplified by eliminating coupon racks and lead pipe loops, and using 30-foot 1/2-inch copper pipe loops with 20 lead-soldered fittings per loop. The focus on lead-soldered copper pipe was particularly warranted in this study, since there were very few lead services remaining in the PSW system.

The Illinois State Water Survey studied a three-loop system under a single water test condition, and found a small but statistically significant variability in results among different loops, probably due to random variations in the quality of soldered joints [7]. To attempt to address this variability, The Crum Creek Plant pipe loop study provided duplicate loops for each of the four conditions simultaneously tested:

Loops 1A and 1B -- Control -- filtered water from the clearwell of the Crum Creek Plant, prior to addition of any corrosion inhibitor.

Loops 2A and 2B -- pH Adjustment -- clearwell water to which caustic soda was added to raise the pH (ultimately at 10 mg/L to achieve pH = 8.0).

Loops 3A and 3B -- Lime Stabilization -- clearwell water to which lime was added at a dose of about 18 mg/L (as CaCO₃) to raise the pH and to develop a target value of calcium carbonate precipitation potential of 4 mg/L.

Loops 4A and 4B -- Plant Effluent, containing bi-metallic phosphate (BMP) corrosion inhibitor at 0.8 to 0.9 mg/L.

Conditions for loop sets #2 and #3 were selected to meet future requirements for corrosion testing contained in the Lead and Copper Rule.

Figure 9 is a schematic of the pipe loop apparatus used in this study. Material and labor costs for the unit were about \$5,000, excluding design, and the cost of sample pumps and automatic valves, which were scavenged. Construction of the apparatus began in April, and was completed in the last week of May, 1992.

Sampling

On May 24, the pipe loops were all flushed at a flow rate of about 1 gpm for 24 hours. The flow was then stopped for 24 hours, and on the morning of May 26 (Day 1), a series of ten 100-mL samples were collected from one loop in each set to evaluate an appropriate volume and flow rate for future sampling. Lead concentrations in these samples were quite high, but generally consistent for each loop tested, as shown in Figures 10 through 13. The nominal volume of each pipe loop is about 1.2 L. The results demonstrated that the planned sample size of 500 mL, collected at a flow rate of about 500 mL per minute, would be representative of water in the entire pipe loop.

On May 27, individual 500 mL samples were taken after a 15-hour stagnation period, and on May 28, collection of routine 6.5-hour stagnation samples began. The apparatus was designed to be operated in 8-hour cycles: water flowed through each loop at 1 gpm for 1 hour, followed by a 7-hour stagnation time. For most of the study, samples were taken twice a week, though at the beginning sampling was more frequent.

The ambient air temperature was recorded when samples were taken. Sample temperatures and pH were measured in the field. Within 2 hours, a second pH measurement was made in the laboratory before sample acidification and metals analyses were done.

After each round of standing samples were collected, a 1 Liter running sample was taken from one of each pair of loops (alternating between the "A" and "B" loops each time), for corrosion-related water quality parameters.

It is significant to note that some equipment failure occurred during the testing. The caustic pump failed on days 16 - 26, days 54 - 57 and days 86 - 88. Problems were also encountered with the lime feed pump. The lime slurry had a tendency to settle out in the tubing, resulting in occasional erratic lime feed. Lime pumping was interrupted on day 7, on days 16-18, and on days 36 -38.

During the first 30 days, the caustic soda feed rate of 9 mg/L proved to be slightly low, resulting in pH levels below 8 most of the time. The feed rate was subsequently increased to about 10 mg/L on day 32.

Results

Running samples were analyzed for pH, alkalinity and conductivity in the laboratory. Station 4 samples (Plant Effluent with the bimetallic phosphate) were also analyzed for ortho phosphate, while Station 3 (lime stabilization) and Station 1 (control) samples were analyzed for Calcium. Average values for these parameters appear in Table 3.

The lead analysis for the first-draw samples was done on a Perkin Elmer Model 4100 graphite furnace AA using EPA Method 239.2. Copper analysis

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was performed on a Perkin Elmer Model 3100 flame AA using EPA Method 220.1.

Lead

Figures 14 through 17 show the lead concentration during the 90-day test period. The effects of the interruption of lime and caustic feed were quite dramatic. Notwithstanding these equipment problems, it is evident that both the caustic and lime treatments produced significantly lower lead concentrations than either the control or the plant effluent. However, the difference in average lead concentration between the control and the plant effluent (treated with BMP) was not significant.

During the first part of the study, the scatter of the data between the A and B loops was significant, especially in the control (Figure 14). The data became more consistent as the study progressed. In general, the differences between the overall average lead concentration for A and B loops were much less than the differences between stations receiving different treatments. Average results for the first, second and third 30 day periods of testing are presented graphically in Figure 18. In calculating the averages, results were omitted for Loop 2A, 2B, 3A and 3B when the chemical feed was interrupted.

Copper

Figures 20 through 23 show the results for copper during the 90-day testing period. Increases in copper levels when caustic and lime feed were interrupted were even more dramatic than for lead. Results for the control loops show the highest copper levels and the greatest variability. Results for the lime feed loops show the lowest levels and the least variability. In general, there was much less scatter in the copper data than in the lead data. Unlike the results for lead, copper levels in the plant effluent (BMP treatment) loops are significantly lower than in the controls, though still above those in the pH adjusted and lime saturated test loops.

Figure 19 presents a bar graph of the average copper concentration in each set of pipe loops over the first, second and third 30 days of testing. Again, data were omitted for samples taken when the lime and caustic feed pumps were not working.

CONCLUSIONS

It is possible to design a single Tier 1 sampling program for a multi-source distribution system that fairly and accurately represents the entire system. Areas served by sources suspected of being more corrosive should be as heavily represented, in proportion to send-out, as areas served by other sources.

Log-normal plots of the data from Tier 1 sampling are very useful in

identifying outliers and comparing subsystems served by different sources. Lead and copper corrosion control studies can be targeted to sources serving subsystems showing the highest lead levels on comparative log-normal plots.

Pipe loop studies are essential to evaluate the potential efficacy of control measures on lead and copper levels at customers' taps. The use of two or more duplicate loops for each condition tested, and simultaneous testing of multiple conditions, should minimize variability due to extraneous factors.

In the Crum Creek plant pipe loop study, testing for lead indicated that lime stabilization and pH adjustment outperformed both the untreated filter effluent and the plant effluent with existing treatment. Testing for copper showed the existing treatment to be reasonably effective in reducing copper corrosion.

For both the lime stabilization and pH adjustment treatments, it was critical to maintain continuous chemical feed. In a full-scale application, it would be necessary to ensure that treatment can be sustained continuously and throughout a large distribution system. This may be problematic with both pH control and lime stabilization. Further tests will be conducted to investigate other strategies and products before a final treatment program is selected.

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TABLE 1

Ranges of Water Quality Parameters for Sources

<u>Water Source</u>	<u>pH</u>	<u>Alkalinity mg/L CaCO₃</u>	<u>Calcium mg/L CaCO₃</u>	<u>Langlier Index</u>
Surface Plants (treated)	7.0 - 7.1	40 - 60	24 - 37	-1.8 to -2.4
Upper Merion Reservoir and Limestone Wells	7.0 - 8.0	120 - 270	43 - 69	-0.02 to -1.0
Triassic Rock Wells	6.5 - 7.0	100 - 120	37 - 56	-0.15 to -1.8
Metamorphic Rock Wells (untreated)	6.5 - 7.0	50 - 75	24 - 66	-1.4 to -2.3

TABLE 2

Percent Sendout, Tier 1 Sites, and Lead Services by Division

<u>Division</u>	<u>Percent of Total Water Delivered</u>	<u>Number of Tier 1 Sites</u>	<u>Number of Lead Service Sites</u>
Western	32	34	13
Eastern	27	23	7
Southern	37	36	10
Great Valley	4	10	0

TABLE 3

Pipeline Study - Average Water Quality Parameters

<u>Station</u>	<u>pH</u>	<u>Alkalinity mg/L CaO₃</u>	<u>Calcium mg/L</u>	<u>Conductivity micromhos</u>	<u>Hardness mg/L CaCO₃</u>	<u>Ortho PO₄ mg/L</u>
Control	7.1	43	21	215	105	
pH Adj	7.7	50		230		
Lime	8.2	56	26	233	120	

FIGURE 1

1987 Lead Service Replacement Sites

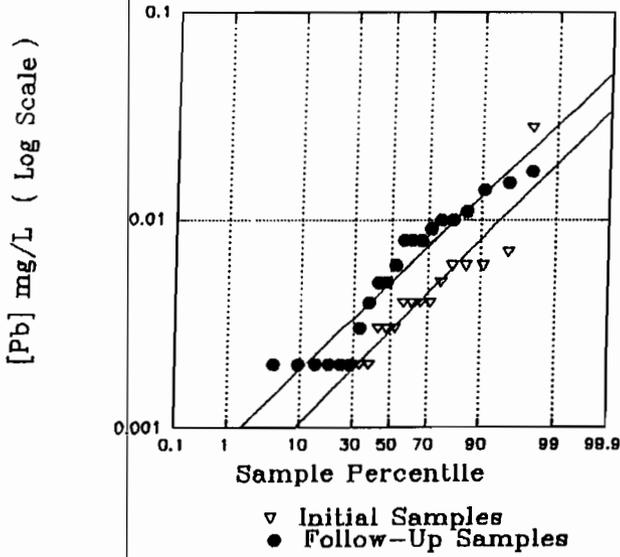


FIGURE 2
TIER 1 SITE LOCATIONS

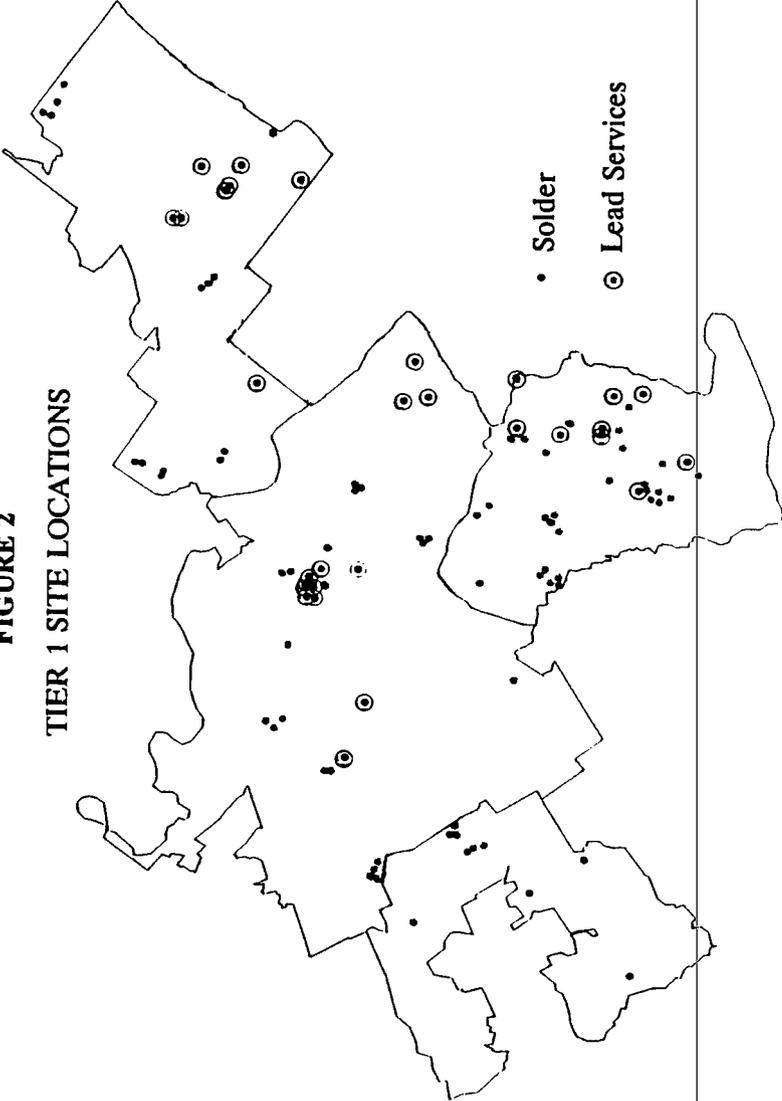


FIGURE 3

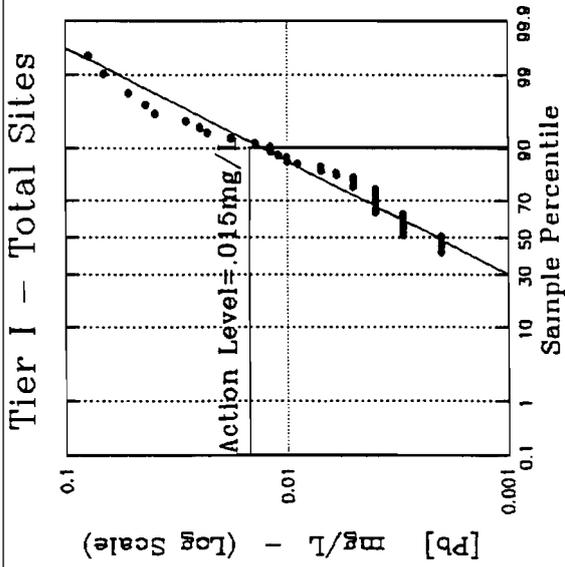


FIGURE 4

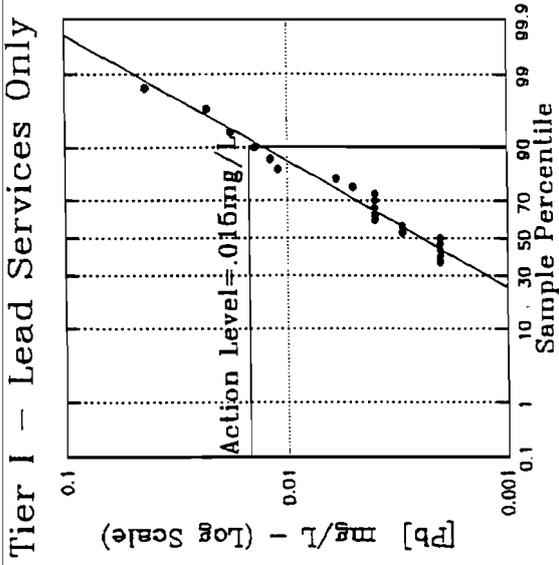


FIGURE 5

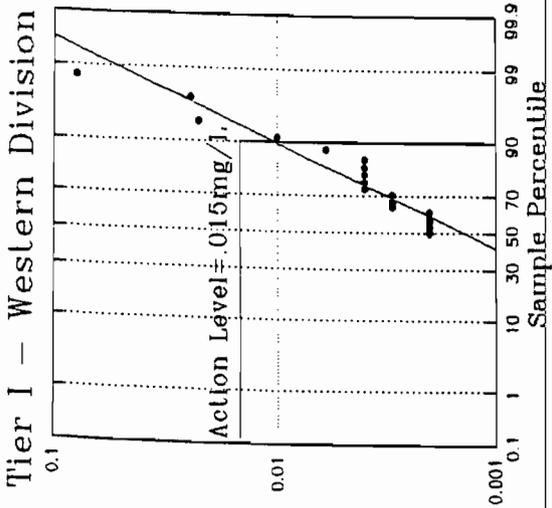


FIGURE 6

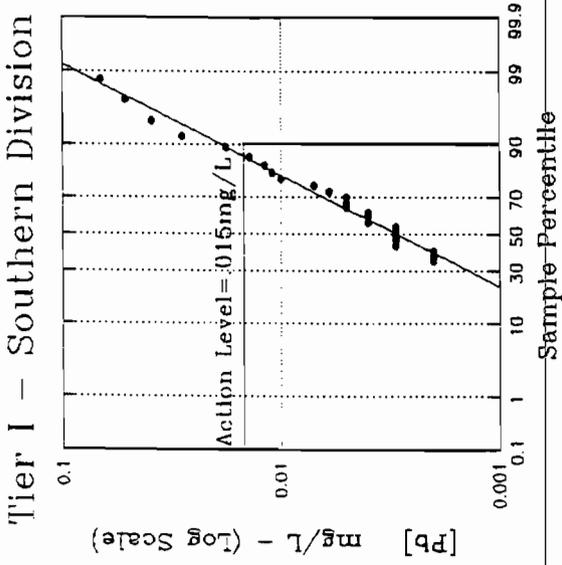


FIGURE 7

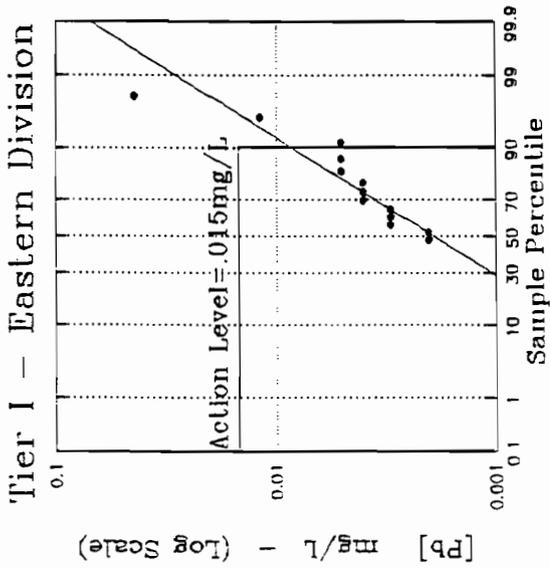


FIGURE 8

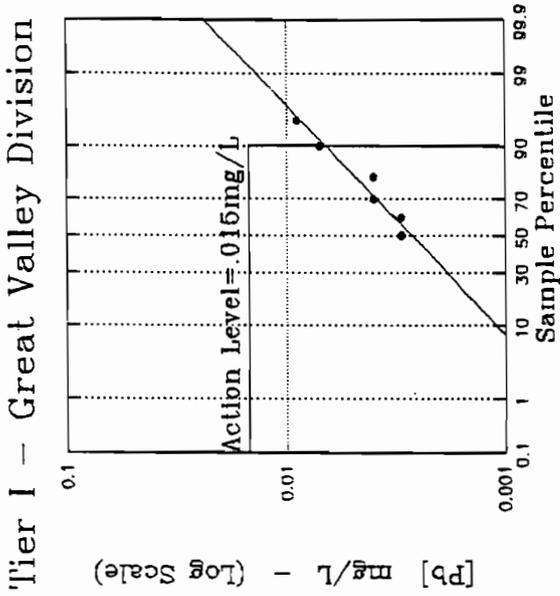


FIGURE 9

PROPOSED PIPE LOOP SCHEMATIC

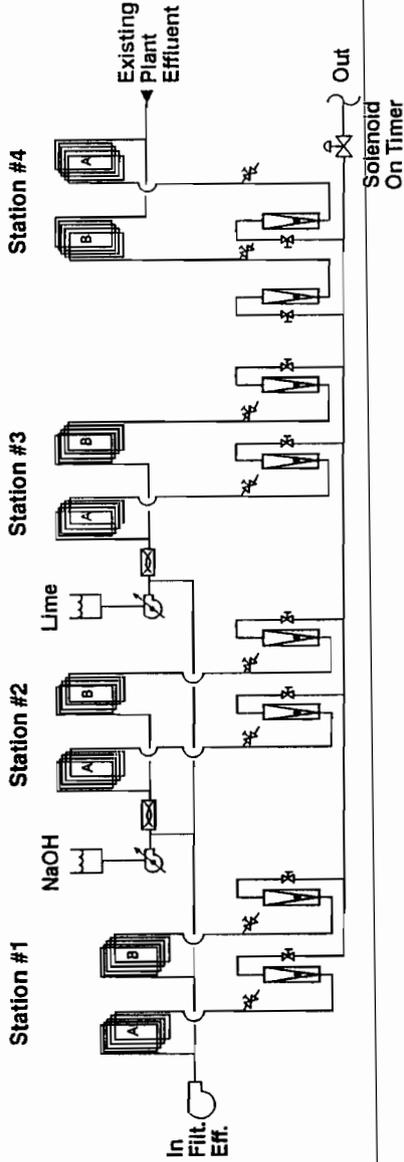


Figure 10
Control

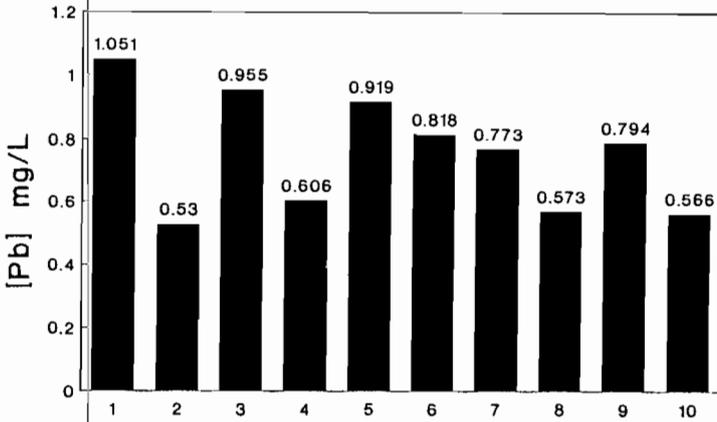
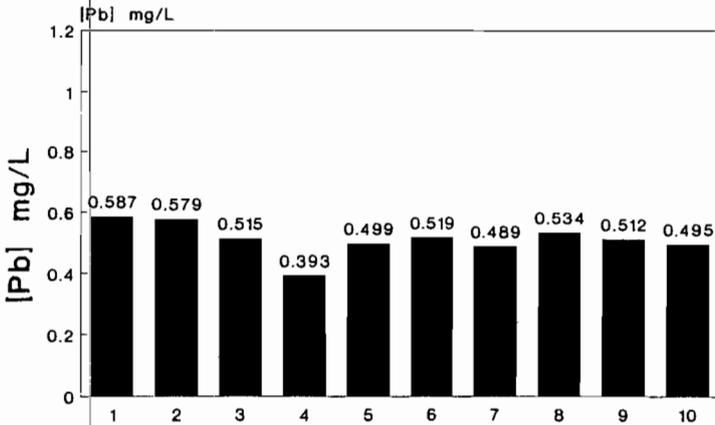


Figure 11
pH Adjustment with NaOH



Successive 100 ml samples
24 hr stagnation

Figure 12
Lime Stabilization

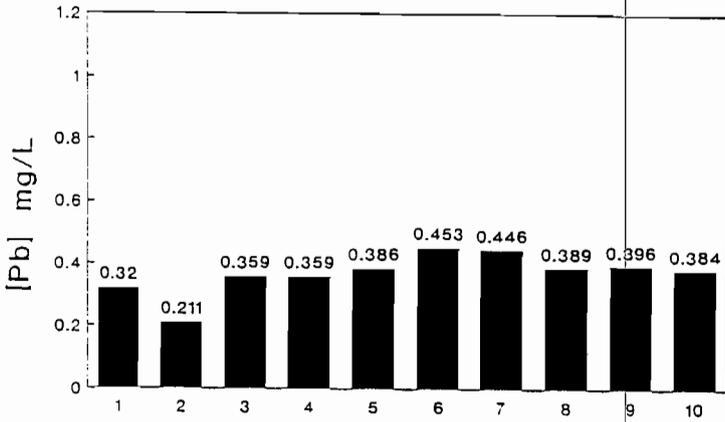


Figure 13
Plant Effluent

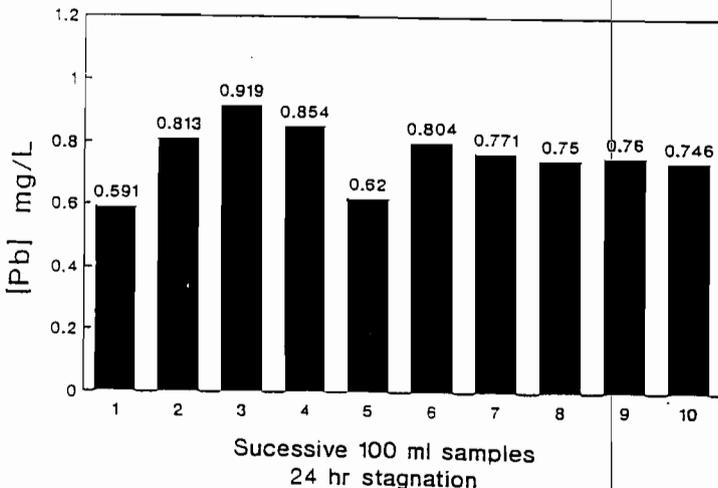


Figure 14
Control - Loops 1A & 1B

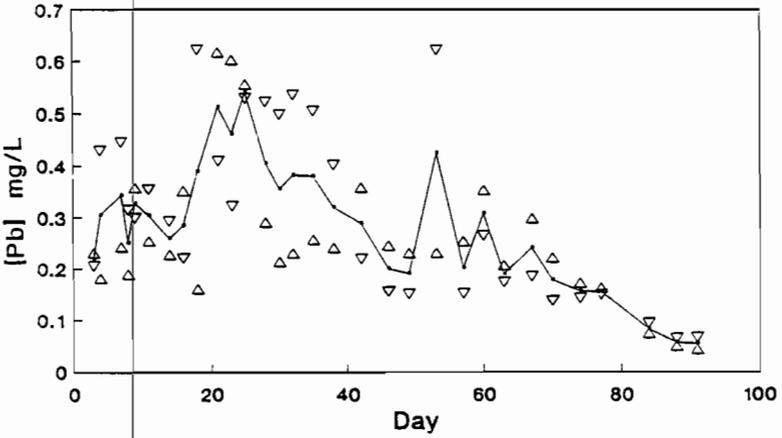
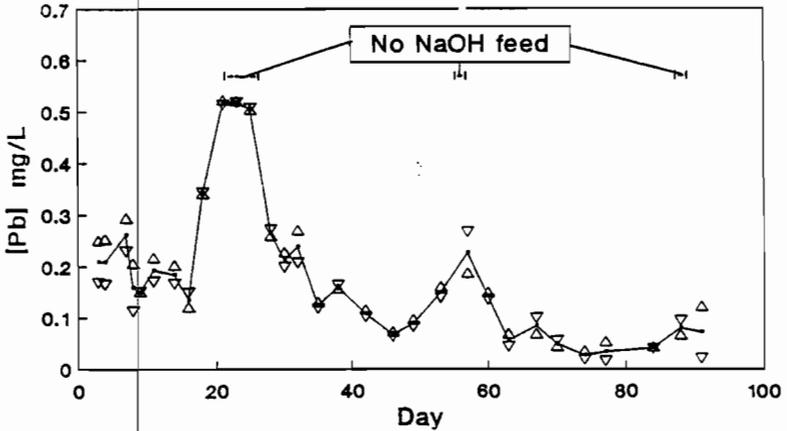


Figure 15
pH Adjustment with NaOH - Loops 2A & 2B



△ Station A ▽ Station B — Station Averaged

Figure 16
Lime Stabilization - Loops 3A & 3B

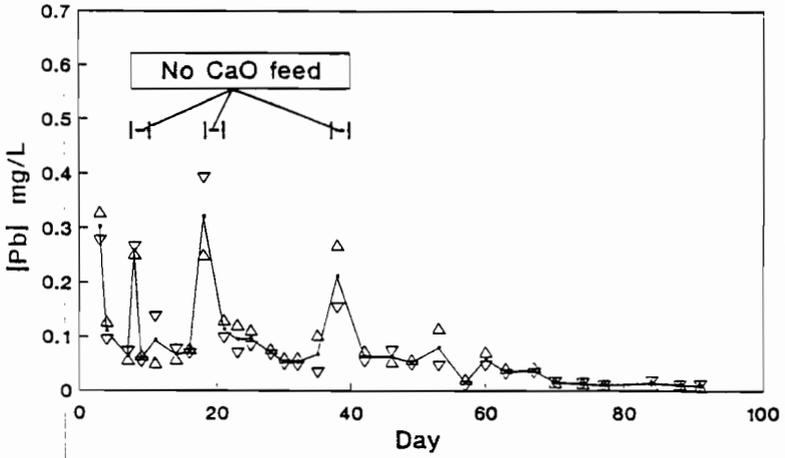


Figure 17
Existing Plant Effluent - Loops 4A & 4B

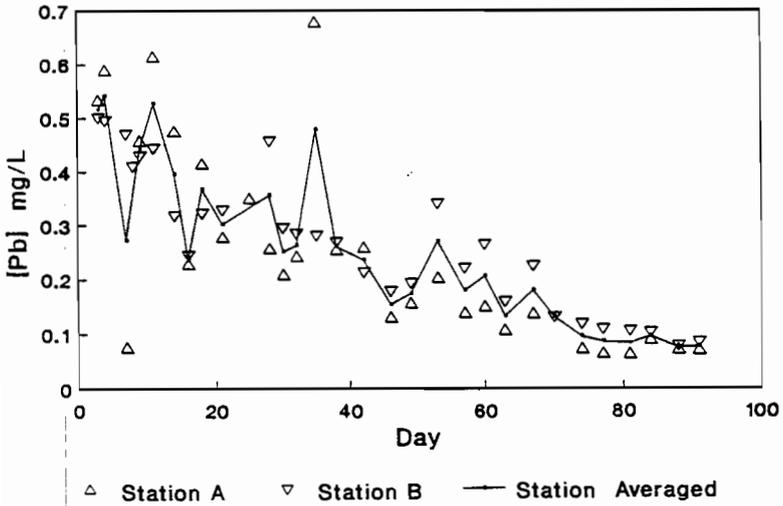
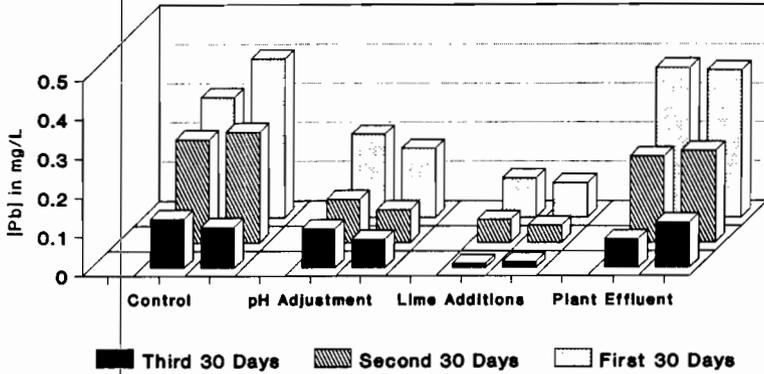
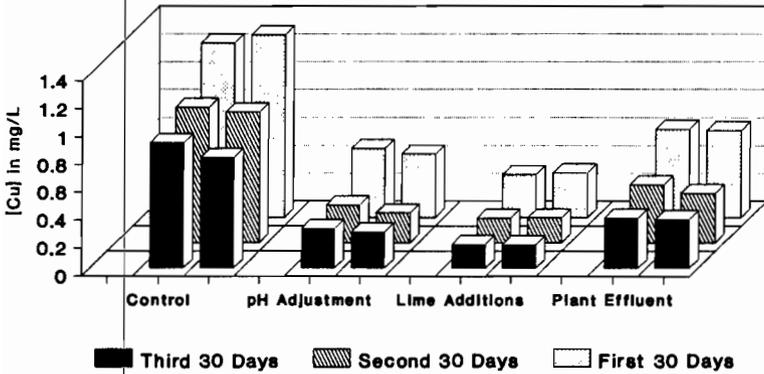


Figure 18
Crum Pipe Loop Corrosion Study - Lead
30 Day Averages



(with exceptions)

Figure 19
Crum Pipe Loop Corrosion Study - Copper
30 Day Averages



(with exceptions)

Figure 20
Control - Loops 1A & 1B

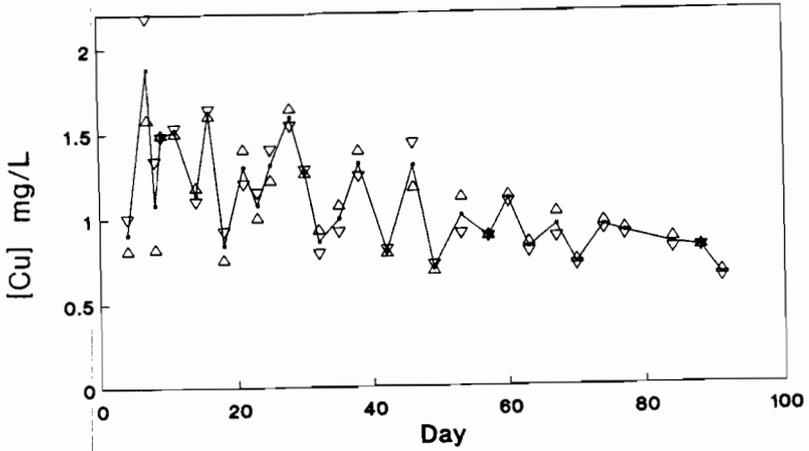


Figure 21
pH Adjustment with NaOH - Loops 2A & 2B

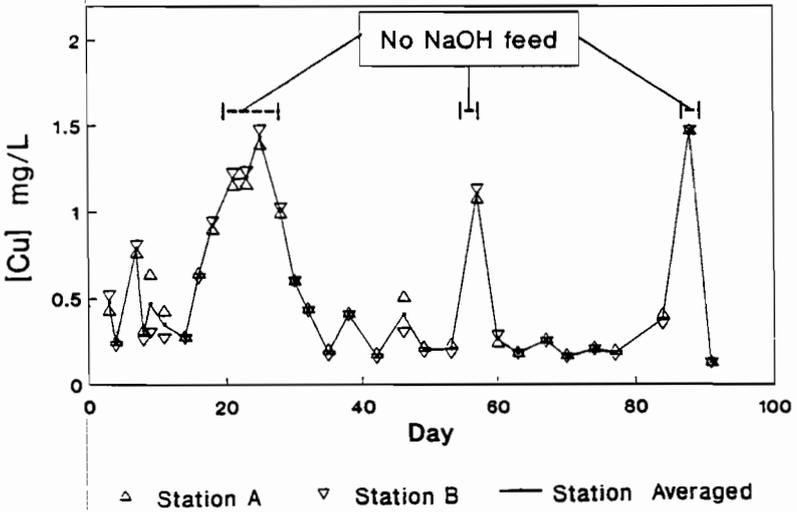


Figure 22
Lime Stabilization - Loops 3A & 3B

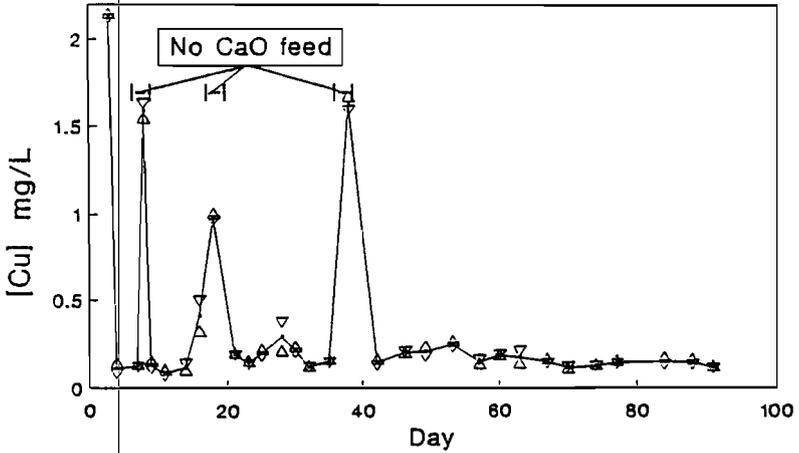
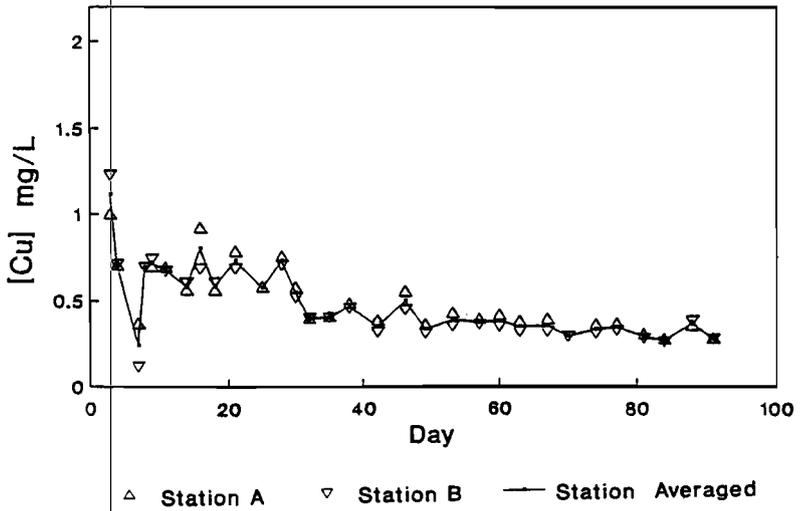


Figure 23
Existing Plant Effluent - Loops 4A & 4B



LEAD OCCURRENCE AND THE IMPACT OF LSL REPLACEMENT IN A WELL BUFFERED GROUNDWATER

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Abstract

While the approach is not new, the application of the analysis and interpretation of lead profile data contribute much needed information on the occurrence and potential control of lead in well buffered ground waters, a water quality type for which limited but somewhat unexpected results have been observed in other studies. For a system in which 20 to 40% of the residential and non-residential premise plumbing samples exceeded the lead action level, this study was critical for i) documenting the extent and magnitude of lead occurrence, and ii) assessing the feasibility of eliminating lead from the system to control lead measured at the tap. Water from a groundwater system in southwest Ontario is the focus of this study.

Introduction and Background

Health Canada's proposed Guideline for Corrosion Control was published in 2007 and makes significant changes to how lead is monitored and potentially controlled. In July 2007, Ontario published Schedule 15.1 – Lead, a new regulation that also significantly changes how lead is monitored and regulated. Both documents introduce monitoring requirements and control of lead as measured at the tap using stagnation samples (30 minutes, up to four 1 L sequential samples), rather than in the distribution system using a flushed sample. As a result, corrosion control may be necessary in systems that previously did not measure lead based on the old sampling protocol. The Ontario regulation differs from the USEPA's Lead and Copper Rule in that the Ontario Drinking Water Standard of 0.010 mg/L for lead is used to trigger corrosion control planning, based on more than 10 percent of samples exceeding 0.010 mg/L in two of three successive sampling rounds.

The City of Guelph (City) is one of the largest municipalities in North America that is exclusively a groundwater system. The City is located approximately 100 kilometers southwest of Toronto, Ontario. The City has 18 groundwater wells and one infiltration gallery, servicing over 100,000 people and geographically distributed throughout the City and neighbouring townships over an area of approximately 150 square kilometers. Three of the 18 wells are considered Ground Water Under the Direct Influence of Surface Water with Effective In-situ Filtration (GUDIWEF). The Arkell Spring Grounds well field, located to the southwest of the City, supplies up to 60 percent of the City's daily water use, and feeds the F.M. Woods treatment and pumping station via a 6 km aqueduct. Disinfection is provided

using sodium hypochlorite for all of the 18 wells and ultra violet light (UV) for eight of the 18 wells. Sodium silicate at a dose of approximately 5 mg/L is used at two of the wells for iron and manganese sequestration. A summary of raw water quality characteristics is presented in Table 1.

Table 1: Raw Water Quality Characteristics

Parameter	Typical Range	Minimum and Maximum Value
pH	7.0 to 7.5	6.5 to 8.5
Alkalinity (mg/L as CaCO ₃)	267 mg/L to 277 mg/L	248 mg/L to 310 mg/L
Hardness	408 mg/L to 493 mg/L	340 mg/L to 612 mg/L
Temperature	8 to 10°C	
Lead	Below Detection Limit (BLD)	

Based on the physical characteristics of the City, including hilly terrain and two rivers that divide the City, the distribution system operates with two pressure zones (zones 1 and 2) to provide relatively constant pressure throughout the distribution system. Some of the buried piping was installed approximately 130 years ago; the dominant water main materials used include cast iron, ductile iron, and polyvinyl chloride (PVC). Areas of the City are fed from different wells in response to water demand, and portions of the system cannot be hydraulically isolated as a function of the source well.

The City's records indicate that approximately 2,500 of the 36,000 customer water service lines in the City are known or suspected to contain lead. In 2008, 71 LSLs were replaced.

The literature on lead control for analogous systems or well-buffered ground water systems is limited (1, 2). The Madison Water Utility explored a range of treatment based approaches for corrosion control for its water characterized as a hard, alkaline water source with high DIC (1). Alternatives examined included alkalinity and pH adjustment, calcium hardness adjustment, polyphosphate and silicates inhibitors. All were deemed ineffective for lead reduction with the exception of orthophosphate. However the application of orthophosphate was limited by observations of elevated copper, increased phosphate loading at the wastewater treatment plant, and increased phosphate levels in storm water run-off. As a result, the Madison Water Utility pursued the use of lead service line (LSL) replacement as the preferred approach to corrosion control on the basis of cost, environmental impact, and public support. Under this program, both the utility owned and the privately owned portions of the LSL are being replaced.

Alternatives to chemical treatment to control lead at the tap are being considered by the City, including LSL replacement. To assess the feasibility of LSL replacement for corrosion control, the City initiated a Lead Profiling Study to examine the impacts of partial and full LSL replacement on reducing lead. Results from this effort are presented in this paper.

Methods

The City implemented a “Lead Profiling Study” involving research and data collection at five residential sample locations over the course of one year. Four homes participated in the study: two with a full LSL replacement and two with a partial LSL replacement. Monitoring started in June 2008, and fourth quarter sampling was completed in summer 2009.

Data for all five sites were analyzed in two ways. Lead profiles were generated to i) relate the source of lead to the lead measured at the tap per Sandvig and Kwan, 2007(3), and ii) assess the short-term impacts on lead levels due to disturbances to the scale during replacement. Data for four weeks of sampling were used in this analysis (pre-replacement, days 1, 2, 3, and 7, and weeks 2, 3 and 4). The City offers free lead sampling and analysis, 6, 12, and 18 months after a municipally and/or residentially owned service line has been replaced to monitor the impact of replacement on lead concentrations measured at the tap.

Site Selection

During the summer of 2008, five single family residential locations were selected to participate in the sampling program based on the following criteria:

- Known or suspected lead on the city side of the water service
- Relatively high lead (above the standard of 10 ug/L)
- Homeowners willing to allow Operators into their home frequently over a period as long as 13 months for sampling purposes

It was also important that any treatment device present could be bypassed for sampling (i.e. water softeners or filters). Five single family residential homes participated in the Lead Profile Study, and the results from three of the sites are presented here (see Table 2).

Table 1: Summary of Participating Sites, Lead Profile Study

Site ID	Description of LSL Replacement	System Characteristics
Site 1 <i>*Reviewed in this paper</i>	Full LSL replacement in two stages	Removed 11.0 m (36 ft) lead and 7.6 m (25 ft) iron
Site 2	No LSL; site removed from study	No lead confirmed during excavation
Site 3 <i>*Reviewed in this paper</i>	Partial LSL replacement	Removed 6.1 m (20 ft) lead on municipal side
Site 4	Full LSL replacement in two stages	Removed 4.6 m (15 ft) lead on municipal side Copper installed on private side prior to study
Site 5 <i>*Reviewed in this paper</i>	Partial LSL replacement	Removed 18.9 m (62 ft) of lead on municipal side

Sampling Protocol

Lead concentrations were monitored at the five locations to create a site specific lead profile. These results were used to identify the source of lead (e.g., sources other than the LSL) and the magnitude of lead release from the premise plumbing. One Operator visited each site to characterize the plumbing system, including:

- Length, diameter and material of in-home plumbing from service line to the kitchen tap, with reference made to the location of the water meter and any other fittings
- Length, diameter, and material of the privately-owned service line
- Length, diameter, and material of the municipally-owned service line
- Material of main feeding the service line

Results from the site characterization were used to relate the sample volume collected to the material used either within the home or in the service line.

The features of the sampling protocol used for the lead Profile study include:

- Collection of up to 13 samples over a one year period, including one prior to LSL replacement and 12 after LSL replacement (or until the stabilization of lead levels was observed)
- Collection of three 1 L samples after a five minute flush, followed by a 30 minute stagnation period and the collection of eight sequential 1 L samples
- The frequency of sampling after the LSL replacement was as follows:
 - 1, 2, and 3 days after LSL replacement
 - 1, 2, 3, and 4 weeks after replacement
 - 2 and 3 months after replacement, and
 - quarterly sampling for up to one year after replacement

The parameters sampled varied with the sampling date, and included total lead, dissolved lead, a full metal scan, alkalinity, total suspended solids, dissolved oxygen, and total organic carbon. The sample collection schedule and the sampling parameters are shown in Table 3. Schedule 1R was followed for samples collected prior to LSL replacement (pre-sample), day 1, and day 7. The “A” beakers were collected after a five minute flush but prior to a 30 minute stagnation period; the “B” beakers were collected after a five minute flush and 30 minute stagnation period. Each beaker was used to collect a 1 L sample; beakers 1A and 2A were collected sequentially after a five minute flushing period. Beakers 1B to 9B were collected sequentially after an additional 30 minute stagnation period. Schedule 2R was followed for samples collected on all sampling days (up to three months for some sites included in this report) excluding samples collected prior to LSL replacement, day 1, and day 7. Schedule 3R was followed for samples collected at hydrants upstream of the homes for the pre-sample, day 1, and day 7 after a five minute flushing period.

Table 3: Sampling Protocol for Lead Profile Study

Schedule No.	Beaker 1A (Flushed 5 min)	Beaker 2A (Flushed 5 min)	Beaker 1B (Standing 30 min)	Beakers 2 – 7B (Standing 30 min)	Beaker 8B (Standing 30 min)	Beaker 9B (Standing 30 min)
1R	Total Pb	Total Pb	Total Pb	Total Pb	Total Pb	
Pre-sample	Dissolved Pb	Dissolved Pb	Dissolved Pb	Dissolved Pb	Dissolved Pb	
Day 1	Alkalinity		Alkalinity			
Day 7	pH		pH			
	Temperature		Temperature			
					Suspended solids	
						Dissolved Oxygen
						TOC
						ICAP Scan
2R	Total Pb	Total Pb	Total Pb	Total Pb	Total Pb	
Day 2	Alkalinity					
Day 3	pH					
Day 14	Temperature					
Etc.					Suspended solids	
3R	Total Pb					
Hydrant	Alkalinity					
	pH					
	Temperature					

The following analytical methods were employed in this study:

Dissolved Oxygen		APHA 4500 OG
Total Lead Dissolved Lead ICAP scan	Lab Filtered Metals by ICPMS Metals Analysis by ICPMS (as received)	EPA 6020
Total Organic Carbon		EPA 415.1 modified
Total Suspended Solids		SM 2540 D

Results and Discussion

Data collected from three of the participating five sites are presented in Figures 1 to 6 to demonstrate the impact of full (Site 1) and partial (Sites 3 and 5) LSL replacement. Data for each site are presented in a similar manner, using two methods of analysis:

- i) lead profiles were generated to relate the source of lead to the lead measured at the tap (per 2) to determine the impact of LSL replacement on lead release
- ii) charts of lead results with time were developed using data in samples collected using Ontario's regulated sampling protocol (based on the higher lead result measured in two sequential 1 L samples following a 30 minute stagnation period) to assess the impact of LSL replacement on regulatory compliance, including any short-term impacts on lead levels due to disturbances to the scale during LSL replacement

Two charts are presented for each site based on the above descriptions. In the lead profile charts (e.g., Figure 1), the pre-LSL replacement samples are denoted by a thick black line; the blue lines in various shades are used to represent the results from lead samples taken after LSL replacement, with lighter blue getting progressively darker as the sample period progressed. The yellow arrows represent the water that may be present in the premise plumbing and service line, based on site characterization information. In the regulatory compliance charts (e.g., Figure 2), data for the lead sample that would be used to determine regulatory compliance is presented with time, starting with a sample collected prior to LSL replacement. Arrows are used to indicate the approximate timing of full or partial LSL replacement.

Site 1 – Full Lead Service Line Replacement

Lead concentrations observed as part of the Legislated Sampling Program were 14 ug/L in round 1 (January 2008) and 22 ug/L in round 2 (June 2008). In samples collected immediately prior to the LSL replacement, lead concentrations above 80 ug/L were observed. Based on the site characterization data, the lead peaks appear to correspond with the LSL (municipal and private side).

During the replacement of the service line, 11.0 m (36 ft) of 12 mm (½ inch) lead pipe was removed on the City side and an additional 7.6 m (25 ft) of iron pipe was removed seven days later on the residential side. As a result of LSL replacement, lead concentrations below 10 ug/L were consistently observed at this site and as a result, sampling was discontinued after 12 weeks (see Figures 1 and 2). The results for this site demonstrate the potential of full LSL replacement to reduce lead concentrations measured at the tap, consistent with studies by others in the literature (2, 3). The disturbance to the lead scale was observed to be minimal at this site based on the short-term elevations in lead levels in the days immediately following LSL replacement (see Figure 1).

Site 3 – Partial Lead Service Line Replacement

Lead measured in samples collected as part of the Legislated Lead Sampling Program varied from non detect in round 1 (January 2008) to 37 ug/L in round 2 (June 2008). In the sample collected the day prior to the LSL replacement, lead peaks greater than 25 ug/L were measured at this site and all pre-LSL replacement samples were above 20 ug/L (see Figure 3). Based on the site characteristics, the privately owned service line is represented by samples Standing L2 and Standing L3, and the municipal owned service line is represented by Standing L4. In replacing the service line, 6.1 m (20 ft) of 12 mm (½ inch) lead pipe was removed from the City side. It was estimated that approximately 10.7 m (35 ft) of 12 mm (½

inch) of lead piping was installed on the residential side from the curb stop to the water meter. Results from the site survey indicated that there was 9.1 to 13.7 m (30 to 45 ft) of unexposed internal plumbing, and this length is also suspected to be lead. After two months of sampling, concentrations of 15 ug/L were still being observed at this location (Figure 4).

Site 5 – Partial Lead Service Line Replacement

Lead measured in samples collected as part of the Legislated Lead Sampling Program in round 2 (June 2008) were as high as 45 ug/L for this site. In the samples collected immediately prior to the LSL replacement, lead concentrations varied from 50 to 160 ug/L. Based on the site characteristics, the privately owned service line is represented by samples Standing L2 and Standing L3, and the municipal owned service line is represented by Standing L4 (see Figure 5). In replacing the service line, 18.9 m (62 ft) of 12 mm (½ inch) lead pipe was removed from the City side. On the private side there is estimated to be approximately 3.0 m (10 ft) of 12 mm (½ inch) lead pipe from the curb stop to the water meter, and 12.2 m (40 ft) of unexposed internal plumbing that is suspected to be lead. It is evident that the partial LSL replacement at this location was successful in decreasing lead concentrations at this site; however, after one month of monitoring, lead continues to be measured at concentrations of 20 ug/L indicating that other sources of lead still remain at this location (see Figures 5 and 6). Results for the 6 month and 12 month sample following LSL replacement were 10 and 11 ug/L, respectively, and the magnitude of the improvement observed at this location is very promising.

Summary

A summary for all five sites that participated in the lead profile study is presented in Table 4, based on samples that would be used to determine compliance (as measured in the higher of the first or second 1 L sample).

Table 4: Summary of Results for Lead Profile Study

Site	Type of LSLR	Impact on Lead Levels	Lead Before LSLR (µg/L) ¹	Lead After LSLR (µg/L) ²	Time After LSLR ³	% Lead Reduced	Less than 10 µg/L?
Site 1	Full	Reduced	24	2.2	2 months	91%	Yes
Site 2	None	N/A	3	3	N/A	N/A	Yes
Site 3	Partial	Reduced	23	13	9 months	43%	No
Site 4	Full ⁴	Reduced	77	3.4	6 months	96%	Yes
Site 5	Partial	Reduced	60	9.8	6 months	84%	Yes

Notes:

1. Based on the higher result measured in the first two 1 L samples collected after a 5 minute flush and 30 minute stagnation period.
2. Based on achieving equilibrium or latest result if equilibrium not yet achieved.
3. Time after LSL replacement to reach reported results.
4. Homeowner’s effort to reduce the number of lead soldered joints was necessary to achieve this performance.

The data suggest that if the full LSL is replaced (site 1 and 4), or if there is no LSL (site 2), lead can be measured at levels well below 10 µg/L, with reductions of 91 to 96 percent observed. If the LSL is only replaced on the municipal side (sites 3 and 5), variability in the results can be observed. For the sites with partial LSL replacement, lead levels increased temporarily and ultimately decreased to levels below concentrations observed before LSL replacement, but not necessarily to levels below 10 µg/L. Reduction of lead varied from 43 to 84 percent following a partial LSL replacement.

Results for site 4 are important in that the efforts by the homeowner to remove of old copper pipe and lead soldered joints in the premise plumbing were required for a higher removal efficiency of 96 percent, which was 6 percent higher than the results achieved after the LSL replacement.

Results that were a factor of almost 20 times higher than the regulatory standard were observed at some locations in samples that went beyond the sampling protocol defined by the regulations (e.g., in the 4th and 5th sequential sample rather than the 1st or 2nd sample). Despite these high peaks, partial and full LSL replacement were observed to reduce lead; of interest however, is whether or not the reductions are enough to bring the site – and the system as a whole – into compliance. To determine this, lead compliance charts were generated using results only for the 1st and 2nd sequential 1 L sample to assess the long-term impacts on LSL replacement. Results showed that following a short term increase (lasting from days to two weeks), lead levels were reduced (at sites with full LSL replacement) or maintained (at sites with partial LSL replacement).

Conclusions and Recommendations

The results from this study have primarily examined the feasibility and benefits of corrosion control by non-treatment with LSL replacement. Further investigation is needed to refine the cost estimates and to assess water quality performance. This may include a pipe loop study to determine appropriate chemical treatment (with phosphates and/or silicates) or additional lead profile studies to determine the effectiveness of LSL replacement. It is crucial that the number of LSLs identified in the City's system be better defined. All financing and timeline determinations depend solely on this number: if the number is not accurate, the schedule – and performance – will be compromised. The City continues its pursuit of identifying lead in the system and undertakes LSL replacements on the municipal side. New information will also be available to homeowners on the importance of replacing lead services. Additional discussions will be held with the regulator to review the feasibility of lead replacement for corrosion control.

The purpose of this study was to determine the feasibility of lead removal as a feasible approach to corrosion control based on the City's unique system features. The City uses a well-buffered ground water made up of 18 wells; there is limited literature on similar systems to assist in the determination of the most appropriate corrosion control alternative. Results from the lead profiling study using samples collected both before and after LSL replacement were mixed:

- As expected, full LSL replacement resulted in reducing lead levels to below the ODWS of 10 ug/L, although temporary spikes in lead levels were observed (Site 1)
- Partial LSL replacement resulted in either a minor impact (Site 3) or a noticeable decrease in lead levels (Site 5); however in both cases temporary spikes were observed but lead levels were still greater than 10 ug/L one to two months after replacement.

Results from other sites (data not included in this presentation) indicated the success of full LSL replacement as well as of partial LSL replacement, suggesting that the benefits of partial LSL replacement is site dependent in the City's water.

Cost estimates were generated for alternatives based on non-treatment (LSL replacement) and treatment (phosphates or silicates, with or without pH adjustment). The distribution system configuration together with the localized nature of lead occurrence in the City lends itself to a non-treatment solution for corrosion control such as LSL replacement. However, the success of a corrosion control strategy based on LSL replacement – while fundamentally correct in that lead is eliminated from the system – is limited by property ownership issues, homeowner participation in private LSL replacement, the number of LSLs that can be replaced per year, and the water quality impacts of partial LSL replacement. The results from this study are being used by the City to assess alternatives for corrosion control in its system, and to develop a corrosion control strategy.

Acknowledgements

This work was undertaken while the lead author was employed with Stantec Consulting. The support of Iva Danilovic (Stantec Consulting) to complete this study is appreciated.

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Figure 1: Site 1 (Full LSL Replacement), Lead Profile

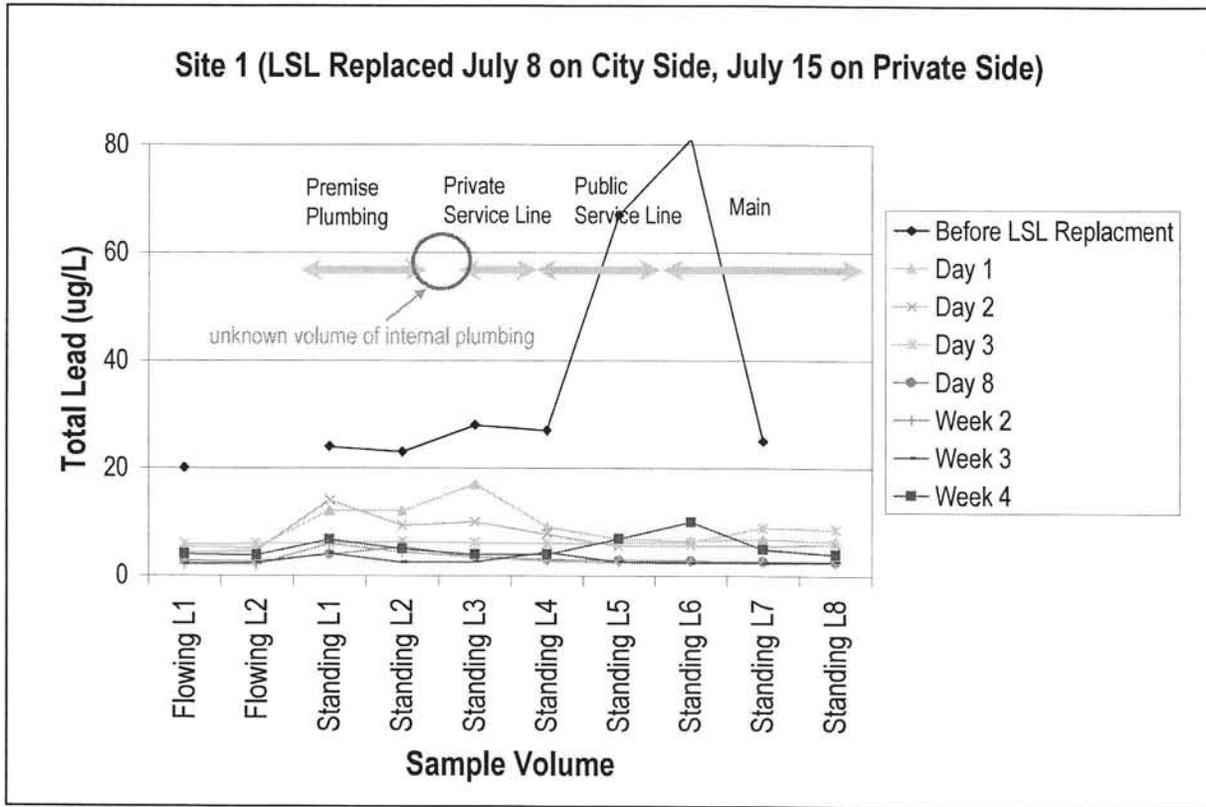


Figure 2: Site 1 (Full LSL Replacement), Regulatory Compliance

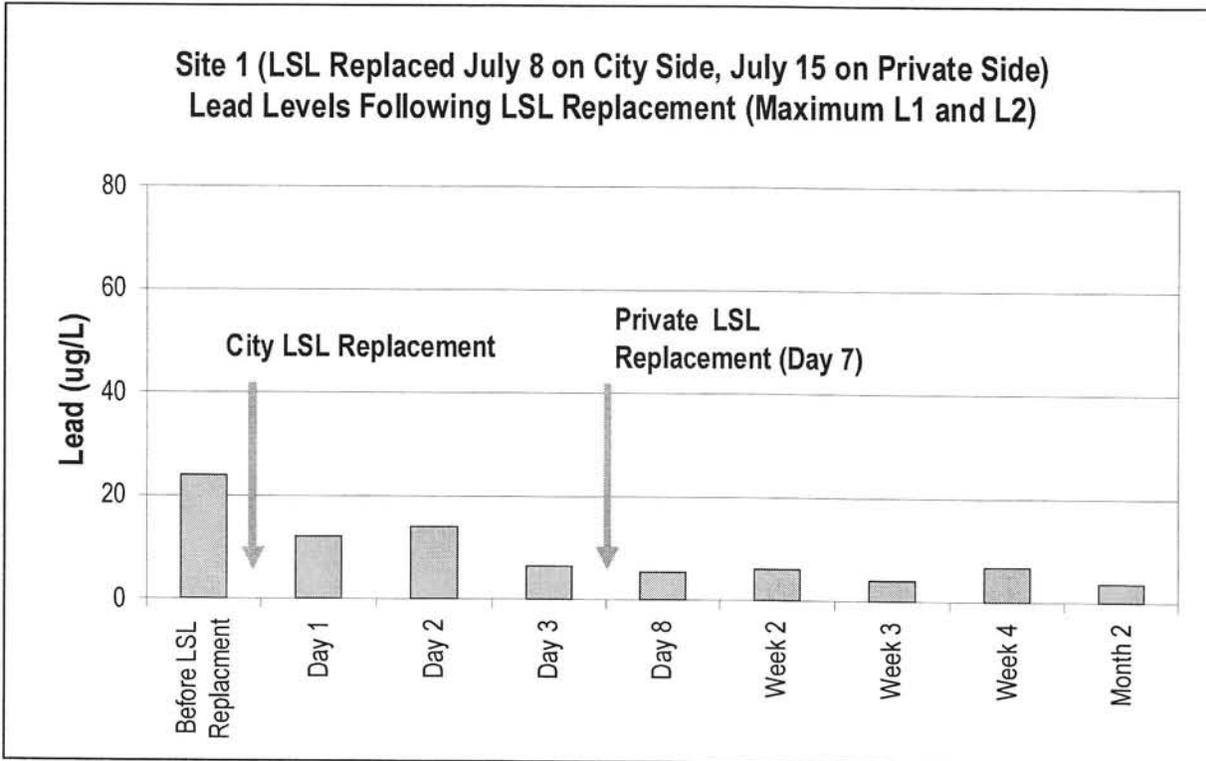


Figure 3: Site 3 (Partial LSL Replacement), Lead Profile

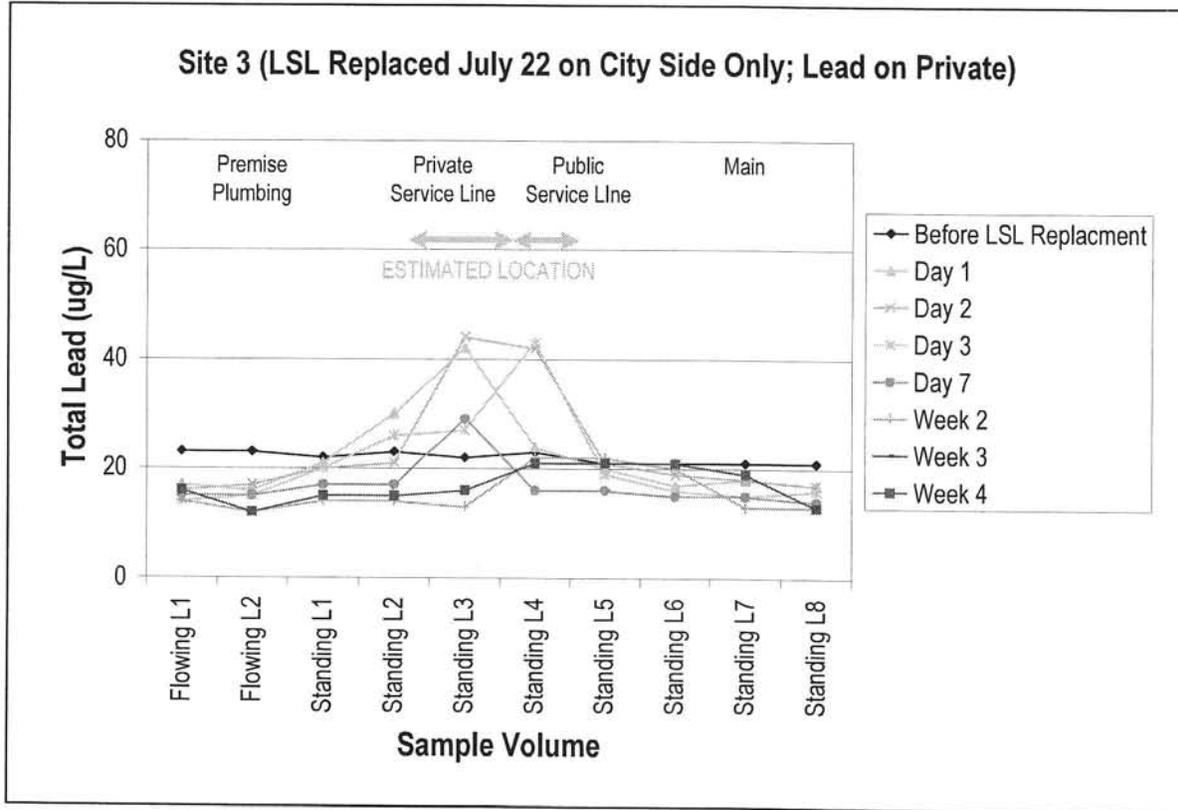


Figure 4: Site 3 (Partial LSL Replacement), Regulatory Compliance

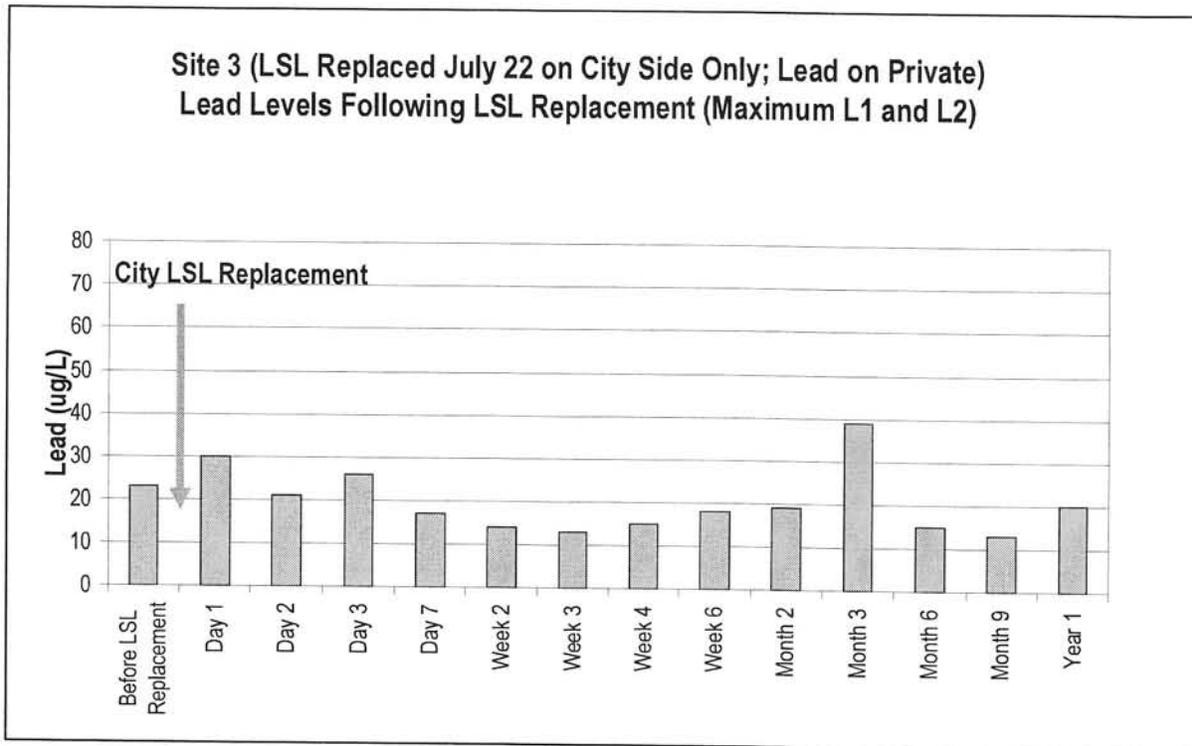


Figure 5: Site 5 (Partial LSL Replacement), Lead Profile

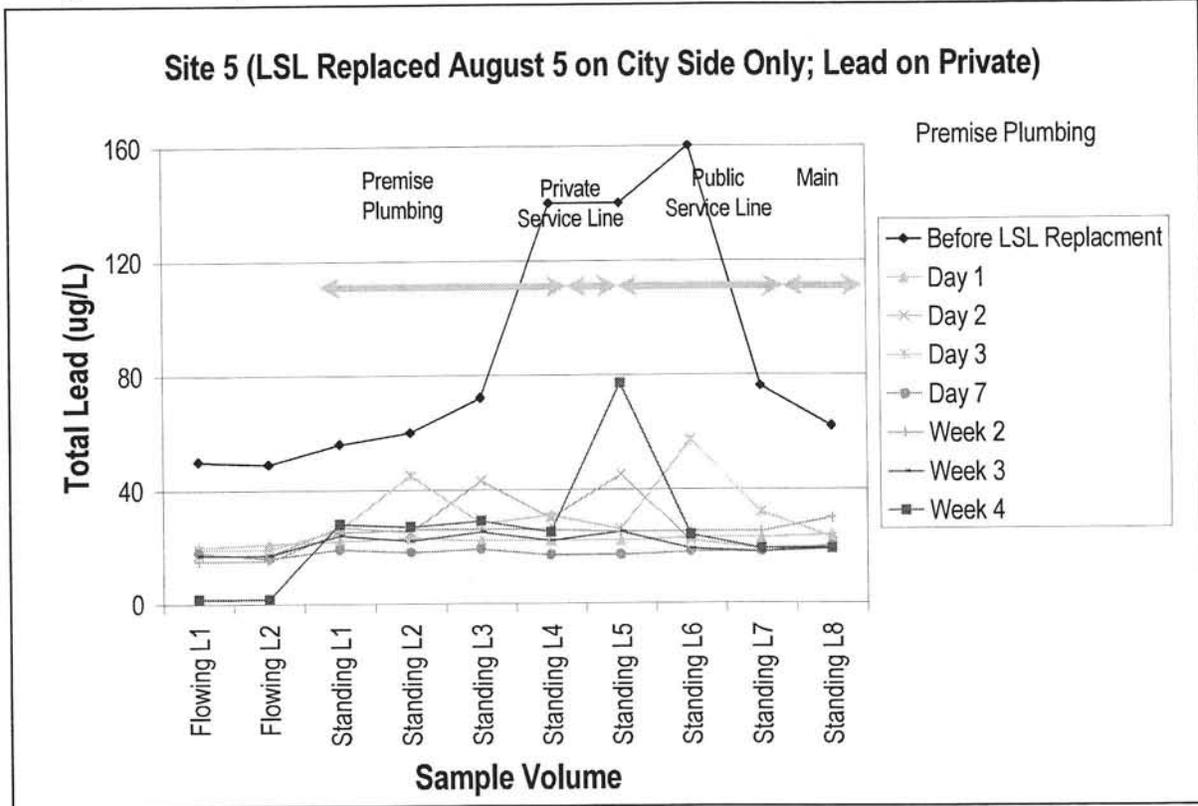
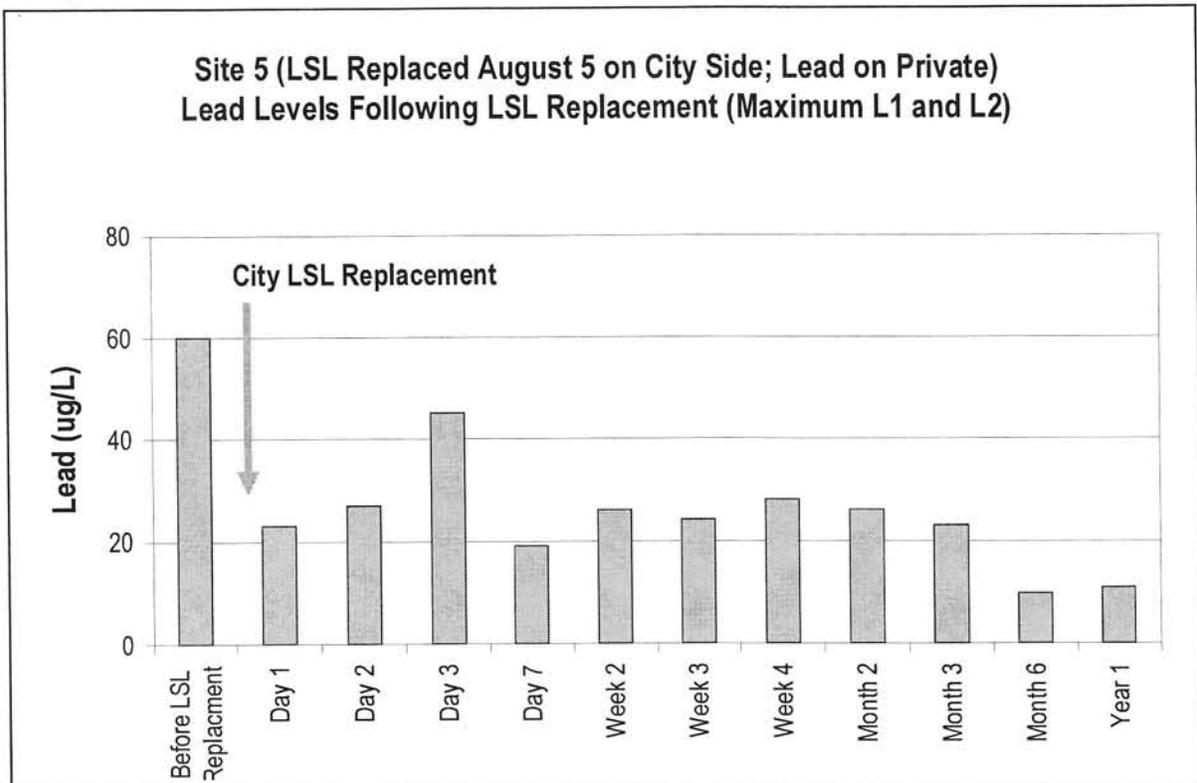


Figure 6: Site 5 (Partial LSL Replacement), Regulatory Compliance



Water Quality Effects of Partial Lead Line Replacement

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INTRODUCTION

The Lead and Copper Rule (USEPA 1991a) was promulgated in 1991 for the purpose of controlling lead and copper leaching into the drinking water. The rule did this by mandating that utilities optimize corrosion control practices to reduce lead and copper leaching. Under this rule, systems are required to monitor lead and copper levels at the taps of specific types of locations. A system is considered optimized if the 90th percentile of all required sampling is below the action levels of 15µg/L for lead and 1.3 mg/L for copper. If a system should have 90th percentile values above the action level for lead, the system would then be triggered into specific actions including specific public notification, a re-optimization of the system, and the system would be required to replace 7% of its lead service branches per year until all of the lead service branches are removed from the system or the system has two consecutive monitoring periods with lead 90th percentiles below the action level.

The purpose of the lead service branch (LSB) replacement requirement was to remove a potentially significant source of lead from the distribution system. However, utilities only have the ability to replace the portion of the lead service branch which they own. Typical utility ownership is from the water main to the property line, but local jurisdictions may interpret the exact point of ownership differently (Kirmeyer et al., 2000, AWWA 2005). Therefore, unless the customer is willing to replace their portion of the LSB, a partial replacement of the LSB is performed. The cost of replacing the customer portion of the LSB can run several thousand dollars and as a result, utilities have had little success getting customers to voluntarily replace the privately-owned portion of the line (AWWA 2005).

In addition to the LCR mandate for non-optimized systems, there are several other circumstances in which partial LSB replacements are performed. Some utilities have established LSB replacement programs that replace the portion of lead branches owned by the utility. In most instances, partial replacement of LSB is necessary when replacing a main that has LSBs connected to it. Sometimes partial replacement of LSBs is necessary because a leak develops on the service branch or the branch becomes damaged for some other reason. In all of these cases, though, replacement of part of the branch still leaves some of the LSB in service.

Several studies have been performed that indicate that physical disturbance of the LSB can result in elevated lead levels at the customers' taps when part of the lead service branch is left in place (Briton and Richards 1981; AwwaRF-GVGW 1985; Hulsmann 1990). It has also been reported that by coupling the existing lead branch with a new copper pipe galvanic mechanisms can exist which can accelerate lead corrosion and result in elevated lead concentrations in the water. It may also be possible that by cutting a lead branch, a fresh unpassivated surface is now created at the cut which can leach elevated levels of lead to the water until a passivating film is formed.

The 1991 Lead and Copper Rule did not resolve the problem of elevated lead levels after replacement. The 2000 amendments to the rule (USEPA 2000) attempts to address this by requiring system which do partial replacements because of action level exceedance to notify the customers at least 45 days in advance of the work then sample the customer's water within three days of the work and notify the customer of the sample results within three days of receiving the results. To mitigate the high lead levels that may occur as a result of the service branch replacement activities, the USEPA advises that the water be flushed before it is used for consumption or food preparation. However, it has been shown that flushing is not successful in all cases to reduce the lead concentration and can even result in higher lead concentrations even after a flush of 10 minutes (Edwards and Dudi 2004).

Because partial LSB replacement is a widespread practice it is very important that the impact of partial LSB replacement be better defined both for the resulting lead concentrations and the duration of exposure to higher lead levels after replacement at the consumers tap.

Objectives and approach. The objectives of this study were to examine the short-term and long-term impact of partial LSB changeover on lead concentrations measured at the consumers' taps. The impacts from partial LSB changeover were also compared with the results from performing complete changeovers as well as from performing no service branch work at all.

The approach used to accomplish these objectives was to perform lead analyses at twenty-one homes with lead service branches. These sites were divided into four groups. For five of these sites, the Greater Cincinnati Water Works (GCWW) replaced the entire service branch from the water main up to the house. For another 5 sites, GCWW performed partial replacement of the service branch from the water main to the property line leaving the original lead branch in tact from the property line into the house. At 6 sites, GCWW performed partial replacements, but covered the freshly cut end with a Teflon shrink wrap tubing. The final five sites acted as control sites with no work performed on the lead service branch. All sites were sampled initially, one week after work was performed (except the control sites), and at one month intervals for a year. Sampling at all sites consisted of a first draw after standing a minimum of 6 hours, after a three minute flush, and after a ten minute flush.

MATERIALS AND METHODS

Description of sampling sites. The locations used in this study consisted of twenty-one single family residences constructed before 1927 with complete lead service branches in use. None of the sites reported any internal plumbing and all sites reported no malfunctioning plumbing such as dripping faucets or leaking toilets. All of the sites had a history of lead detections during previous Lead and Copper Rule compliance sampling.

All residences were provided with end of the faucet type water purification devices and replacement filters to obtain drinking water and water for food preparation during the study period to remove high lead levels that may occur as a result of the study. However, the filtration systems were bypassed for the purposes of sample collection.

Description of line replacement. After the pool of sites was identified, the pool was randomly divided into four groups. The “Complete Changeover” group had the entire service line replaced from the main into the house replaced with copper. The “Partial Changeover” group had only the portion owned by the GCWW replaced with copper. This portion was the part of the lead line between the water main and the curb stop. In these locations, the customer owned portion of the service line running from the curb stop into the house was not disturbed other than what was necessary for the partial replacement. After performing the work, the service line was flushed to remove metal filings, etc. that may have resulted from the work.

The “Partial with Sleeve” group had part of the service line removed as was performed in the “Partial Changeover” group. However, before coupling the property owner’s portion of the line (which was lead) into the new copper line, the installation crew slid a piece of Teflon heat shrink tubing (Ain Plastics, Mt. Vernon, NY) and heated it so the tubing would shrink and adhere tightly to the lead line and cover the freshly cut end. Once installed, the tubing formed a barrier between the cut end and the water.

Given the quantity of work, the service branch or partial service branch removal could not all be completed at the same time. The work was organized so that the locations in each study group was performed within a few week period of other members of the same group.

Sample collection. For all sampling, the residents of the sites collected the samples following written instructions provided by GCWW. Residents were instructed to collect first draw after a 6 hour period of no use, immediately followed by a three minute flush and sample collection, and a ten minute flush and sample collection. The volume of each sample was 750 ml. All samples were collected in high density polyethylene (HDPE) bottles.

Initial samples were collected in October 1998 before any work was performed on any service branch. This sample provided an initial baseline sample. Partial, partial with sleeve, and complete changeover sites provided samples 1 week after the work was completed. These sites also provided samples at approximately monthly intervals for lead analyses for one year. The sites where no work was performed collected samples for 15 months in order to yield corresponding samples with all of the study groups.

Sample analysis. All lead samples were preserved at the GCWW laboratory with nitric acid within 14 days of collection. Lead analyses were performed as per Standard Methods 3113B using a flame atomic adsorption spectrometer (Atomic Absorption Spectrometer Graphite Furnace Varian SpectrAA 640Z)

Water quality. GCWW's Richard Miller Treatment Plant (RMTP) provided water to all of the study sites. The RMTP obtains its water from the Ohio River. Treatment at the RMTP at the time of this study consisted of alum and cationic polymer coagulation, flocculation, and sedimentation. Following sedimentation, lime was added to raise the pH to a little over 8. After the initial pH adjustment, the water was filtered through rapid sand filters and then granular activated carbon contactors. The final steps consisted of free chlorination, fluoridation, and final pH adjustment with sodium hydroxide. Carbonate passivation by pH adjustment was the corrosion control method at the RMTP. Table 1 provides a summary of select water quality parameters during this study.

During the initial sample collection, the finished water pH supplied to the sites was approximately 8.5. However, in January 1999, soon after the initial sample collections, GCWW began adjusting the pH upward ultimately to 8.8. This adjustment was necessary to maintain internal goals of lead control throughout the system. The timing of the adjustment was coincidental to this study. This pH adjustment affected all of the study sites at about the same time, but after the initial sample. The pH remained approximately 8.8 for the duration of the study. All study samples except the initial samples and the 1 month sample for the Complete Changeover sites were collected under the 8.8 pH condition. Typically, there is little if any pH change in the distribution system as compared with the plant effluent.

RESULTS AND DISCUSSION

Initial spike. The lead results of all of the first draw samplings are reported for each group in Figure 1. In the figure, sites N1 through N5 represent the No Work sites in which no work was performed on the service lines, sites P1 through P5 represent the partial changeover sites in which a partial service branch changeover was performed, sites PS1 through PS 6 represent sites in which a partial service branch changeover was performed and a Teflon shrink wrap sleeve was used to cover the end of the freshly cut lead line, and sites C1 through C5 represent the complete changeover group in which entire service branches were replaced.

The first set of samples for all groups was collected in late October 1998 with the target pH of 8.5 leaving the plant. This set of samples was collected before any work was performed. With the pH increase to 8.8 in January 1999, it was expected that the first draw lead levels at all locations would decrease and this decrease was seen in all of the No Work sites and the Complete Changeover sites even though work was performed at the Complete Changeover sites.

In three of the eleven sites from the two partial replacement groups the first draw lead values did not decrease as seen in the No Work and Complete Changeover groups. In sites P1 and P2, spikes in lead concentrations occurred with lead concentrations reaching 185 µg/L, and 600 µg/L, respectively in the samples collected within a few days after the work. Site PS4 did not show an increase after the work compared to the initial sample nor did it show a decrease in lead levels as was observed in most of the other lines.

Additionally, at site (PS1) the first draw sample collected after the work was lower than the initial sample. However, both the 3 minute and the 10 minute flush samples showed a marked increase reaching 170 and 210 µg/L, respectively in the week and month following the work as

depicted in Figure 2. Even though the increase was not observed in the first draw sample, the increase in the flush samples' lead levels was probably related to the service line work.

In this study, no spike in lead concentrations occurred in the No Work or the Complete Changeover sites following the work, but this spike was evident in 4 of 11 (36%) of the sites following a partial replacement. High concentrations of lead occurring in some locations after the completion of partial service line changeovers have been demonstrated by others (Britton and Richards 1981, USEPA 1991b). Although the exact cause of this high concentration is not known, it can likely be attributed to some aspect of performing a partial renewal of the service line. Some possible reasons for this could be the physical disturbance of the service lines causing the release of particulate lead, galvanic corrosion facilitated by joining the lead line to new copper material, or even the exposure of a freshly cut lead surface to the water.

The purpose of the placement of the Teflon sleeves on sites PS1 through PS6 was to cover the cut LSB ends and act as a barrier to prevent lead dissolution at the freshly cut ends. The sleeves may have acted as a barrier, but since two of the six sites exhibited high lead concentrations in the first draw or the flush samples, it is evident that the high lead concentrations after the work can not be entirely attributed to the exposure of the freshly cut end.

The temporary increase in lead concentrations was considered by the EPA when developing the 2000 revisions to the Lead and Copper Rule. In the preamble the EPA discusses the possibility but the agency states "It is expected that potential for temporary increased in lead levels will be minimal for those systems where corrosion control has been fully implemented and optimized according to the rule" (USEPA 2000). Since implementation of the Lead and Copper Rule, the GCWW system has always met the action level so the system could be considered as having "fully implemented" corrosion control and be "optimized according to the rule."

Steady state lead concentrations. For the purposes of this evaluation, steady state is defined as the time period starting one month after the work was completed until 12 months after the work. This time period excludes any initial elevated concentration spike that may have occurred as a result of the service branch replacement work. This time period was more typical of the lead concentrations occurring at the tap throughout the year.

The results of the steady state lead monitoring are given in Table 2 for each of the test locations. The data on the table represent two time frames: January to December of 1999 and April, 1999 to March, 2000. Separating the sites into two time frames is necessary because all of the work on all of the sites was not able to be accomplished at the same time. All of the work for both sets of partial replacements was completed around March of 1999 so the one month sample was taken around April 1999. All of the work for the complete changeover sites was accomplished in December 1998 so the one month sample was collected in January 1999. Data collection for the No Work sample was extended to cover both time frames and the statistics for each time frame for the No Work samples is also represented on the table. This allows for a direct comparison between the No Work data and the data collected for each of the other groups.

The average steady state data for the various groups are reported in Figure 3. Both time periods for the no work locations averaged around 11.5 µg/L for the steady state period. Partially replacing the service lines on average showed little improvement averaging 10 µg/L for the study period. Based on these averages, there would be little, if any, benefit to the customer of replacing a partial service branch. In addition, since these were the steady state values, the large spikes in lead concentrations demonstrated in 2 of the 5 partial replacement lines were not

included. If these spikes were considered, then the benefit to the consumer is further diminished as not only is there little reduction in overall lead concentration compared with doing no work, but the customer may be exposed to elevated concentrations of lead for a period of time immediately following the partial service line replacement.

The partial branches with the sleeve did show some improvement compared with no work with an average value of 6.3 µg/L in the steady state period. Even though covering of the end of the lead branch did not eliminate the occurrence of the initial spike, it may have offered some protection as measured in the longer term effects on lead concentrations at these sites. Some work has been done on rehabilitation methods for lead service lines (Kirmeyer et al, 2000.), but these studies did not evaluate the effect on water quality by the different rehabilitation techniques.

The complete changeover group showed the biggest improvement on average with a mean value of 3.4 µg/L as compared with the 11.5 µg/L of the No Work groups. Although the Complete group did not have lead in their service lines during the steady state phase, the data show that there are still sources of lead at these locations that can contribute to the lead concentration. This can be expected as lead solder, brass fittings, and faucets can be significant sources of lead at the tap. It is also possible that lead particulates may have been present similar to what Cantor (2006) reportedly found from homes years after lead service branch removal.

CONCLUSIONS

Utilities with lead service branches face many challenges in compliance and day-to-day operational issues associate with the branches. Because of ownership issues, there are situations in which partial replacement of lead branches may be unavoidable such as in main replacement and some repair work.

Although removing sources of lead is generally considered to be a positive action, the partial replacement of lead service branches may not necessarily be effective in reducing water lead levels compared with doing no replacement at all.

In this study, partial replacements of lead lines resulted in much higher lead levels in the water for up to 1 month after replacement even though the system was optimized for corrosion control. In addition, the sites with partial replacements had similar water lead concentrations as the sites in which the entire lead line was left in place. In this study, only completely replacing the lead service line resulted in reduction in short and long-term water quality improvements in all of the sites tested.

The use of a Teflon sleeve or some other method of treating the portion of the line remaining in service may help to protect water quality, but much more needs to be done in this area to identify construction techniques or materials that will protect water quality when partial lead service line replacement is necessary.

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Table 1: GCWW finished water quality parameters during the study period (October 1998 – March 2000).

	pH	Total Alkalinity (mg/L as CaCO ₃)	Total Hardness (mg/L as CaCO ₃)	Calcium Hardness (mg/L as CaCO ₃)	Total Dissolved Solids (mg/L)	Temperature (°F, °C)	Free Chlorine (mg/L)
Average	8.8	70	145	105	273	60, 15	1.15
Minimum	8.4	44	92	76	120	37, 2.8	0.92
Maximum	9.2	100	215	177	629	88, 31	1.44

Table 2: Effect of service branch changeover on first draw steady state lead concentrations.

Site	Min Lead Conc. (µg/L)	Max Lead Conc. (µg/L)	January 1999 - December 1999			April 1999 - March 2000			Summer Humps Present?
			Average Lead Conc. (µg/L)	Month 1 Lead Conc. (µg/L)	Month 12 Lead Conc. (µg/L)	Average Lead Conc. (µg/L)	Month 1 Lead Conc. (µg/L)	Month 12 Lead Conc. (µg/L)	
N1	5.2	17.7	10.4	7.2	7.4	10.3	12.8	12.7	Yes
N2	3.4	12.8	7.8	9.8	4.6	7.0	8.1	3.4	Yes
N3	4.7	26.5	12.9	9.7	8.9	7.6	5.4	4.1	Yes
N4	3.2	30.9	17.5	5.4	10.7	19.2	3.2	11.3	Yes
N5	4.1	11.9	8.4	7.4	4.8	13.7	7.8	10.7	Yes
P1	12.6	29.1				16.2	13.4	12.7	Yes
P2	0	7.3				2.6	3.4	1.1	No
P3	15.7	40.6				23.5	16.6	11.4	Yes
P4	1.5	4.5				2.7	4.0	1.1	No
P5	2.8	9.6				5.1	5.9	2.7	Yes
PS1	2.6	12.6				8.2	12.1	2.6	No
PS2	4.2	23.5				11.0	11.6	4.2	Yes
PS3	1.2	6.8				3.8	4.2	1.2	No
PS4	4.9	13.8				9.5	8.2	6.7	Yes
PS5	1.3	5.6				3.0	5.2	1.5	No
PS6	0	4.4				2.4	2.5	1.2	No
C1	1.3	6.9	3.7	4.6	1.3				No
C2	1.3	6.1	2.9	6.1	1.3				No
C3	1.1	1.6	3.9	5.3	2.1				No
C4	1.1	8.2	5.3	9.3	No Sample				No
C5	0	2.9	1.3	1.9	<1.0				No

N = No Work

P = Partial LSB Replacement

PS = Partial LSB Replacement with Teflon Sleeve

C = Complete LSB Replacement

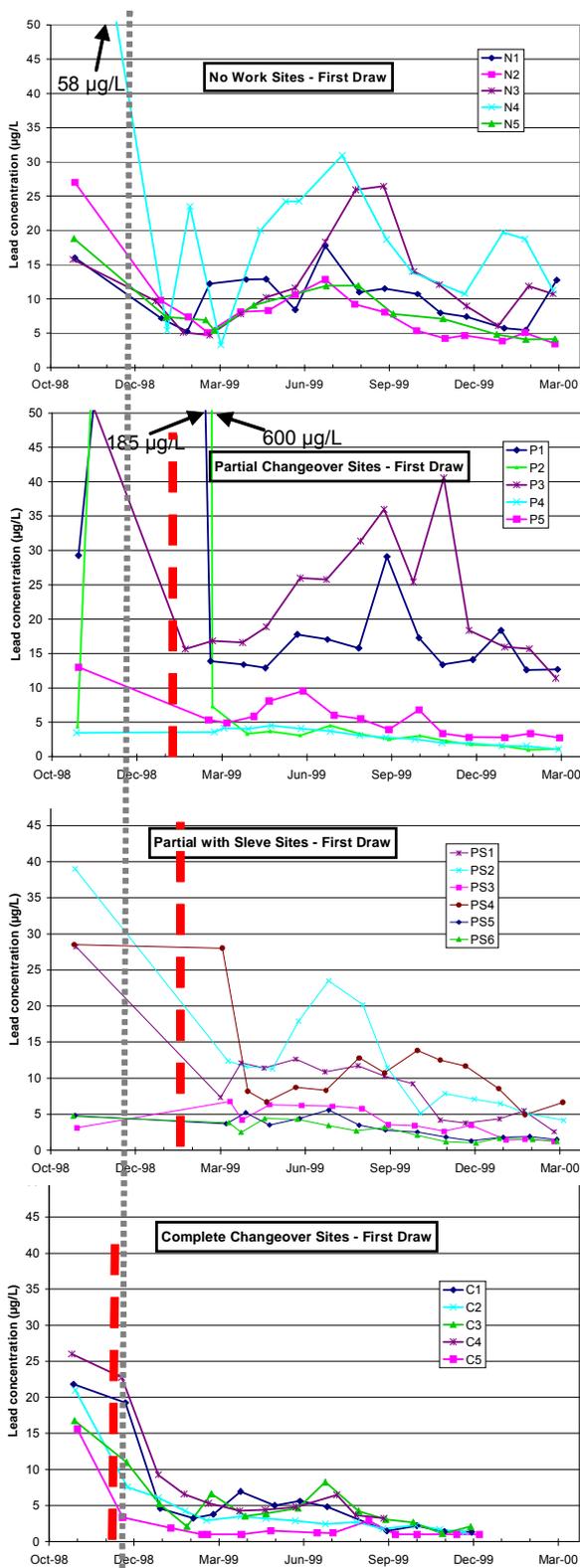


Figure 1: First draw lead concentrations from all study sites. The red dashed line represents the date of work on the service branches and the grey dashed line represents time of pH adjustment from 8.5 to 8.8.

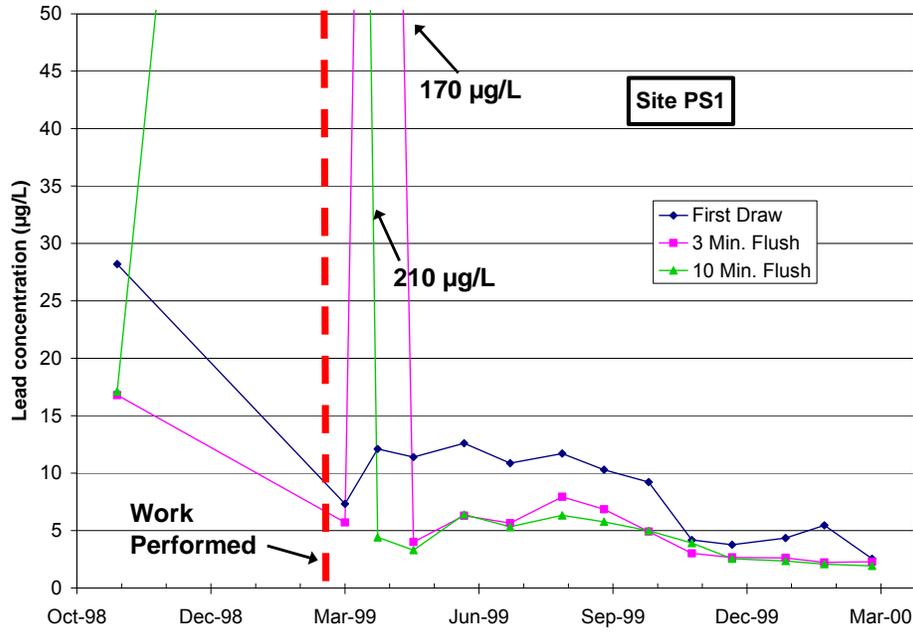


Figure 2: First draw, 3 minute flush, and 10 minute flush lead concentrations from site PS1.

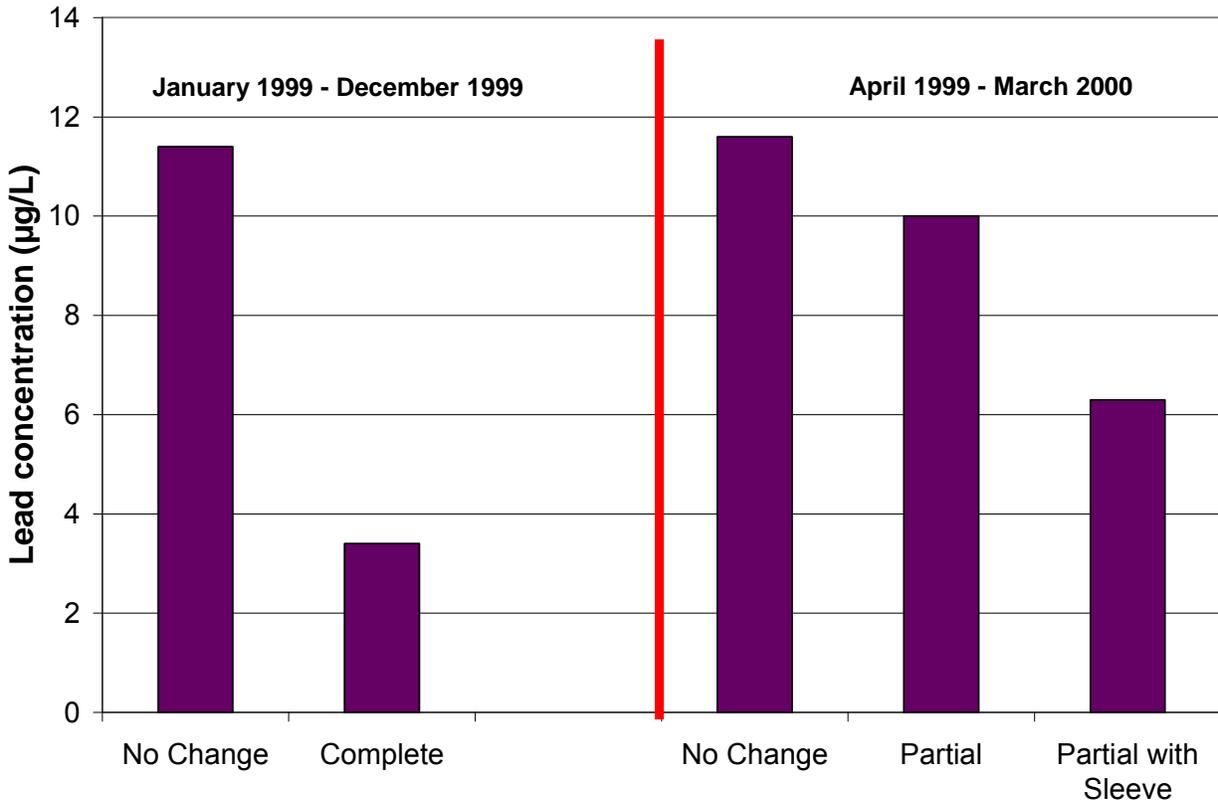


Figure 3: Steady state average data for first draw samples from each study group.

**Summary
Peach Orchard Monitoring
Lead Service Line Replacement Study**

Barbara M. Wysock

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Technical Support
Division, April 1991*

Objective

The objective of this part of the Oakwood Corrosion Study was to determine if lead service line replacement would impact levels in drinking water at the tap on Peach Orchard Street in Oakwood, Ohio.

Method

Houses were chosen on the Peach Orchard Street because the city was doing street repairs there. If lead service lines were identified, the city replaced the service line with copper. Water samples were taken at houses before and after any service lines were replaced.

There were 8 houses without lead service lines and 7 houses with lead service lines. Plumbing inspections were conducted by LJB personnel at each house. All but one of the houses had home water softeners. The softeners were bypassed during sampling. Tables 1 and 2 list characteristics of the plumbing at each house.

Samples were taken on 7/25, 7/27, 8/1, and 8/2 before service line replacement and on 9/20, 9/27, and 10/4 after service line replacement. Morning first draw and service line samples were collected by the homeowner at each home. Appendix A describes the sampling protocol used. Table 3 lists which houses sampled on each round. Samples were analyzed for lead, iron, copper, zinc, sodium, calcium, magnesium, and manganese. Some samples were also analyzed for pH, alkalinity, chloride, sulfate, potassium, ammonia, silica, total phosphate, and ortho-phosphate. Sample preservation occurred in the field by LJB personnel for the metals and in the lab for the other parameters. Blanks were included with all sample rounds to identify any source of contamination. Internal standards were used to check precision and accuracy.

Results

The overall water quality indicates the raw water is hard, has neutral pH, and contains no lead, raw. Table 4 lists the ranges for water quality parameters other than the metals.

The results of the monitoring are reported in Tables 5 - 7, Figures 1 and 2, and Appendices B - D. The graphs in Appendix B represent the lead concentrations in samples collected at each house. Averages were calculated for lead, copper, and iron results for water that did not pass through a home water softener. The averages are listed in Tables 5-7. Figures 1 and 2 represent morning first draw lead distributions. The tables in Appendix C list the data from each house. Observations about the results of each home are attached in Appendix D.

Morning first draw sample lead concentrations were not different before and after lead service line replacement at a 95% confidence level. Service line sample lead concentrations were not different before and after lead service line replacement. See Table 5.

Results of X-ray diffraction analysis indicate interior films on lead service lines contain basic and normal lead carbonate, lead oxide, PbO_2 , and some silica and phosphate.

Discussion

Fourteen of the 15 houses had water softeners. The homeowners were instructed to bypass the softeners the night before sampling the water. The sodium, calcium, and magnesium data show softeners were not always bypassed or the softener regenerated overnight. This raises a key issue for the regulatory monitoring. Should water softeners be bypassed for monitoring? If so, this does not represent the water quality that is present in the home on most days. The effect of softened water on corrosion in home plumbing is still being debated among the technical community. Until the debate is supported by more data, softeners will be bypassed in some studies and not in others, depending on the researchers' needs.

The protocol used to collect service line samples may not be optimum. The volume of pipe between the service line and sample point was estimated. This volume estimate was then rounded up to the nearest quart. Each homeowner was instructed to waste this volume between the morning first draw sample and the first service line sample. Error could result in overestimating the waste volume or confusion during sampling. The protocol was not verified during the study. In the future, the protocol will be compared to other service line sampling protocols.

Sampling locations were chosen at taps in each house that did not receive softened water or a more convenient tap for the homeowner than the kitchen tap. Using taps other than kitchen taps is not consistent with the proposed lead regulation rule but met the needs of this study. Future monitoring studies will follow regulation protocol unless the objectives are better met by changing the regulation protocol.

Clear communication with the homeowners was critical for the proper execution of the study. A face to face orientation between the homeowners and the researchers would have been helpful to avoid confusion and to explain the importance of following the protocol. Faster turn around of the results was needed to inform homeowners of the safe or high lead levels of lead in the samples collected. A better system needs to be used in future studies.

Costs

The overall costs for this monitoring were \$33,000. This figure includes supply costs, work hour costs, and analyses costs. Most of the costs result from the analyses. It's expensive to perform more than the bare minimum of water analyses.

Conclusions

The overall conclusion of this study is lead service line replacement did not significantly impact the lead levels at the tap on Peach Orchard Street in Oakwood, Ohio. Obtaining service line samples is very difficult. Clear communication with homeowners is essential to the proper execution of the monitoring study.

Future Work

Monitoring protocol needs to be studied to determine the best techniques to obtain service line samples and to determine the error introduced when the homeowner versus trained staff takes samples. Pilot system sampling in the laboratory needs to be compared to house sampling to determine which yields more useful results for corrosion control.

Acknowledgments

Many people contributed to the completion of this study. These people are Peach Orchard Street residents, Jim Walasek, Mike Schock, Bonnie Newport, Chris Jordan, Lou Trombley, Jim Caldwell, Chris Frebis, John Eastman, and Gary Wachter.

Table 1

Houses With Lead Service Lines

House # Age	Year Built	Service Line Material		Water Softener Yes or No	Sampling Location	Faucet
		Main to Curb	Curb to House			
4	1924	Pb	Pb	No	Kitchen Tap	1959
5	1929	Pb	Cu	Yes	Kitchen Tap	1988
6	1928	Pb	Pb	Yes	NA	1952
7	1934	Pb	Galv	Yes	Kitchen Tap	1989
8	1921	Pb	Pb	Yes	NA	1921
11	1950	Pb	Galv	Yes*	Bar Sink	1968
12	1920's	Pb	Pb	Yes	Outside Spigot	Na

*additional home treatment

Household Plumbing

House #	Age	Material
4	1924	Galv
5	1929	Galv
6	1928	Galv
7	1934	Galv
8	1921	Galv
11	1950	Galv & Cu
12	NA	Galv & Cu

Table 2

Houses Without Lead Service Lines

House # Age	Year Built	Service Line Material		Water Softener Yes or No	Sampling Location	Faucet
		Main to Curb	Curb to House			
1	1942	Cu	Cu	Yes*	Inside Spigot	NA
2	1940	Cu	Cu	Yes	Basement Tap	1987
3	1927	Cu	Cu	Yes	Kitchen Tap	NA
9	1955	Cu	Cu	Yes	Kitchen Tap	1955
10	1959	NA	NA	Yes	Kitchen Tap	1984
13	1929	Cu	Cu	Yes	Kitchen Tap	NA
14	1948	Cu	Cu	Yes	Kitchen Tap	1948
15	1949	Cu	Cu	Yes	Master Bath	NA

*additional home treatment

Household Plumbing

House #	Age	Material
1	1942	Galv
2	1940	Galv
3	1927	Galv
9	1955	Cu+Pb/Sn
10	1955	Cu+Pb/Sn
13	1929	NA
14	1948	Galv
15	NA	Cu+Pb/Sn

Table 3

Sample Dates

House #	7/25	7/27	8/1	8/2	9/20	9/27	10/4
1	*			*	*	*	*
2	*			*	*		
3	*	*		*	*	*	*
4	*		*	*	*	*	*
5	*	*	*	*	*	*	*
6	*	*	*	*	*	*	*
7	*	*		*	*		
8	*	*	*	*	*	*	
9	*	*	*	*	*	*	
10	*	*	*	*	*	*	*
11	*	*	*	*	*	*	*
12		*		*	*		
13	*	*	*			*	*
14		*	*		*	*	
15			*		*	*	*

Table 4

Water Quality

Peach Orchard Houses 1, 2, 9, 10

	Range	Average	S.D.	N
Chloride (mg/l)	127-160	148	8.9	10
Sulfate (mg/l)	52-66	59	4.2	10
Potassium (mg/l)	2.5-2.6	2.5	0.05	10
Ammonia (mg/l NH ₃ -N)	<0.02	<0.02	0	10
Silica (mg/l)	12-14.9	14.3	0.84	10
Ortho Phosphate (mg/l P)	<0.05	<0.05	0	10
Total Phosphate (mg/l P)	<0.10	<0.05	0	10
pH	7.05-7.14	7.09	0.03	8
Alkalinity (mg/l CaCO ₃)	285-362	341	18.7	22

Table 5

Pb

<u>MFD</u>	Avg. (ppb)	Std. Dev.	Var.
<u>With Lead Service Line</u>			
Before	37.9	42.2	1781.4
After	45.6	59.0	3480.1
<u>Without Lead Service Line</u>			
Before	31.6	43.4	1881.6
After	8.4	4.7	22.5

SERV

<u>With Lead Service Line</u>			
Before	9.1	2.7	7.5
After	8.5	6.3	40.1
<u>Without Lead Service Line</u>			
Before	4.9	3.8	14.3
After	6.2	10.2	103.5

Comparisons at 95% Confidence Interval:

MFD	With Before vs After	No difference	(p-value=0.2910)
MFD	Without Before vs After	No difference	(0.2001)
SERV	With Before vs After	No difference	(0.9951)
SERV	Without Before vs After	No difference	(0.5898)
MFD	With vs Without	No difference	(0.0798)
SERV	With vs Without	No difference	(0.6501)

Table 6

Fe

<u>MFD</u>	Avg. (ppb)	Std. Dev.	Var.
<u>With Lead Service Line</u>			
Before	1535.5	3173.6	10,071,979.4
After	1730.8	3312.4	10,971,795.3
<u>Without Lead Service Line</u>			
Before	526.4	923.9	853,656.0
After	173.3	109.7	12,038.9

SERV

<u>With Lead Service Line</u>			
Before	211.1	205.2	42,116.8
After	275.6	369.8	136,722.9
<u>Without Lead Service Line</u>			
Before	69.4	72.9	5,316.4
After	0.0	0.0	0.0

Comparisons at 95% Confidence Interval:

MFD	With Before vs After	No difference	(p-value=0.6796)
MFD	Without Before vs After	No difference	(0.3285)
SERV	With Before vs After	No difference	(0.8092)
SERV	Without Before vs After	Before > After	(0.0135)
MFD	With vs Without	No difference	(0.2622)
SERV	With vs Without	No difference	(0.5601)

Table 7

Cu

<u>MFD</u>	Avg. (ppb)	Std. Dev.	Var.
<u>With Lead Service Line</u>			
Before	67.7	34.8	1209.9
After	33.1	32.0	1024.9
<u>Without Lead Service Line</u>			
Before	162.9	215.3	46,373.8
After	89.0	112.0	12,555.0

<u>SERV</u>	Avg. (ppb)	Std. Dev.	Var.
<u>With Lead Service Line</u>			
Before	75.4	50.0	2504.7
After	53.5	51.6	2665.0
<u>Without Lead Service Line</u>			
Before	43.5	32.1	1033.0
After	28.3	48.4	2344.1

Comparisons at 95% Confidence Interval:

MFD	With Before vs After	No difference	(p-value=0.1687)
MFD	Without Before vs After	No difference	(0.6798)
SERV	With Before vs After	Before > After	(0.0323)
SERV	Without Before vs After	No difference	(0.1133)
MFD	With vs Without	No difference	(0.7927)
SERV	With vs Without	No difference	(0.9356)

FIGURE 1

Morning First Draw Results Before Lead Service Line Replacement

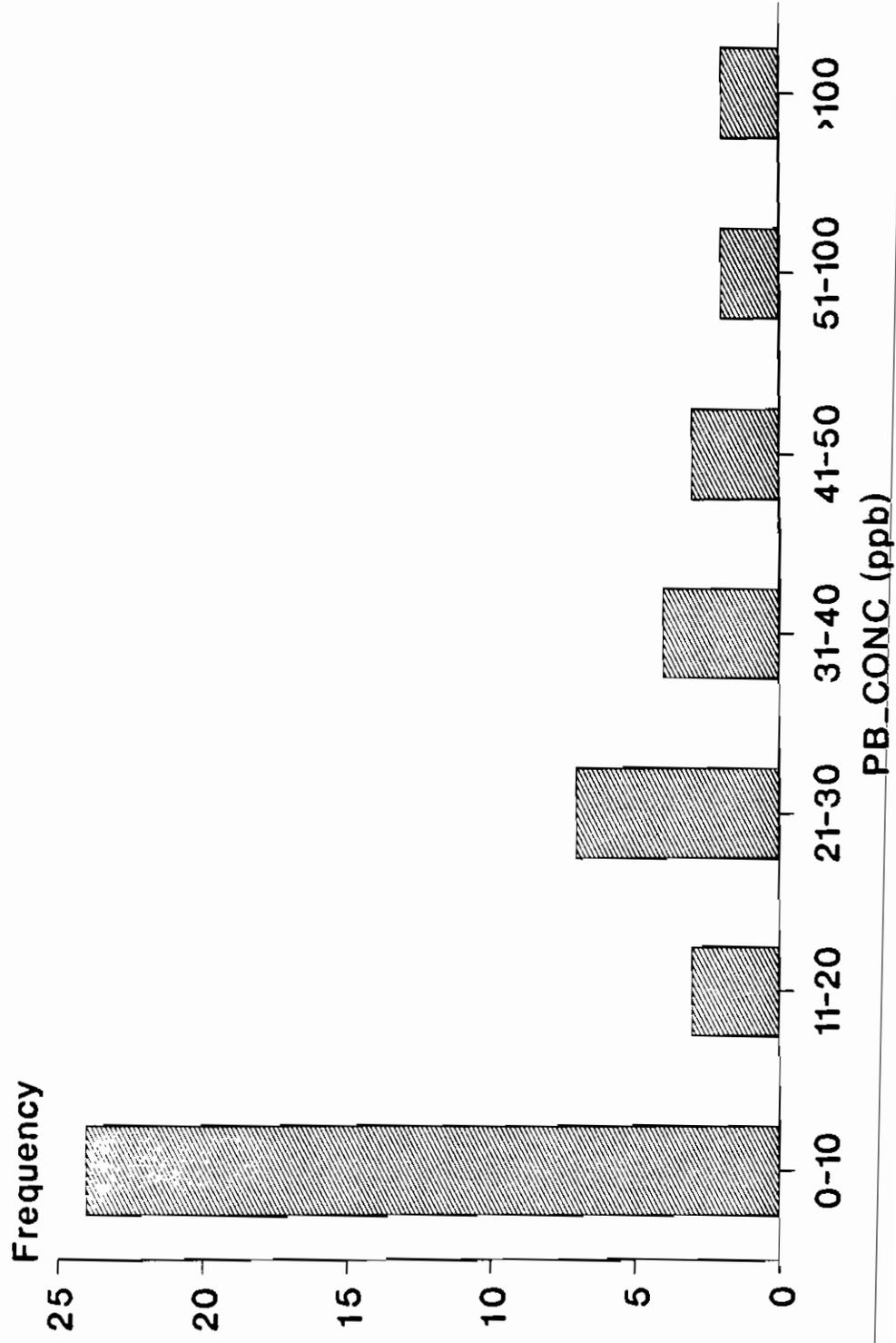
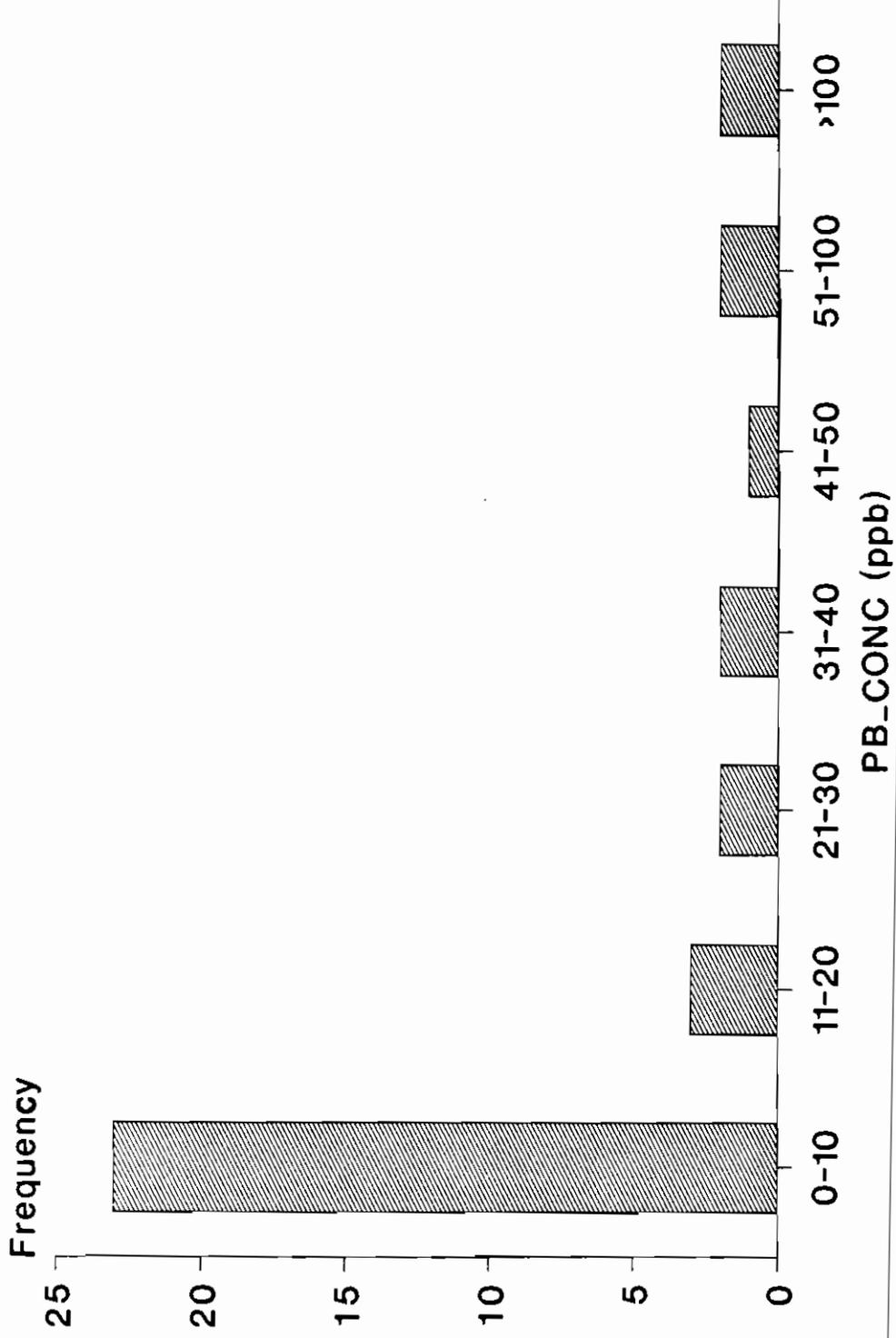


FIGURE 2

Morning First Draw Results After Lead Service Line Replacement



APPENDIX A

Consumer's Instructions for Collecting Drinking Water Samples for Lead Service Line Replacement Study

Please read these instructions carefully before collecting your drinking water samples.

- Check sampling kit box to see that it contains:
 - 1 - One quart Cubitainer w/cap
 - 3 - 250 mL Plastic bottles w/caps
 - 4 - Labels w/preprinted sample numbers
 - 1 - Pen w/red waterproof ink
 - The night before you are scheduled to collect the sample:
 - Complete as much of the label information as you can-sample tap location (Source) and Sampler's Signature (or initials). Pen works best if label is dry.
 - Set containers out next to the faucet you will be sampling (probably the kitchen sink).
 - **IMPORTANT: Do Not Use Any Water The Rest Of The Night!** This includes water used in flushing the toilet.
- NOTE:** If collection of the samples in the morning would be inconvenient or impractical, and the house is unoccupied during the day, it may be possible to collect the samples when you return to the home later in the day. Discuss this option with your survey representative.
- In the morning before you use any water:
 - Write in the Date and Time on the labels. (Photo #1)
 - Remove the cap from the Cubitainer and place the Cubitainer under the faucet. (Photo #2A)
 - Turn on the COLD water, and fill the container. (Photo #2B)
 - Turn off the water, and screw the cap back on the container.



IMPORTANT - The next three (3) samples you will be collecting are Service Line Samples. To ensure that you are getting a sample from the service line you should waste a specific volume of water before

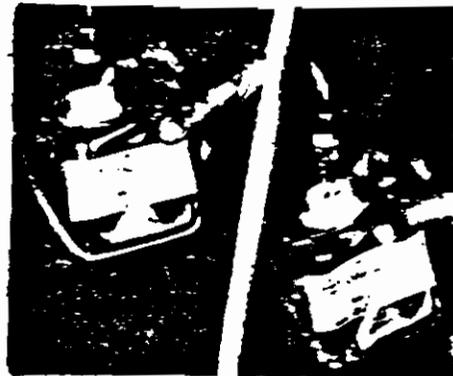
you fill the remaining bottles. Your survey representative can help you determine the proper volume to waste. The "volume-to-waste" method is described below:

- Place a graduated container such as a large measuring cup (not supplied) under the faucet and turn the cold water back on to catch and measure out ____ quarts.
- When the recommended volume of water has flowed from the faucet turn off the water and place the first small bottle (label with "2" following the OK prefix, e.g., OK 2-07-1) under the tap, turn on the water and fill to the neck. Turn off the water. (Photo #4A & 4B)
- Place the next bottle (label with "3" after the OK prefix) under the faucet and fill to the neck. Turn off the water.
- Repeat for the third bottle (label with "4" after the OK prefix). Turn off the water.
- Put the containers back in the box and set it outside your front door for pickup by survey personnel.

Refer to the photos below for additional information on the sample collection procedures.



#1 Filling Out Labels



#2 Filling Cubitainer



#3 Wasting Specific Volume



#4 Filling 250 mL Bottle

Thank you for your assistance. If you have any questions please call Jim Walasek at (513) 569-7919 Collect or contact your survey representative at 293-6967.

MFD = Morning First Draw Sample

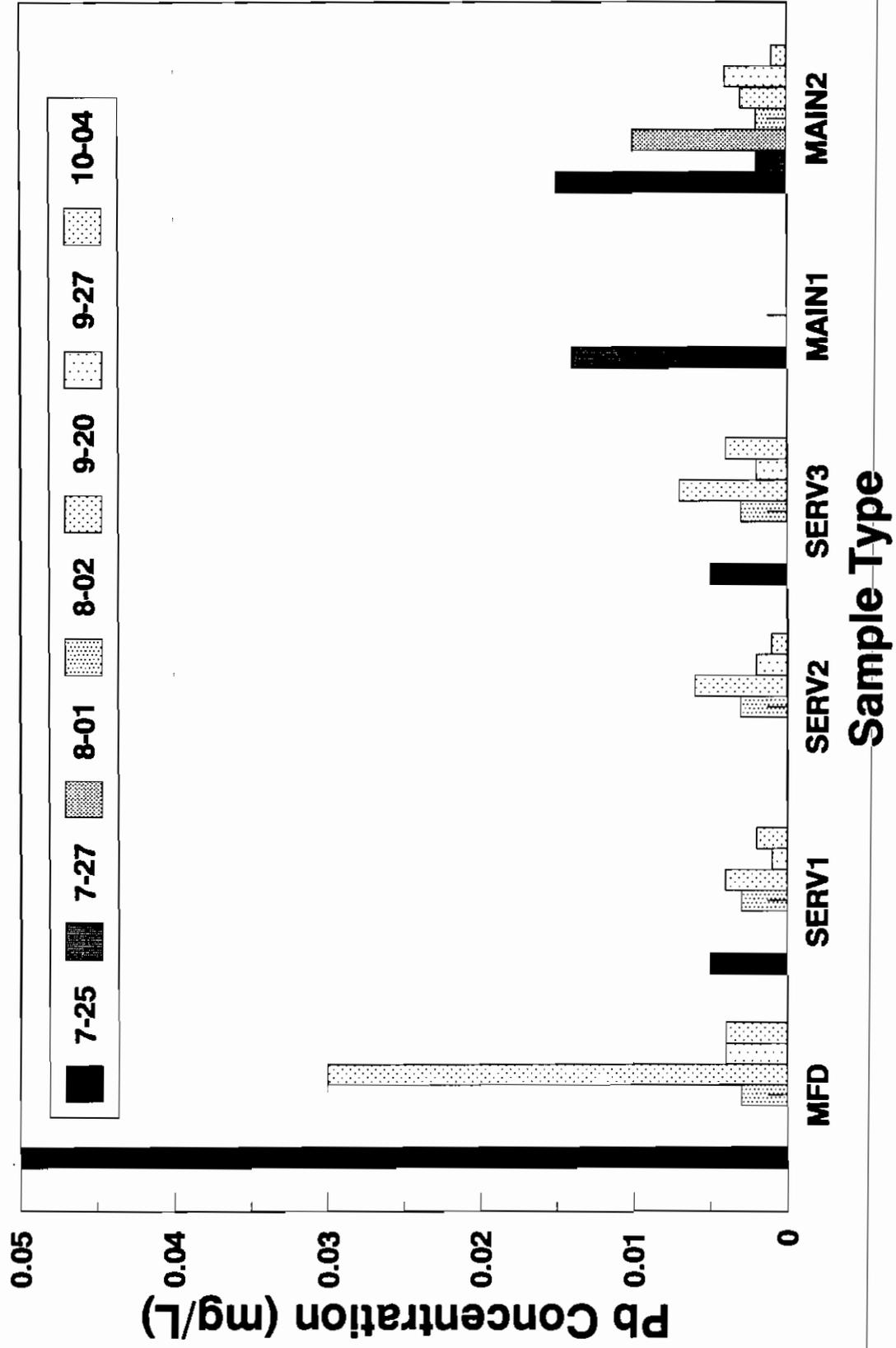
SERV 1,2,3 = Service Line Sample

MAIN 1,2, = Flushed Sample

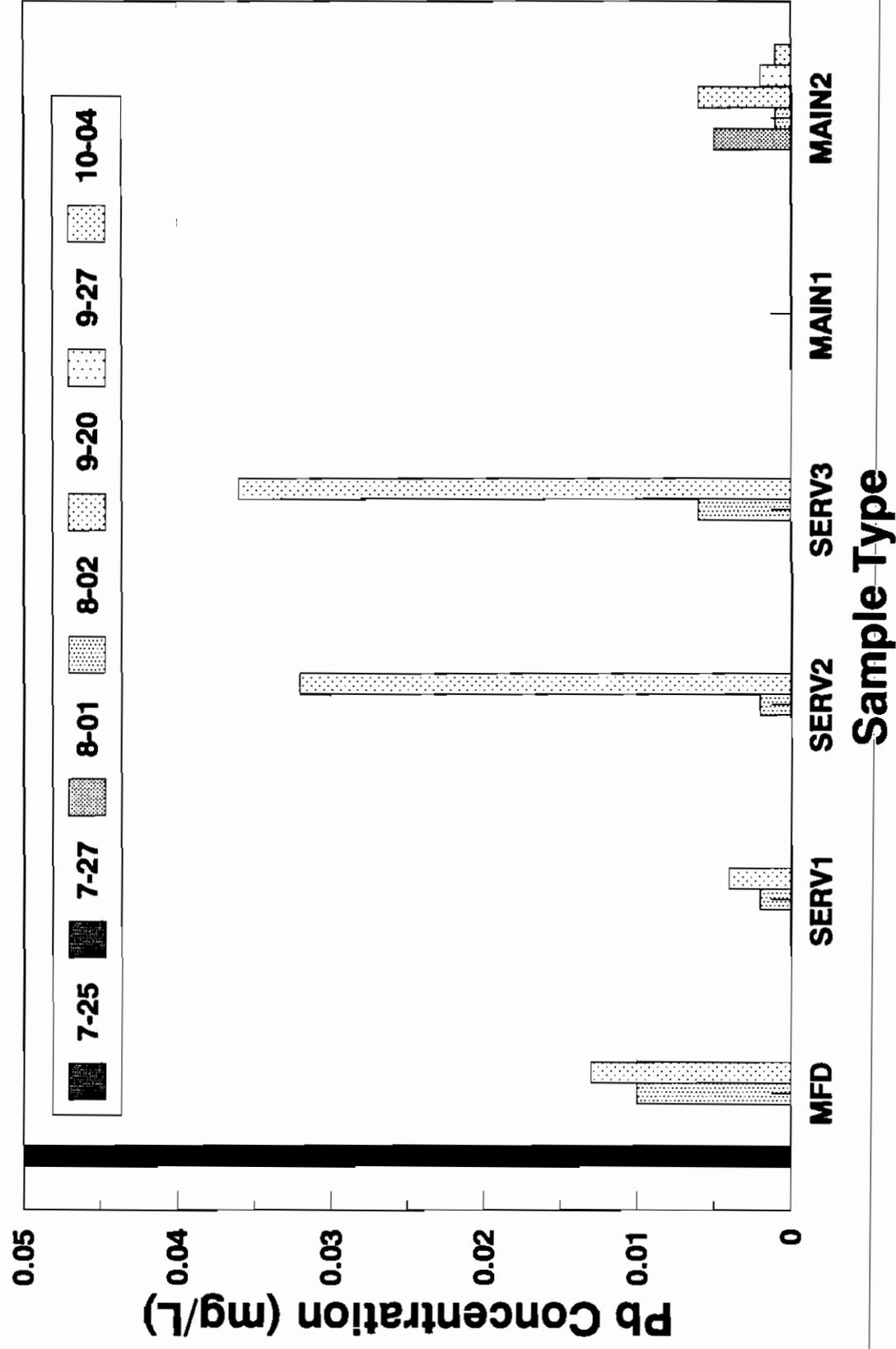
APPENDIX B

Peach Orchard Lead Results Bar Graphs

Peach Orchard House 01 Lead Results

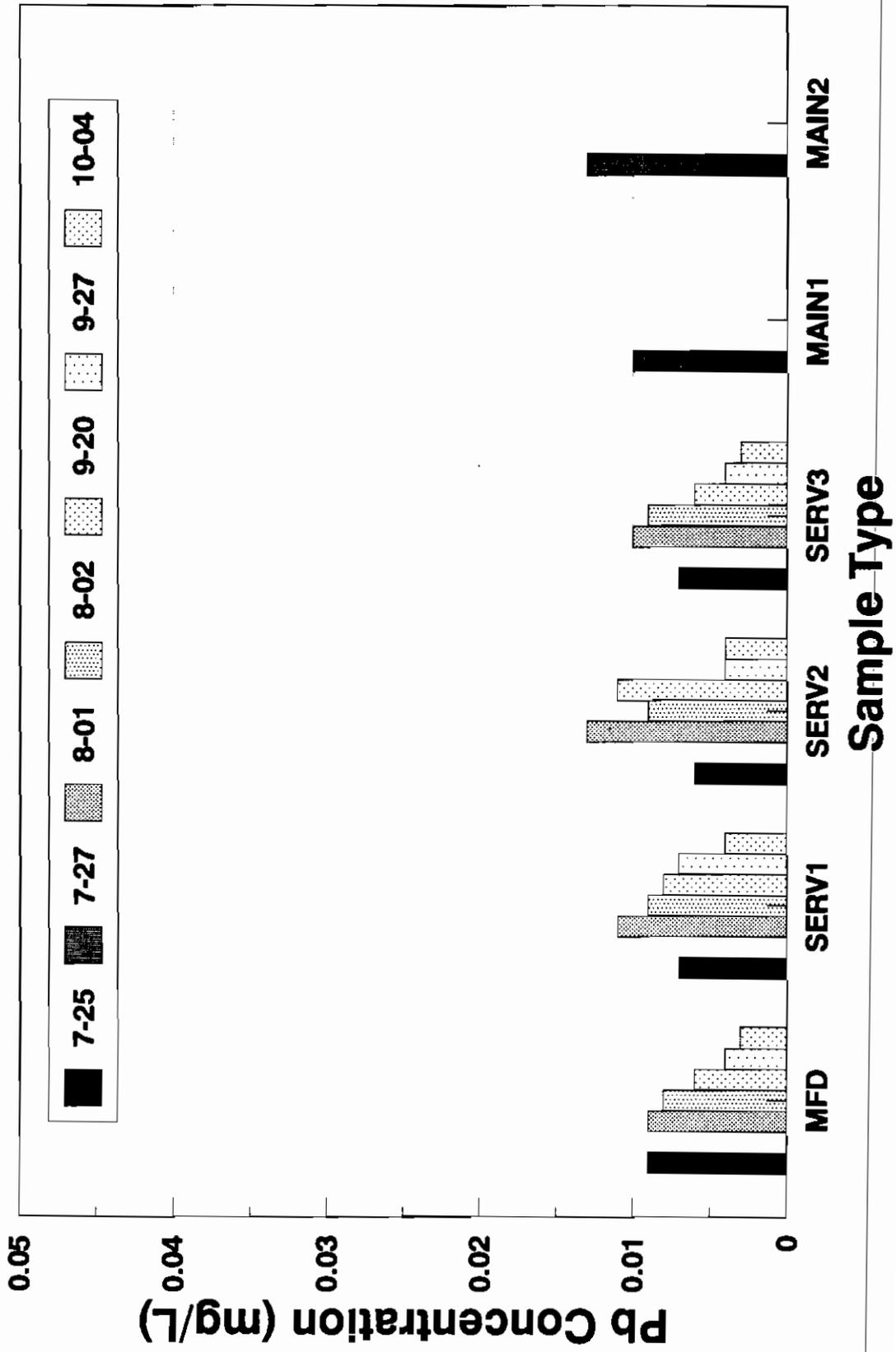


Peach Orchard House 02 Lead Results



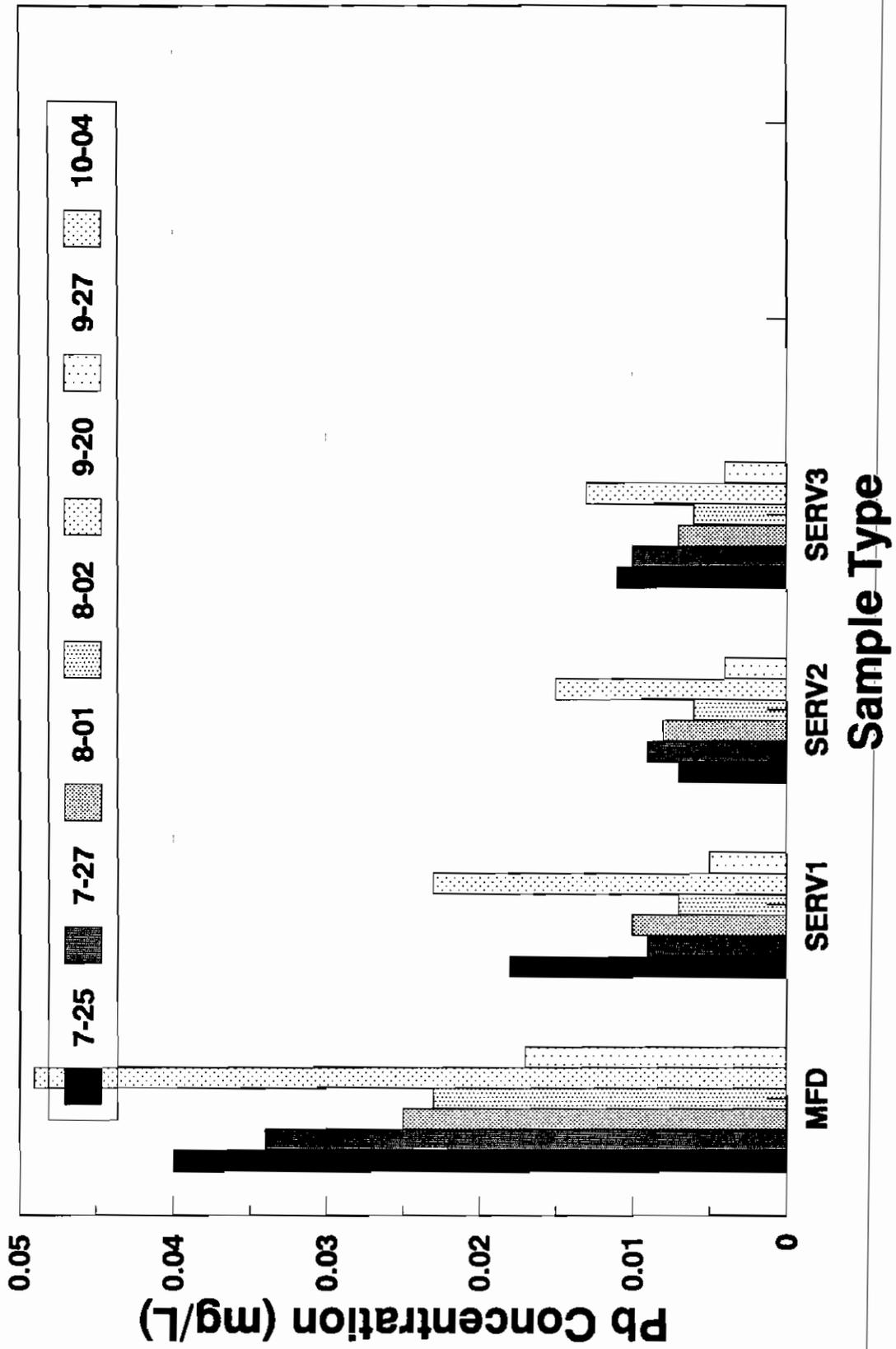
Peach Orchard House 04

Lead Results



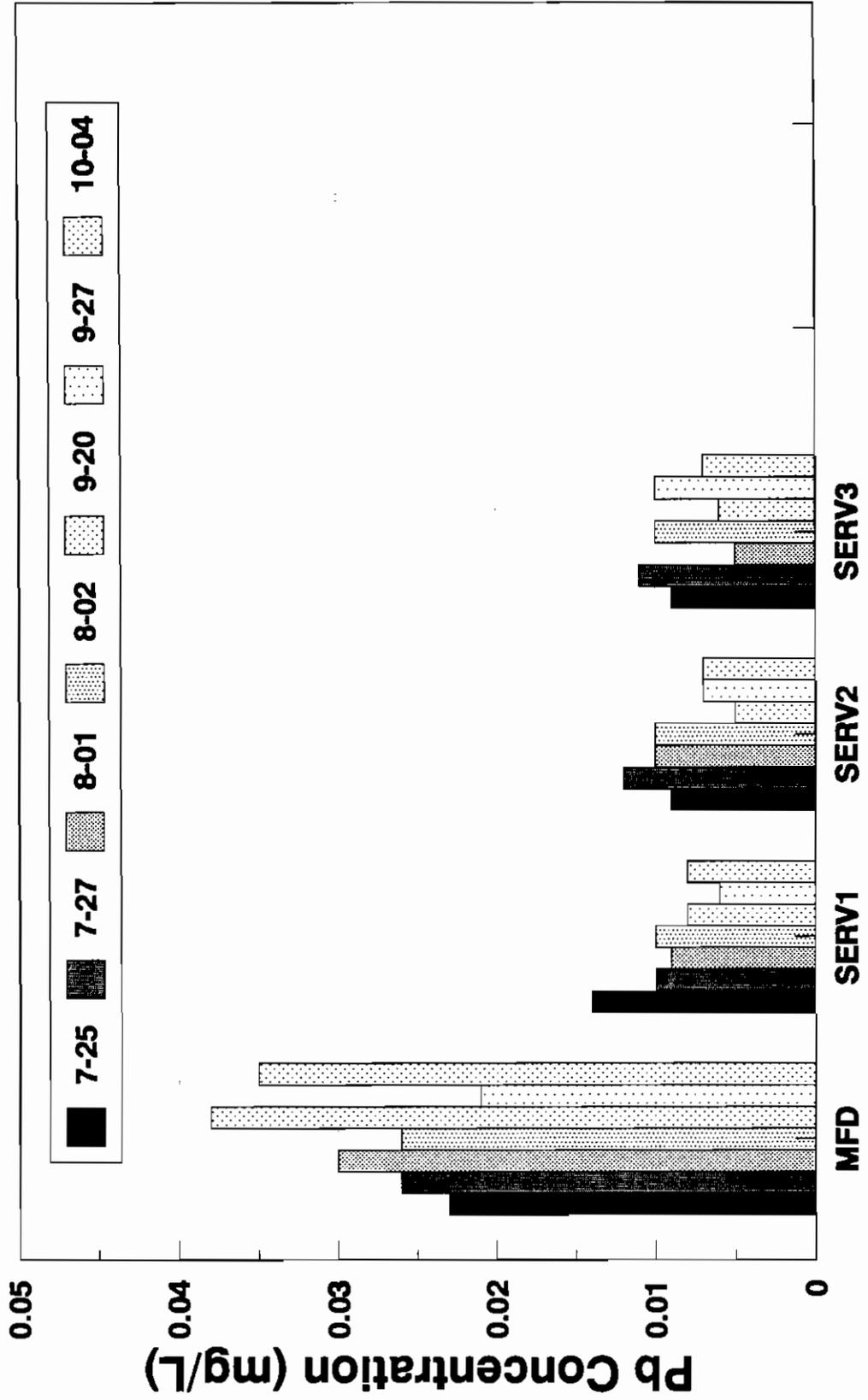
Peach Orchard House 08

Lead Results



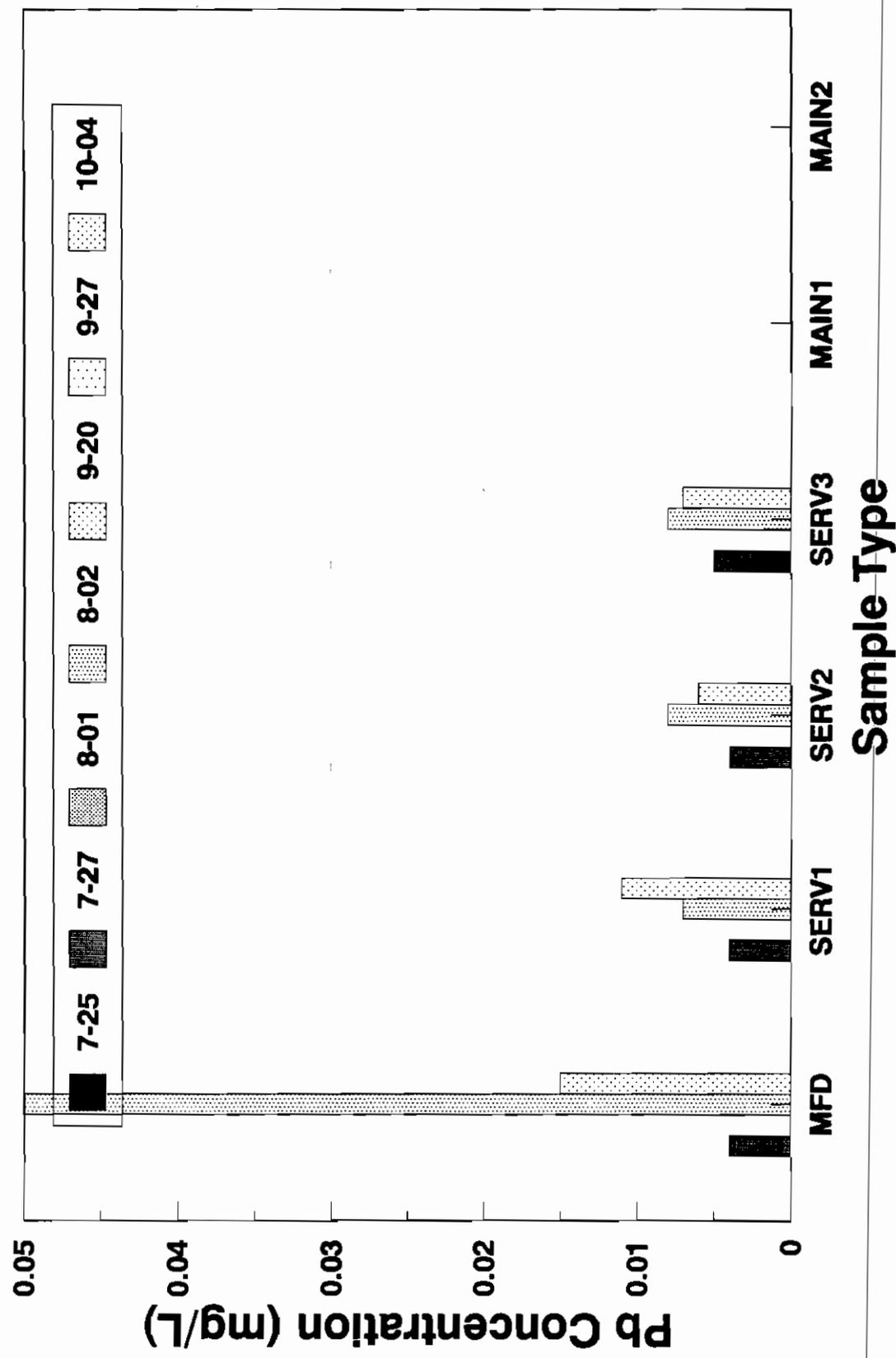
Peach Orchard House 11

Lead Results



Sample Type

Peach Orchard House 12 Lead Results



APPENDIX C

Peach Orchard Results

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-01-1	MFD	25-Jul-89	0.242	0.45	0.03	0.22	72.3
OK-02-01-1	SERV1	25-Jul-89	0.005	0.00	0.10	0.04	71.5
OK-03-01-1	SERV2	25-Jul-89	0.000	0.00	0.10	0.02	72.0
OK-04-01-1	SERV3	25-Jul-89	0.005	0.00	0.10	0.02	72.1
OK-06-01-1	MAIN2	25-Jul-89	0.015	0.17	0.10	0.06	70.1
OK-05-01-2	MAIN1	27-Jul-89	0.014	0.22	0.04	0.06	68.0
OK-06-01-2	MAIN2	27-Jul-89	0.002	0.17	0.00	0.00	69.0
OK-06-01-3	MAIN2	01-Aug-89	0.010	0.19	0.00	0.11	96.0
OK-01-01-4	MFD	02-Aug-89	0.003	0.00	0.00	0.00	88.0
OK-02-01-4	SERV1	02-Aug-89	0.003	0.00	0.00	0.00	59.0
OK-03-01-4	SERV2	02-Aug-89	0.003	0.00	0.00	0.01	79.0
OK-04-01-4	SERV3	02-Aug-89	0.003	0.00	0.00	0.01	34.0
OK-06-01-4	MAIN2	02-Aug-89	0.002	0.00	0.00	0.01	67.0
OK-01-01-5	MFD	20-Sep-89	0.030	0.23	0.09	0.12	89.0
OK-02-01-5	SERV1	20-Sep-89	0.004	0.00	0.00	0.02	88.5
OK-03-01-5	SERV2	20-Sep-89	0.006	0.00	0.00	0.01	94.0
OK-04-01-5	SERV3	20-Sep-89	0.007	0.00	0.00	0.02	95.0
OK-06-01-5	MAIN2	20-Sep-89	0.003	0.00	0.00	0.02	97.5
OK-01-01-6	MFD	27-Sep-89	0.004	0.00	0.00	0.01	66.0
OK-02-01-6	SERV1	27-Sep-89	0.001	0.00	0.00	0.00	66.0
OK-03-01-6	SERV2	27-Sep-89	0.002	0.00	0.00	0.01	65.5
OK-04-01-6	SERV3	27-Sep-89	0.002	0.00	0.00	0.00	63.5
OK-06-01-6	MAIN2	27-Sep-89	0.004	0.00	0.00	0.03	65.5
OK-01-01-7	MFD	04-Oct-89	0.004	0.00	0.00	0.04	74.4
OK-02-01-7	SERV1	04-Oct-89	0.002		0.00	0.03	
OK-03-01-7	SERV2	04-Oct-89	0.001		0.00	0.01	
OK-04-01-7	SERV3	04-Oct-89	0.004		0.00	0.02	
OK-06-01-7	MAIN2	04-Oct-89	0.001	0.00	0.00	0.05	62.4

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-01-1	MFD	25-Jul-89	103.45	43.5	0.16		
OK-02-01-1	SERV1	25-Jul-89	100.20	42.5	0.08		
OK-03-01-1	SERV2	25-Jul-89	104.25	43.0	0.10		
OK-04-01-1	SERV3	25-Jul-89	98.40	43.0	0.10		
OK-06-01-1	MAIN2	25-Jul-89	102.10	44.0	0.13		285
OK-05-01-2	MAIN1	27-Jul-89	79.00	32.0	0.11		
OK-06-01-2	MAIN2	27-Jul-89	79.00	33.0	0.13		
OK-06-01-3	MAIN2	01-Aug-89	112.00	45.0	0.14	7.12	362
OK-01-01-4	MFD	02-Aug-89	130.00	38.0	0.09		
OK-02-01-4	SERV1	02-Aug-89	119.00	36.0	0.06		
OK-03-01-4	SERV2	02-Aug-89	124.00	36.0	0.05		
OK-04-01-4	SERV3	02-Aug-89	120.00	36.0	0.04		
OK-06-01-4	MAIN2	02-Aug-89	116.00	34.0	0.06	7.10	358
OK-01-01-5	MFD	20-Sep-89	83.90	39.5	0.24		
OK-02-01-5	SERV1	20-Sep-89	83.70	39.5	0.21		
OK-03-01-5	SERV2	20-Sep-89	83.90	41.0	0.29		
OK-04-01-5	SERV3	20-Sep-89	85.75	41.0	0.18		
OK-06-01-5	MAIN2	20-Sep-89	81.30	41.0	0.22		355
OK-01-01-6	MFD	27-Sep-89	100.50	44.0	0.23		
OK-02-01-6	SERV1	27-Sep-89		43.5	0.23		
OK-03-01-6	SERV2	27-Sep-89		44.0	0.22		
OK-04-01-6	SERV3	27-Sep-89		45.0	0.24		
OK-06-01-6	MAIN2	27-Sep-89	106.80	45.5	0.30		330
OK-01-01-7	MFD	04-Oct-89	102.60	48.4	0.03		
OK-02-01-7	SERV1	04-Oct-89		45.2			
OK-03-01-7	SERV2	04-Oct-89		50.0			
OK-04-01-7	SERV3	04-Oct-89		49.6			
OK-06-01-7	MAIN2	04-Oct-89	111.00	46.4	0.03		349

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-02-1	MFD	25-Jul-89	0.095	5.22	0.10	2.30	78.1
OK-02-02-1	SERV1	25-Jul-89	0.000	0.10	0.10	0.05	76.4
OK-03-02-1	SERV2	25-Jul-89	0.000	0.10	0.10	0.06	75.9
OK-04-02-1	SERV3	25-Jul-89	0.000	0.10	0.10	0.06	75.7
OK-06-02-3	MAIN2	01-Aug-89	0.005	0.10	0.00	0.04	98.0
OK-01-02-4	MFD	02-Aug-89	0.010	0.00	0.00	1.70	60.0
OK-02-02-4	SERV1	02-Aug-89	0.002	0.00	0.00	0.02	63.0
OK-03-02-4	SERV2	02-Aug-89	0.002	0.00	0.00	0.02	50.0
OK-04-02-4	SERV3	02-Aug-89	0.006	0.35	0.00	1.28	182.0
OK-06-02-4	MAIN2	02-Aug-89	0.001	0.00	0.00	0.00	47.0
OK-01-02-5	MFD	20-Sep-89	0.013	0.32	0.00	3.53	74.0
OK-02-02-5	SERV1	20-Sep-89	0.004	0.00	0.00	0.05	71.5
OK-03-02-5	SERV2	20-Sep-89	0.032	0.00	0.00	0.04	69.0
OK-04-02-5	SERV3	20-Sep-89	0.036	0.00	0.00	0.04	69.5
OK-06-02-5	MAIN2	20-Sep-89	0.006	0.00	0.00	0.00	95.5
OK-06-02-6	MAIN2	27-Sep-89	0.002	0.00	0.00	0.02	66.5
OK-06-02-7	MAIN2	04-Oct-89	0.001	0.00	0.00	0.03	70.0

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-02-1	MFD	25-Jul-89	105.80	45.0	0.19		
OK-02-02-1	SERV1	25-Jul-89	106.35	44.0	0.11		
OK-03-02-1	SERV2	25-Jul-89	104.40	44.0	0.08		
OK-04-02-1	SERV3	25-Jul-89	107.85	45.0	0.07		
OK-06-02-3	MAIN2	01-Aug-89	109.00	45.0	0.14	7.06	360
OK-01-02-4	MFD	02-Aug-89	121.00	34.0	0.04		
OK-02-02-4	SERV1	02-Aug-89	130.00	36.0	0.06		
OK-03-02-4	SERV2	02-Aug-89	122.00	36.0	0.00		
OK-04-02-4	SERV3	02-Aug-89	39.00	12.0	0.05		
OK-06-02-4	MAIN2	02-Aug-89	112.00	36.0	0.01	7.14	353
OK-01-02-5	MFD	20-Sep-89	110.40	45.0	0.33		
OK-02-02-5	SERV1	20-Sep-89		45.0	0.29		
OK-03-02-5	SERV2	20-Sep-89		44.0	0.30		
OK-04-02-5	SERV3	20-Sep-89		44.0	0.17		
OK-06-02-5	MAIN2	20-Sep-89	80.40	40.0	0.17		351
OK-06-02-6	MAIN2	27-Sep-89	104.40	45.5	0.20		328
OK-06-02-7	MAIN2	04-Oct-89	107.10	51.6	0.03		345

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-03-1	MFD	25-Jul-89	0.013	0.10	0.66	0.10	166.0
OK-02-03-1	SERV1	25-Jul-89	0.004	0.10	0.10	0.01	126.0
OK-03-03-1	SERV2	25-Jul-89	0.006	0.10	0.10	0.01	125.0
OK-04-03-1	SERV3	25-Jul-89	0.006	0.10	0.10	0.01	127.0
OK-01-03-2	MFD	27-Jul-89	0.016	0.21	0.60	0.08	80.0
OK-02-03-2	SERV1	27-Jul-89	0.007	0.22	0.02	0.00	88.0
OK-03-03-2	SERV2	27-Jul-89	0.007	0.19	0.01	0.00	87.0
OK-04-03-2	SERV3	27-Jul-89	0.006	0.19	0.03	0.01	87.0
OK-01-03-3	MFD	01-Aug-89	0.016	0.16	0.48	0.07	107.0
OK-02-03-3	SERV1	01-Aug-89	0.007	0.12	0.00	0.00	106.0
OK-03-03-3	SERV2	01-Aug-89	0.007	0.13	0.00	0.00	106.0
OK-04-03-3	SERV3	01-Aug-89	0.004	0.17	0.00	0.01	94.0
OK-01-03-5	MFD	20-Sep-89	0.010	0.00	0.58	0.05	361.5
OK-02-03-5	SERV1	20-Sep-89	0.006	0.00	0.00	0.00	355.5
OK-03-03-5	SERV2	20-Sep-89	0.006	0.00	0.00	0.00	365.0
OK-04-03-5	SERV3	20-Sep-89	0.005	0.00	0.00	0.01	358.5
OK-01-03-6	MFD	27-Sep-89	0.003	0.00	0.35	0.03	193.5
OK-02-03-6	SERV1	27-Sep-89	0.004	0.00	0.03	0.04	210.0
OK-03-03-6	SERV2	27-Sep-89	0.002	0.00	0.01	0.01	194.5
OK-04-03-6	SERV3	27-Sep-89	0.002	0.00	0.00	0.01	191.0
OK-01-03-7	MFD	04-Oct-89	0.003	0.00	0.13	0.05	266.8
OK-02-03-7	SERV1	04-Oct-89	0.003		0.00	0.02	
OK-03-03-7	SERV2	04-Oct-89	0.003		0.00	0.02	
OK-04-03-7	SERV3	04-Oct-89	0.003		0.00	0.02	

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-03-1	MFD	25-Jul-89	40.75	52.5	0.07		
OK-02-03-1	SERV1	25-Jul-89	55.65	69.5	0.10		
OK-03-03-1	SERV2	25-Jul-89	54.95	69.0	0.07		
OK-04-03-1	SERV3	25-Jul-89	55.10	68.5	0.08		
OK-01-03-2	MFD	27-Jul-89	88.00	35.0	0.14		
OK-02-03-2	SERV1	27-Jul-89	97.00	38.0	0.12		
OK-03-03-2	SERV2	27-Jul-89	98.00	38.0	0.11		
OK-04-03-2	SERV3	27-Jul-89	96.00	38.0	0.14		
OK-01-03-3	MFD	01-Aug-89	112.00	46.0	0.13		
OK-02-03-3	SERV1	01-Aug-89	111.00	44.0	0.15		
OK-03-03-3	SERV2	01-Aug-89	111.00	44.0	0.14		
OK-04-03-3	SERV3	01-Aug-89	106.00	44.0	0.12		
OK-01-03-5	MFD	20-Sep-89	0.00	0.4	0.17		
OK-02-03-5	SERV1	20-Sep-89	0.00	0.3	0.20		
OK-03-03-5	SERV2	20-Sep-89	0.00	0.4	0.27		
OK-04-03-5	SERV3	20-Sep-89	0.00	0.3	0.24		
OK-01-03-6	MFD	27-Sep-89	8.40	0.5	0.27		
OK-02-03-6	SERV1	27-Sep-89		0.4	0.27		
OK-03-03-6	SERV2	27-Sep-89		0.4	0.16		
OK-04-03-6	SERV3	27-Sep-89		0.4	0.19		
OK-01-03-7	MFD	04-Oct-89	8.10	0.1	0.03		
OK-02-03-7	SERV1	04-Oct-89		0.1			
OK-03-03-7	SERV2	04-Oct-89		0.1			
OK-04-03-7	SERV3	04-Oct-89		0.1			

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-04-1	MFD	25-Jul-89	0.009	0.06	0.10	0.60	72.7
OK-02-04-1	SERV1	25-Jul-89	0.007	0.10	0.10	0.05	70.2
OK-03-04-1	SERV2	25-Jul-89	0.006	0.10	0.10	0.05	71.2
OK-04-04-1	SERV3	25-Jul-89	0.007	0.10	0.10	0.05	72.2
OK-05-04-2	MAIN1	27-Jul-89	0.010	0.22	0.00	0.58	84.0
OK-06-04-2	MAIN2	27-Jul-89	0.013	0.15	0.00	0.09	89.0
OK-01-04-3	MFD	01-Aug-89	0.009	0.21	0.00	0.75	86.0
OK-02-04-3	SERV1	01-Aug-89	0.011	0.12	0.00	0.07	86.0
OK-03-04-3	SERV2	01-Aug-89	0.013	0.15	0.00	0.10	86.0
OK-04-04-3	SERV3	01-Aug-89	0.010	0.15	0.00	0.08	85.0
OK-01-04-4	MFD	02-Aug-89	0.008	0.00	0.00	0.58	59.0
OK-02-04-4	SERV1	02-Aug-89	0.009	0.00	0.00	0.04	72.0
OK-03-04-4	SERV2	02-Aug-89	0.009	0.00	0.00	0.05	82.0
OK-04-04-4	SERV3	02-Aug-89	0.009	0.00	0.00	0.04	50.0
OK-01-04-5	MFD	20-Sep-89	0.006	0.00	0.00	0.82	97.5
OK-02-04-5	SERV1	20-Sep-89	0.008	0.00	0.00	0.04	94.5
OK-03-04-5	SERV2	20-Sep-89	0.011	0.00	0.00	0.05	95.0
OK-04-04-5	SERV3	20-Sep-89	0.006	0.00	0.00	0.06	95.5
OK-01-04-6	MFD	27-Sep-89	0.004	0.00	0.00	0.08	65.5
OK-02-04-6	SERV1	27-Sep-89	0.007	0.00	0.00	0.05	67.0
OK-03-04-6	SERV2	27-Sep-89	0.004	0.00	0.00	0.06	66.5
OK-04-04-6	SERV3	27-Sep-89	0.004	0.00	0.00	0.05	66.0
OK-01-04-7	MFD	04-Oct-89	0.003	0.01	0.08	0.44	95.2
OK-02-04-7	SERV1	04-Oct-89	0.004		0.19	0.05	
OK-03-04-7	SERV2	04-Oct-89	0.004		0.23	0.04	
OK-04-04-7	SERV3	04-Oct-89	0.003		0.22	0.04	

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-04-1	MFD	25-Jul-89	103.10	44.5	0.10		
OK-02-04-1	SERV1	25-Jul-89	88.75	38.5	0.09		
OK-03-04-1	SERV2	25-Jul-89	98.95	42.5	0.05		
OK-04-04-1	SERV3	25-Jul-89	100.45	42.5	0.06		
OK-05-04-2	MAIN1	27-Jul-89	89.00	37.0	0.14		
OK-06-04-2	MAIN2	27-Jul-89	94.00	38.0	0.10		
OK-01-04-3	MFD	01-Aug-89	107.00	44.0	0.12		
OK-02-04-3	SERV1	01-Aug-89	104.00	43.0	0.10		
OK-03-04-3	SERV2	01-Aug-89	105.00	44.0	0.16		
OK-04-04-3	SERV3	01-Aug-89	105.00	44.0	0.14		
OK-01-04-4	MFD	02-Aug-89	120.00	36.0	0.04		
OK-02-04-4	SERV1	02-Aug-89	124.00	36.0	0.00		
OK-03-04-4	SERV2	02-Aug-89	122.00	36.0	0.02		
OK-04-04-4	SERV3	02-Aug-89	116.00	36.0	0.00		
OK-01-04-5	MFD	20-Sep-89	73.40	42.5	0.21		
OK-02-04-5	SERV1	20-Sep-89	76.85	41.5	0.22		
OK-03-04-5	SERV2	20-Sep-89	75.40	44.0	0.22		
OK-04-04-5	SERV3	20-Sep-89	75.70	40.0	0.33		
OK-01-04-6	MFD	27-Sep-89	101.40	43.5	0.14		
OK-02-04-6	SERV1	27-Sep-89		42.5	0.21		
OK-03-04-6	SERV2	27-Sep-89		43.0	0.16		
OK-04-04-6	SERV3	27-Sep-89		43.5	0.19		
OK-01-04-7	MFD	04-Oct-89	94.20	44.0	0.03		
OK-02-04-7	SERV1	04-Oct-89		46.8			
OK-03-04-7	SERV2	04-Oct-89		47.6			
OK-04-04-7	SERV3	04-Oct-89		43.6			

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-05-1	MFD	25-Jul-89	0.005	0.10	0.05	0.35	161.2
OK-02-05-1	SERV1	25-Jul-89	0.004	0.10	0.10	0.30	73.5
OK-03-05-1	SERV2	25-Jul-89	0.005	0.10	0.10	0.02	77.9
OK-04-05-1	SERV3	25-Jul-89	0.004	0.10	0.10	0.02	77.2
OK-01-05-2	MFD	27-Jul-89	0.004	0.23	0.05	0.37	81.0
OK-02-05-2	SERV1	27-Jul-89	0.006	0.24	0.13	0.02	93.0
OK-03-05-2	SERV2	27-Jul-89	0.006	0.15	0.12	0.02	92.0
OK-04-05-2	SERV3	27-Jul-89	0.007	0.17	0.14	0.02	91.0
OK-01-05-3	MFD	01-Aug-89	0.004	0.26	0.00	0.40	164.0
OK-02-05-3	SERV1	01-Aug-89	0.007	0.15	0.00	0.02	83.0
OK-03-05-3	SERV2	01-Aug-89	0.007	0.17	0.00	0.02	85.0
OK-04-05-3	SERV3	01-Aug-89	0.007	0.15	0.00	0.02	85.0
OK-01-05-4	MFD	02-Aug-89	0.005	0.00	0.03	0.29	81.0
OK-02-05-4	SERV1	02-Aug-89	0.004	0.00	0.06	0.01	77.0
OK-03-05-4	SERV2	02-Aug-89	0.004	0.00	0.08	0.01	83.0
OK-04-05-4	SERV3	02-Aug-89	0.006	0.00	0.07	0.01	73.0
OK-01-05-5	MFD	20-Sep-89	0.004	0.00	0.01	0.22	135.0
OK-02-05-5	SERV1	20-Sep-89	0.002	0.00	0.00	0.02	97.5
OK-03-05-5	SERV2	20-Sep-89	0.004	0.00	0.00	0.02	98.0
OK-04-05-5	SERV3	20-Sep-89	0.004	0.00	0.00	0.02	98.5
OK-01-05-6	MFD	27-Sep-89	0.001	0.00	0.02	0.32	134.5
OK-02-05-6	SERV1	27-Sep-89	0.003	0.00	0.12	0.02	67.5
OK-03-05-6	SERV2	27-Sep-89	0.002	0.00	0.14	0.02	67.5
OK-04-05-6	SERV3	27-Sep-89	0.002	0.00	0.16	0.02	68.5
OK-01-05-7	MFD	04-Oct-89	0.004	0.00	0.00	0.08	70.0
OK-02-05-7	SERV1	04-Oct-89	0.005		0.00	0.08	
OK-03-05-7	SERV2	04-Oct-89	0.007		0.00	0.09	
OK-04-05-7	SERV3	04-Oct-89	0.004		0.00	0.09	

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-05-1	MFD	25-Jul-89	56.85	25.0	0.08		
OK-02-05-1	SERV1	25-Jul-89	97.95	42.5	0.07		
OK-03-05-1	SERV2	25-Jul-89	99.35	42.0	0.07		
OK-04-05-1	SERV3	25-Jul-89	94.55	42.5	0.05		
OK-01-05-2	MFD	27-Jul-89	90.00	36.0	0.13		
OK-02-05-2	SERV1	27-Jul-89	90.00	38.0	0.11		
OK-03-05-2	SERV2	27-Jul-89	91.00	38.0	0.14		
OK-04-05-2	SERV3	27-Jul-89	93.00	38.0	0.11		
OK-01-05-3	MFD	01-Aug-89	72.00	28.0	0.15		
OK-02-05-3	SERV1	01-Aug-89	109.00	45.0	0.10		
OK-03-05-3	SERV2	01-Aug-89	112.00	45.0	0.12		
OK-04-05-3	SERV3	01-Aug-89	108.00	45.0	0.12		
OK-01-05-4	MFD	02-Aug-89	112.00	36.0	0.00		
OK-02-05-4	SERV1	02-Aug-89	111.00	36.0	0.01		
OK-03-05-4	SERV2	02-Aug-89	111.00	34.0	0.02		
OK-04-05-4	SERV3	02-Aug-89	115.00	34.0	0.00		
OK-01-05-5	MFD	20-Sep-89	60.30	33.5	0.29		
OK-02-05-5	SERV1	20-Sep-89	75.40	42.5	0.21		
OK-03-05-5	SERV2	20-Sep-89	77.20	40.0	0.25		
OK-04-05-5	SERV3	20-Sep-89	74.60	41.5	0.23		
OK-01-05-6	MFD	27-Sep-89	73.20	28.0	0.20		
OK-02-05-6	SERV1	27-Sep-89		44.5	0.20		
OK-03-05-6	SERV2	27-Sep-89		44.0	0.18		
OK-04-05-6	SERV3	27-Sep-89		44.0	0.20		
OK-01-05-7	MFD	04-Oct-89	113.70	43.2	0.03		
OK-02-05-7	SERV1	04-Oct-89		46.4			
OK-03-05-7	SERV2	04-Oct-89		42.4			
OK-04-05-7	SERV3	04-Oct-89		45.6			

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-06-1	MFD	25-Jul-89	0.355	10.82	0.31	3.11	69.8
OK-02-06-1	SERV1	25-Jul-89	0.005	1.06	0.10	0.20	76.1
OK-03-06-1	SERV2	25-Jul-89	0.017	0.47	0.10	0.14	75.6
OK-04-06-1	SERV3	25-Jul-89	0.024	0.48	0.10	0.23	75.7
OK-01-06-2	MFD	27-Jul-89	0.045	8.45	0.00	2.10	92.0
OK-02-06-2	SERV1	27-Jul-89	0.014	0.76	0.00	0.49	92.0
OK-03-06-2	SERV2	27-Jul-89	0.004	0.85	0.00	0.15	92.0
OK-04-06-2	SERV3	27-Jul-89	0.003	0.59	0.00	0.12	91.0
OK-01-06-3	MFD	01-Aug-89	0.076	8.83	0.00	2.36	84.0
OK-02-06-3	SERV1	01-Aug-89	0.005	1.16	0.00	0.12	89.0
OK-03-06-3	SERV2	01-Aug-89	0.015	1.01	0.00	0.11	90.0
OK-04-06-3	SERV3	01-Aug-89	0.009	1.12	0.00	0.11	91.0
OK-01-06-4	MFD	02-Aug-89	0.042	6.62	0.00	2.24	82.0
OK-02-06-4	SERV1	02-Aug-89	0.011	0.14	0.00	0.09	70.0
OK-03-06-4	SERV2	02-Aug-89	0.004	0.00	0.00	0.08	59.0
OK-04-06-4	SERV3	02-Aug-89	0.005	0.00	0.00	0.09	71.0
OK-01-06-5	MFD	20-Sep-89	0.285	8.14	0.00	2.49	85.5
OK-02-06-5	SERV1	20-Sep-89	0.009	0.36	0.00	0.10	97.0
OK-03-06-5	SERV2	20-Sep-89	0.006	0.41	0.00	0.10	96.0
OK-04-06-5	SERV3	20-Sep-89	0.005	0.32	0.00	0.09	96.0
OK-01-06-6	MFD	27-Sep-89	0.086	9.33	0.00	3.19	84.0
OK-02-06-6	SERV1	27-Sep-89	0.003	0.27	0.00	0.11	70.5
OK-03-06-6	SERV2	27-Sep-89	0.004	0.24	0.00	0.10	77.0
OK-04-06-6	SERV3	27-Sep-89	0.006		0.10	0.48	
OK-01-06-7	MFD	04-Oct-89	0.106	7.48	0.02	2.71	61.2
OK-02-06-7	SERV1	04-Oct-89	0.002		0.00	0.15	
OK-03-06-7	SERV2	04-Oct-89	0.004		0.00	0.15	
OK-04-06-7	SERV3	04-Oct-89	0.005		0.00	0.15	

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-06-1	MFD	25-Jul-89	86.60	40.5	0.14		
OK-02-06-1	SERV1	25-Jul-89	97.95	43.0	0.07		
OK-03-06-1	SERV2	25-Jul-89	96.60	42.5	0.08		
OK-04-06-1	SERV3	25-Jul-89	96.75	42.0	0.07		
OK-01-06-2	MFD	27-Jul-89	90.00	38.0	0.18		
OK-02-06-2	SERV1	27-Jul-89	88.00	38.0	0.12		
OK-03-06-2	SERV2	27-Jul-89	94.00	38.0	0.14		
OK-04-06-2	SERV3	27-Jul-89	92.00	38.0	0.12		
OK-01-06-3	MFD	01-Aug-89	103.00	43.0	0.23		
OK-02-06-3	SERV1	01-Aug-89	104.00	44.0	0.15		
OK-03-06-3	SERV2	01-Aug-89	104.00	44.0	0.12		
OK-04-06-3	SERV3	01-Aug-89	103.00	44.0	0.14		
OK-01-06-4	MFD	02-Aug-89	104.00	34.0	0.08		
OK-02-06-4	SERV1	02-Aug-89	120.00	36.0	0.00		
OK-03-06-4	SERV2	02-Aug-89	112.00	34.0	0.01		
OK-04-06-4	SERV3	02-Aug-89	111.00	34.0	0.00		
OK-01-06-5	MFD	20-Sep-89	70.40	40.0	0.28		
OK-02-06-5	SERV1	20-Sep-89	75.95	40.5	0.23		
OK-03-06-5	SERV2	20-Sep-89	72.10	40.5	0.27		
OK-04-06-5	SERV3	20-Sep-89	74.20	40.0	0.28		
OK-01-06-6	MFD	27-Sep-89	109.50	48.5	0.28		
OK-02-06-6	SERV1	27-Sep-89		42.5	0.20		
OK-03-06-6	SERV2	27-Sep-89		45.0	0.18		
OK-04-06-6	SERV3	27-Sep-89		59.2			
OK-01-06-7	MFD	04-Oct-89	90.60	37.6	0.03		
OK-02-06-7	SERV1	04-Oct-89		44.4			
OK-03-06-7	SERV2	04-Oct-89		40.4			
OK-04-06-7	SERV3	04-Oct-89		46.0			

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-07-1	MFD	25-Jul-89	0.036	0.08	0.10	0.10	119.0
OK-02-07-1	SERV1	25-Jul-89	0.009	0.10	0.10	0.01	76.3
OK-03-07-1	SERV2	25-Jul-89	0.006	0.10	0.10	0.01	77.1
OK-04-07-1	SERV3	25-Jul-89	0.009	0.10	0.10	0.01	77.1
OK-01-07-2	MFD	27-Jul-89	0.028	0.47	0.01	0.13	91.0
OK-02-07-2	SERV1	27-Jul-89	0.010	0.38	0.00	0.00	81.0
OK-03-07-2	SERV2	27-Jul-89	0.009	0.37	0.00	0.00	80.0
OK-04-07-2	SERV3	27-Jul-89	0.009	0.32	0.00	0.01	80.0
OK-01-07-4	MFD	02-Aug-89	0.031	0.00	0.06	0.11	76.0
OK-02-07-4	SERV1	02-Aug-89	0.008	0.00	0.00	0.00	77.0
OK-03-07-4	SERV2	02-Aug-89	0.007	0.53	0.07	0.01	83.2
OK-04-07-4	SERV3	02-Aug-89	0.010	0.40	0.07	0.01	80.0
OK-01-07-5	MFD	20-Sep-89	0.055	1.91	0.04	0.30	96.5
OK-02-07-5	SERV1	20-Sep-89	0.020	0.88	0.00	0.02	97.0
OK-03-07-5	SERV2	20-Sep-89	0.023	1.01	0.00	0.02	97.5
OK-04-07-5	SERV3	20-Sep-89	0.022	0.86	0.00	0.02	97.5

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-07-1	MFD	25-Jul-89	83.20	35.0	0.10		
OK-02-07-1	SERV1	25-Jul-89	93.85	42.5	0.10		
OK-03-07-1	SERV2	25-Jul-89	95.80	42.5	0.08		
OK-04-07-1	SERV3	25-Jul-89	94.80	42.5	0.07		
OK-01-07-2	MFD	27-Jul-89	89.00	38.0	0.18		
OK-02-07-2	SERV1	27-Jul-89	86.00	36.0	0.19		
OK-03-07-2	SERV2	27-Jul-89	88.00	36.0	0.23		
OK-04-07-2	SERV3	27-Jul-89	86.00	36.0	0.21		
OK-01-07-4	MFD	02-Aug-89	100.00	34.0	0.09		
OK-02-07-4	SERV1	02-Aug-89	105.00	32.0	0.07		
OK-03-07-4	SERV2	02-Aug-89	141.20	36.0	0.08		
OK-04-07-4	SERV3	02-Aug-89	134.80	34.2	0.03		
OK-01-07-5	MFD	20-Sep-89	69.20	39.5	0.83		
OK-02-07-5	SERV1	20-Sep-89	72.90	40.0	1.01		
OK-03-07-5	SERV2	20-Sep-89	73.00	39.5	0.90		
OK-04-07-5	SERV3	20-Sep-89	79.70	39.5	0.87		

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-08-1	MFD	25-Jul-89	0.040	1.18	0.10	3.05	84.8
OK-02-08-1	SERV1	25-Jul-89	0.018	0.10	0.10	0.41	81.3
OK-03-08-1	SERV2	25-Jul-89	0.007	0.10	0.10	0.18	82.0
OK-04-08-1	SERV3	25-Jul-89	0.011	0.10	0.10	0.22	81.3
OK-01-08-2	MFD	27-Jul-89	0.034	1.06	0.00	3.49	217.0
OK-02-08-2	SERV1	27-Jul-89	0.009	0.22	0.00	0.15	314.0
OK-03-08-2	SERV2	27-Jul-89	0.009	0.21	0.00	0.21	309.0
OK-04-08-2	SERV3	27-Jul-89	0.010	0.19	0.00	0.11	273.0
OK-01-08-3	MFD	01-Aug-89	0.025	1.13	0.00	3.23	153.0
OK-02-08-3	SERV1	01-Aug-89	0.010	0.55	0.00	0.13	306.0
OK-03-08-3	SERV2	01-Aug-89	0.008	0.56	0.00	0.12	303.0
OK-04-08-3	SERV3	01-Aug-89	0.007	0.54	0.00	0.11	292.0
OK-01-08-4	MFD	02-Aug-89	0.023	0.52	0.07	0.92	328.8
OK-02-08-4	SERV1	02-Aug-89	0.007	0.20	0.04	0.11	340.8
OK-03-08-4	SERV2	02-Aug-89	0.006	0.12	0.08	0.10	338.4
OK-04-08-4	SERV3	02-Aug-89	0.006	0.12	0.07	0.10	340.8
OK-01-08-5	MFD	20-Sep-89	0.049	0.72	0.00	2.70	164.0
OK-02-08-5	SERV1	20-Sep-89	0.023	0.00	0.00	0.24	277.0
OK-03-08-5	SERV2	20-Sep-89	0.015	0.00	0.00	0.21	274.0
OK-04-08-5	SERV3	20-Sep-89	0.013	0.00	0.00	0.28	270.5
OK-01-08-6	MFD	27-Sep-89	0.017	1.47	0.02	2.58	262.0
OK-02-08-6	SERV1	27-Sep-89	0.005		0.00	0.45	
OK-03-08-6	SERV2	27-Sep-89	0.004		0.00	0.41	
OK-04-08-6	SERV3	27-Sep-89	0.004		0.00	0.40	

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-08-1	MFD	25-Jul-89	96.45	44.5	0.02		
OK-02-08-1	SERV1	25-Jul-89	100.45	46.0	0.02		
OK-03-08-1	SERV2	25-Jul-89	89.20	45.5	0.00		
OK-04-08-1	SERV3	25-Jul-89	97.75	46.0	0.00		
OK-01-08-2	MFD	27-Jul-89	38.00	14.5	0.12		
OK-02-08-2	SERV1	27-Jul-89	1.30	0.4	0.10		
OK-03-08-2	SERV2	27-Jul-89	1.50	0.5	0.14		
OK-04-08-2	SERV3	27-Jul-89	1.50	0.4	0.13		
OK-01-08-3	MFD	01-Aug-89	55.00	27.0	0.15		
OK-02-08-3	SERV1	01-Aug-89	1.96	0.8	0.13		
OK-03-08-3	SERV2	01-Aug-89	2.44	1.0	0.11		
OK-04-08-3	SERV3	01-Aug-89	2.24	0.9	0.13		
OK-01-08-4	MFD	02-Aug-89	4.60	1.7	0.03		
OK-02-08-4	SERV1	02-Aug-89	0.70	0.3	0.01		
OK-03-08-4	SERV2	02-Aug-89	0.80	0.3	0.00		
OK-04-08-4	SERV3	02-Aug-89	0.70	0.3	0.00		
OK-01-08-5	MFD	20-Sep-89	35.60	33.5	0.27		
OK-02-08-5	SERV1	20-Sep-89	14.85	11.5	0.39		
OK-03-08-5	SERV2	20-Sep-89	14.40	12.0	0.41		
OK-04-08-5	SERV3	20-Sep-89	14.95	12.0	0.38		
OK-01-08-6	MFD	27-Sep-89	9.74	9.7	0.02		
OK-02-08-6	SERV1	27-Sep-89		1.8			
OK-03-08-6	SERV2	27-Sep-89		0.7			
OK-04-08-6	SERV3	27-Sep-89		0.5			

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-09-1	MFD	25-Jul-89	0.009	0.10	0.27	0.06	84.5
OK-02-09-1	SERV1	25-Jul-89	0.005	0.10	0.10	0.00	77.5
OK-03-09-1	SERV2	25-Jul-89	0.003	0.10	0.10	0.00	78.3
OK-04-09-1	SERV3	25-Jul-89	0.004	0.10	0.10	0.00	77.6
OK-06-09-1	MAIN2	25-Jul-89	0.020	0.10	0.10	0.00	74.2
OK-01-09-2	MFD	27-Jul-89	0.009	0.14	0.31	0.10	81.0
OK-02-09-2	SERV1	27-Jul-89	0.006	0.10	0.08	0.00	87.0
OK-03-09-2	SERV2	27-Jul-89	0.003	0.17	0.09	0.00	85.0
OK-04-09-2	SERV3	27-Jul-89	0.003	0.12	0.07	0.00	84.0
OK-01-09-3	MFD	01-Aug-89	0.010	0.54	0.14	0.05	94.0
OK-02-09-3	SERV1	01-Aug-89	0.003	0.09	0.08	0.00	85.0
OK-03-09-3	SERV2	01-Aug-89	0.005	0.14	0.08	0.00	70.0
OK-04-09-3	SERV3	01-Aug-89	0.003	0.14	0.06	0.00	77.0
OK-06-09-3	MAIN2	01-Aug-89	0.004	0.05	0.02	0.00	75.0
OK-01-09-4	MFD	02-Aug-89	0.010	0.14	0.42	0.04	96.0
OK-02-09-4	SERV1	02-Aug-89	0.003	0.04	0.10	0.00	95.2
OK-03-09-4	SERV2	02-Aug-89	0.004	0.00	0.12	0.00	97.6
OK-04-09-4	SERV3	02-Aug-89	0.003	0.13	0.16	0.00	95.2
OK-06-09-4	MAIN2	02-Aug-89	0.009	0.34	0.16	0.00	87.2
OK-01-09-5	MFD	20-Sep-89	0.010	0.00	0.14	0.03	92.0
OK-02-09-5	SERV1	20-Sep-89	0.008	0.00	0.08	0.01	93.0
OK-03-09-5	SERV2	20-Sep-89	0.006	0.00	0.05	0.00	92.5
OK-04-09-5	SERV3	20-Sep-89	0.004	0.00	0.01	0.01	91.5
OK-06-09-5	MAIN2	20-Sep-89	0.003	0.00	0.00	0.00	91.0
OK-01-09-6	MFD	27-Sep-89	0.008	0.24	0.35	0.35	79.6
OK-02-09-6	SERV1	27-Sep-89	0.001		0.02	0.32	
OK-03-09-6	SERV2	27-Sep-89	0.001		0.03	0.32	
OK-04-09-6	SERV3	27-Sep-89	0.002		0.07	0.34	
OK-06-09-6	MAIN2	27-Sep-89	0.001	0.17	0.00	0.33	76.5
OK-06-09-7	MAIN2	04-Oct-89	0.003	0.00	0.00	0.00	72.0

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-09-1	MFD	25-Jul-89	100.70	45.0	0.00		
OK-02-09-1	SERV1	25-Jul-89	93.65	42.5	0.00		
OK-03-09-1	SERV2	25-Jul-89	96.20	42.5	0.00		
OK-04-09-1	SERV3	25-Jul-89	97.15	43.0	0.00		
OK-06-09-1	MAIN2	25-Jul-89	89.95	42.0	0.00		321
OK-01-09-2	MFD	27-Jul-89	96.00	41.0	0.11		
OK-02-09-2	SERV1	27-Jul-89	99.00	41.0	0.10		
OK-03-09-2	SERV2	27-Jul-89	94.00	40.0	0.09		
OK-04-09-2	SERV3	27-Jul-89	94.00	40.0	0.12		
OK-01-09-3	MFD	01-Aug-89	104.00	44.0	0.11		
OK-02-09-3	SERV1	01-Aug-89	111.00	34.0	0.17		
OK-03-09-3	SERV2	01-Aug-89	115.00	36.0	0.12		
OK-04-09-3	SERV3	01-Aug-89	108.00	34.0	0.12		
OK-06-09-3	MAIN2	01-Aug-89	141.00	38.0	0.11	7.06	361
OK-01-09-4	MFD	02-Aug-89	144.96	36.8	0.00		
OK-02-09-4	SERV1	02-Aug-89	139.60	36.0	0.00		
OK-03-09-4	SERV2	02-Aug-89	129.36	36.8	0.00		
OK-04-09-4	SERV3	02-Aug-89	141.44	36.0	0.00		
OK-06-09-4	MAIN2	02-Aug-89	122.00	35.2	0.00	7.09	334
OK-01-09-5	MFD	20-Sep-89	73.85	40.0	0.43		
OK-02-09-5	SERV1	20-Sep-89	76.45	41.5	0.38		
OK-03-09-5	SERV2	20-Sep-89	76.55	39.5	0.31		
OK-04-09-5	SERV3	20-Sep-89	69.25	39.5	0.29		
OK-06-09-5	MAIN2	20-Sep-89	72.70	39.5	0.36		351
OK-01-09-6	MFD	27-Sep-89	121.50	46.8	0.01		
OK-02-09-6	SERV1	27-Sep-89		36.0			
OK-03-09-6	SERV2	27-Sep-89		40.0			
OK-04-09-6	SERV3	27-Sep-89		40.8			
OK-06-09-6	MAIN2	27-Sep-89	117.60	42.4	0.00		325
OK-06-09-7	MAIN2	04-Oct-89	101.70	40.4	0.03		330

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-10-1	MFD	25-Jul-89	0.006	0.10	0.57	0.15	326.0
OK-02-10-1	SERV1	25-Jul-89	0.006	0.18	0.12	0.01	280.0
OK-03-10-1	SERV2	25-Jul-89	0.003	0.23	0.07	4.60	282.0
OK-04-10-1	SERV3	25-Jul-89	0.005	0.20	0.06	0.03	288.0
OK-01-10-2	MFD	27-Jul-89	0.005	0.09	0.49	0.03	266.0
OK-02-10-2	SERV1	27-Jul-89	0.006	0.10	0.00	0.01	276.0
OK-03-10-2	SERV2	27-Jul-89	0.003	0.08	0.00	0.00	276.0
OK-04-10-2	SERV3	27-Jul-89	0.004	0.10	0.00	0.00	275.0
OK-01-10-3	MFD	01-Aug-89	0.008	0.09	0.55	0.17	260.0
OK-02-10-3	SERV1	01-Aug-89	0.005	0.12	0.02	0.00	256.0
OK-03-10-3	SERV2	01-Aug-89	0.004	0.09	0.04	0.00	239.0
OK-04-10-3	SERV3	01-Aug-89	0.004	0.08	0.05	0.00	318.0
OK-06-10-3	MAINE	01-Aug-89	0.009	0.03	0.10	0.07	68.0
OK-01-10-4	MFD	02-Aug-89	0.007	0.15	0.66	0.14	316.0
OK-02-10-4	SERV1	02-Aug-89	0.005	0.06	0.10	0.00	330.4
OK-03-10-4	SERV2	02-Aug-89	0.005	0.03	0.10	0.00	339.2
OK-04-10-4	SERV3	02-Aug-89	0.005	0.00	0.13	0.00	331.2
OK-06-10-4	MAINE	02-Aug-89	0.018	0.13	0.09	0.15	87.2
OK-01-10-5	MFD	20-Sep-89	0.005	0.00	0.33	0.14	315.0
OK-02-10-5	SERV1	20-Sep-89	0.001	0.00	0.00	0.00	314.0
OK-03-10-5	SERV2	20-Sep-89	0.002	0.00	0.00	0.01	317.5
OK-04-10-5	SERV3	20-Sep-89	0.001	0.00	0.00	0.01	312.5
OK-06-10-5	MAINE	20-Sep-89	0.000	0.00	0.00	0.02	96.0
OK-01-10-6	MFD	27-Sep-89	0.004	0.19	0.54	0.77	324.0
OK-02-10-6	SERV1	27-Sep-89	0.002		0.00	0.35	
OK-03-10-6	SERV2	27-Sep-89	0.001		0.00	0.33	
OK-04-10-6	SERV3	27-Sep-89	0.001		0.00	0.33	
OK-06-10-6	MAINE	27-Sep-89	0.001	0.09	0.00	0.32	79.8
OK-01-10-7	MFD	04-Oct-89	0.005	0.00	0.65	0.33	239.6
OK-02-10-7	SERV1	04-Oct-89	0.001		0.00	0.02	
OK-03-10-7	SERV2	04-Oct-89	0.000		0.00	0.01	
OK-04-10-7	SERV3	04-Oct-89	0.000		0.00	0.01	
OK-06-10-7	MAINE	04-Oct-89	0.000	0.00	0.00	0.01	83.2

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-10-1	MFD	25-Jul-89	0.23	0.2	0.00		
OK-02-10-1	SERV1	25-Jul-89	0.40	0.1	0.07		
OK-03-10-1	SERV2	25-Jul-89	0.40	0.1	0.10		
OK-04-10-1	SERV3	25-Jul-89	0.30	0.1	0.06		
OK-01-10-2	MFD	27-Jul-89	0.40	0.1	0.15		
OK-02-10-2	SERV1	27-Jul-89	0.40	0.2	0.12		
OK-03-10-2	SERV2	27-Jul-89	0.40	0.1	0.11		
OK-04-10-2	SERV3	27-Jul-89	0.40	0.2	0.12		
OK-01-10-3	MFD	01-Aug-89	0.31	0.1	0.13		
OK-02-10-3	SERV1	01-Aug-89	0.39	0.2	0.17		
OK-03-10-3	SERV2	01-Aug-89	0.43	0.2	0.12		
OK-04-10-3	SERV3	01-Aug-89	0.39	0.2	0.18		
OK-06-10-3	MAIN2	01-Aug-89	126.00	36.0	0.12	7.05	361
OK-01-10-4	MFD	02-Aug-89	0.30	0.2	0.00		
OK-02-10-4	SERV1	02-Aug-89	0.30	0.2	0.00		
OK-03-10-4	SERV2	02-Aug-89	0.30	0.2	0.00		
OK-04-10-4	SERV3	02-Aug-89	0.30	0.2	0.00		
OK-06-10-4	MAIN2	02-Aug-89	125.52	35.2	0.00	7.11	326
OK-01-10-5	MFD	20-Sep-89	0.00	0.3	0.28		
OK-02-10-5	SERV1	20-Sep-89	0.00	0.2	0.27		
OK-03-10-5	SERV2	20-Sep-89	0.00	0.2	0.27		
OK-04-10-5	SERV3	20-Sep-89	0.00	0.2	0.31		
OK-06-10-5	MAIN2	20-Sep-89	73.80	45.5	0.28		355
OK-01-10-6	MFD	27-Sep-89	0.64	0.7	0.00		
OK-02-10-6	SERV1	27-Sep-89		0.2			
OK-03-10-6	SERV2	27-Sep-89		0.2			
OK-04-10-6	SERV3	27-Sep-89		0.2			
OK-06-10-6	MAIN2	27-Sep-89	102.60	46.0	0.01		326
OK-01-10-7	MFD	04-Oct-89	0.81	0.1	0.03		
OK-02-10-7	SERV1	04-Oct-89		0.1			
OK-03-10-7	SERV2	04-Oct-89		0.1			
OK-04-10-7	SERV3	04-Oct-89		0.1			
OK-06-10-7	MAIN2	04-Oct-89	95.40	42.4	0.03		331

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/1	FE mg/1	CU mg/1	ZN mg/1	NA mg/1
OK-01-11-1	MFD	25-Jul-89	0.023	0.43	0.14	1.01	99.0
OK-02-11-1	SERV1	25-Jul-89	0.014	0.27	0.12	0.15	84.0
OK-03-11-1	SERV2	25-Jul-89	0.009	0.24	0.12	0.15	86.0
OK-04-11-1	SERV3	25-Jul-89	0.009	0.23	0.10	0.15	87.0
OK-01-11-2	MFD	27-Jul-89	0.026	0.34	0.12	0.68	98.0
OK-02-11-2	SERV1	27-Jul-89	0.010	0.20	0.10	0.13	93.0
OK-03-11-2	SERV2	27-Jul-89	0.012	0.18	0.09	0.12	94.0
OK-04-11-2	SERV3	27-Jul-89	0.011	0.13	0.08	0.12	97.0
OK-01-11-3	MFD	01-Aug-89	0.030	0.23	0.11	0.57	82.0
OK-02-11-3	SERV1	01-Aug-89	0.009	0.05	0.17	0.10	80.0
OK-03-11-3	SERV2	01-Aug-89	0.010	0.01	0.16	0.07	63.0
OK-04-11-3	SERV3	01-Aug-89	0.005	0.06	0.17	0.08	82.0
OK-01-11-4	MFD	02-Aug-89	0.026	0.23	0.21	0.37	128.8
OK-02-11-4	SERV1	02-Aug-89	0.010	0.17	0.29	0.04	91.2
OK-03-11-4	SERV2	02-Aug-89	0.010	0.06	0.33	0.06	90.4
OK-04-11-4	SERV3	02-Aug-89	0.010	0.01	0.33	0.07	90.4
OK-01-11-5	MFD	20-Sep-89	0.038	0.00	0.00	0.28	90.0
OK-02-11-5	SERV1	20-Sep-89	0.008	0.00	0.00	0.14	100.5
OK-03-11-5	SERV2	20-Sep-89	0.005	0.00	0.00	0.16	104.5
OK-04-11-5	SERV3	20-Sep-89	0.006	0.05	0.04	0.14	87.0
OK-01-11-6	MFD	27-Sep-89	0.021	0.44	0.07	1.15	108.0
OK-02-11-6	SERV1	27-Sep-89	0.006		0.15	0.27	
OK-03-11-6	SERV2	27-Sep-89	0.007		0.14	0.31	
OK-04-11-6	SERV3	27-Sep-89	0.010		0.10	0.37	
OK-01-11-7	MFD	04-Oct-89	0.035	0.27	0.07	0.67	91.6
OK-02-11-7	SERV1	04-Oct-89	0.008		0.12	0.08	
OK-03-11-7	SERV2	04-Oct-89	0.007		0.11	0.10	
OK-04-11-7	SERV3	04-Oct-89	0.007		0.12	0.10	

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-11-1	MFD	25-Jul-89	92.00	34.0	0.13		
OK-02-11-1	SERV1	25-Jul-89	97.00	37.0	0.05		
OK-03-11-1	SERV2	25-Jul-89	97.00	37.0	0.09		
OK-04-11-1	SERV3	25-Jul-89	100.00	37.0	0.13		
OK-01-11-2	MFD	27-Jul-89	99.00	42.0	0.07		
OK-02-11-2	SERV1	27-Jul-89	115.00	47.0	0.10		
OK-03-11-2	SERV2	27-Jul-89	112.00	47.0	0.08		
OK-04-11-2	SERV3	27-Jul-89	111.00	48.0	0.09		
OK-01-11-3	MFD	01-Aug-89	119.00	34.0	0.14		
OK-02-11-3	SERV1	01-Aug-89	127.00	36.0	0.11		
OK-03-11-3	SERV2	01-Aug-89	119.00	34.0	0.14		
OK-04-11-3	SERV3	01-Aug-89	114.00	36.0	0.18		
OK-01-11-4	MFD	02-Aug-89	108.40	30.4	0.00		
OK-02-11-4	SERV1	02-Aug-89	126.08	36.8	0.00		
OK-03-11-4	SERV2	02-Aug-89	141.28	36.8	0.00		
OK-04-11-4	SERV3	02-Aug-89	130.64	36.8	0.00		
OK-01-11-5	MFD	20-Sep-89	72.15	40.5	0.24		
OK-02-11-5	SERV1	20-Sep-89	73.15	43.0	0.22		
OK-03-11-5	SERV2	20-Sep-89	69.95	45.0	0.22		
OK-04-11-5	SERV3	20-Sep-89		49.0	0.18		
OK-01-11-6	MFD	27-Sep-89	87.60	50.8	0.00		
OK-02-11-6	SERV1	27-Sep-89		41.6			
OK-03-11-6	SERV2	27-Sep-89		42.4			
OK-04-11-6	SERV3	27-Sep-89		41.6			
OK-01-11-7	MFD	04-Oct-89	93.30	35.6	0.03		
OK-02-11-7	SERV1	04-Oct-89		40.0			
OK-03-11-7	SERV2	04-Oct-89		39.6			
OK-04-11-7	SERV3	04-Oct-89		41.2			

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-12-2	MFD	27-Jul-89	0.004	0.18	0.01	0.02	83.0
OK-02-12-2	SERV1	27-Jul-89	0.004	0.14	0.00	0.00	102.0
OK-03-12-2	SERV2	27-Jul-89	0.004	0.19	0.00	0.00	101.0
OK-04-12-2	SERV3	27-Jul-89	0.005	0.13	0.00	0.00	101.0
OK-01-12-4	MFD	02-Aug-89	0.050	0.05	0.12	0.00	88.8
OK-02-12-4	SERV1	02-Aug-89	0.007	0.00	0.10	0.00	100.0
OK-03-12-4	SERV2	02-Aug-89	0.008	0.23	0.09	0.00	100.0
OK-04-12-4	SERV3	02-Aug-89	0.008	0.06	0.07	0.00	98.4
OK-01-12-5	MFD	20-Sep-89	0.015	0.02	0.09	0.30	81.0
OK-02-12-5	SERV1	20-Sep-89	0.011	0.00	0.17	0.02	81.5
OK-03-12-5	SERV2	20-Sep-89	0.006	0.65	0.00	0.07	86.5
OK-04-12-5	SERV3	20-Sep-89	0.007	0.00	0.06	0.02	81.0

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-12-2	MFD	27-Jul-89	105.00	44.0	0.10		
OK-02-12-2	SERV1	27-Jul-89	115.00	48.0	0.11		
OK-03-12-2	SERV2	27-Jul-89	113.00	48.0	0.09		
OK-04-12-2	SERV3	27-Jul-89	112.00	48.0	0.09		
OK-01-12-4	MFD	02-Aug-89	141.36	36.8	0.00		
OK-02-12-4	SERV1	02-Aug-89	146.32	37.6	0.00		
OK-03-12-4	SERV2	02-Aug-89	148.64	37.6	0.00		
OK-04-12-4	SERV3	02-Aug-89	135.28	36.8	0.00		
OK-01-12-5	MFD	20-Sep-89	126.30	49.5	0.19		
OK-02-12-5	SERV1	20-Sep-89		48.5	0.21		
OK-03-12-5	SERV2	20-Sep-89		48.0	0.25		
OK-04-12-5	SERV3	20-Sep-89		48.0	0.29		

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-13-1	MFD	25-Jul-89	0.007	0.26	0.09	1.61	93.0
OK-02-13-1	SERV1	25-Jul-89	0.007	0.20	0.08	0.11	91.0
OK-03-13-1	SERV2	25-Jul-89	0.008	0.23	0.07	0.15	92.0
OK-04-13-1	SERV3	25-Jul-89	0.038	0.19	0.07	0.15	92.0
OK-01-13-2	MFD	27-Jul-89	0.006	0.24	0.02	0.62	88.0
OK-02-13-2	SERV1	27-Jul-89	0.007	0.18	0.04	0.05	90.0
OK-03-13-2	SERV2	27-Jul-89	0.011	0.12	0.04	0.05	91.0
OK-04-13-2	SERV3	27-Jul-89	0.007	0.14	0.03	0.06	90.0
OK-01-13-3	MFD	01-Aug-89	0.007	0.23	0.03	0.85	218.0
OK-02-13-3	SERV1	01-Aug-89	0.009	0.00	0.04	0.06	68.0
OK-03-13-3	SERV2	01-Aug-89	0.009	0.00	0.04	0.06	46.0
OK-04-13-3	SERV3	01-Aug-89	0.008	0.02	0.05	0.06	63.0
OK-01-13-6	MFD	27-Sep-89	0.002	0.26	0.17	0.56	84.4
OK-02-13-6	SERV1	27-Sep-89	0.002		0.11	0.45	
OK-03-13-6	SERV2	27-Sep-89	0.002		0.14	0.44	
OK-04-13-6	SERV3	27-Sep-89	0.003		0.13	0.39	
OK-01-13-7	MFD	04-Oct-89	0.002	0.16	0.00	0.84	108.4
OK-02-13-7	SERV1	04-Oct-89	0.000		0.00	0.03	
OK-03-13-7	SERV2	04-Oct-89	0.000		0.00	0.03	
OK-04-13-7	SERV3	04-Oct-89	0.000		0.00	0.04	

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-13-1	MFD	25-Jul-89	92.00	38.0	0.14		
OK-02-13-1	SERV1	25-Jul-89	100.00	39.0	0.12		
OK-03-13-1	SERV2	25-Jul-89	102.00	38.0	0.14		
OK-04-13-1	SERV3	25-Jul-89	99.00	39.0	0.12		
OK-01-13-2	MFD	27-Jul-89	103.00	44.0	0.09		
OK-02-13-2	SERV1	27-Jul-89	106.00	45.0	0.11		
OK-03-13-2	SERV2	27-Jul-89	110.00	45.0	0.12		
OK-04-13-2	SERV3	27-Jul-89	100.00	45.0	0.14		
OK-01-13-3	MFD	01-Aug-89	35.00	12.0	0.11		
OK-02-13-3	SERV1	01-Aug-89	111.00	34.0	0.12		
OK-03-13-3	SERV2	01-Aug-89	114.00	34.0	0.15		
OK-04-13-3	SERV3	01-Aug-89	112.00	34.0	0.09		
OK-01-13-6	MFD	27-Sep-89	96.00	40.8	0.00		
OK-02-13-6	SERV1	27-Sep-89		39.6			
OK-03-13-6	SERV2	27-Sep-89		39.6			
OK-04-13-6	SERV3	27-Sep-89		39.6			
OK-01-13-7	MFD	04-Oct-89	82.20	35.6	0.03		
OK-02-13-7	SERV1	04-Oct-89		7.2			
OK-03-13-7	SERV2	04-Oct-89		6.0			
OK-04-13-7	SERV3	04-Oct-89		6.0			

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-14-2	MFD	27-Jul-89	0.004	0.22	0.01	0.28	91.0
OK-02-14-2	SERV1	27-Jul-89	0.004	0.15	0.00	0.02	103.0
OK-03-14-2	SERV2	27-Jul-89	0.005	0.15	0.00	0.02	102.0
OK-04-14-2	SERV3	27-Jul-89	0.003	0.15	0.00	0.02	102.0
OK-01-14-3	MFD	01-Aug-89	0.004	0.00	0.00	0.06	50.0
OK-02-14-3	SERV1	01-Aug-89	0.003	0.00	0.00	0.00	44.0
OK-03-14-3	SERV2	01-Aug-89	0.002	0.00	0.00	0.00	46.0
OK-04-14-3	SERV3	01-Aug-89	0.004	0.00	0.00	0.00	52.0
OK-01-14-5	MFD	20-Sep-89	0.002	0.00	0.00	0.23	224.5
OK-02-14-5	SERV1	20-Sep-89	0.003	0.00	0.00	0.02	85.5
OK-03-14-5	SERV2	20-Sep-89	0.002	0.00	0.00	0.02	90.5
OK-04-14-5	SERV3	20-Sep-89	0.003	0.00	0.00	0.01	84.5
OK-01-14-6	MFD	27-Sep-89	0.003	0.32	0.00	0.68	156.0
OK-02-14-6	SERV1	27-Sep-89	0.003		0.00	0.33	
OK-03-14-6	SERV2	27-Sep-89	0.003		0.00	0.33	
OK-04-14-6	SERV3	27-Sep-89	0.003		0.00	0.27	

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-14-2	MFD	27-Jul-89	105.00	45.0	0.15		
OK-02-14-2	SERV1	27-Jul-89	111.00	47.0	0.15		
OK-03-14-2	SERV2	27-Jul-89	112.00	47.0	0.15		
OK-04-14-2	SERV3	27-Jul-89	113.00	47.0	0.17		
OK-01-14-3	MFD	01-Aug-89	108.00	34.0	0.07		
OK-02-14-3	SERV1	01-Aug-89	112.00	34.0	0.12		
OK-03-14-3	SERV2	01-Aug-89	113.00	34.0	0.08		
OK-04-14-3	SERV3	01-Aug-89	112.00	36.0	0.09		
OK-01-14-5	MFD	20-Sep-89	48.00	15.5	0.22		
OK-02-14-5	SERV1	20-Sep-89		48.0	0.24		
OK-03-14-5	SERV2	20-Sep-89		47.0	0.24		
OK-04-14-5	SERV3	20-Sep-89		47.5	0.25		
OK-01-14-6	MFD	27-Sep-89	57.20	6.4	0.00		
OK-02-14-6	SERV1	27-Sep-89		34.4			
OK-03-14-6	SERV2	27-Sep-89		37.6			
OK-04-14-6	SERV3	27-Sep-89		36.4			

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	PB mg/l	FE mg/l	CU mg/l	ZN mg/l	NA mg/l
OK-01-15-3	MFD	01-Aug-89	0.010	0.00	0.13	0.06	50.0
OK-02-15-3	SERV1	01-Aug-89	0.005	0.00	0.02	0.00	51.0
OK-03-15-3	SERV2	01-Aug-89	0.006	0.00	0.03	0.00	60.0
OK-04-15-3	SERV3	01-Aug-89	0.006	0.00	0.03	0.00	66.0
OK-01-15-5	MFD	20-Sep-89	0.004	0.00	0.00	0.03	76.0
OK-02-15-5	SERV1	20-Sep-89	0.001	0.00	0.00	0.00	75.0
OK-03-15-5	SERV2	20-Sep-89	0.004	0.00	0.00	0.00	74.5
OK-04-15-5	SERV3	20-Sep-89	0.001	0.00	0.00	0.00	74.5
OK-01-15-6	MFD	27-Sep-89	0.010	0.25	0.00	0.31	70.7
OK-02-15-6	SERV1	27-Sep-89	0.001		0.00	0.29	
OK-03-15-6	SERV2	27-Sep-89	0.001		0.00	0.02	
OK-04-15-6	SERV3	27-Sep-89	0.001		0.00	0.02	
OK-01-15-7	MFD	04-Oct-89	0.002	0.02	0.00	1.28	69.6
OK-02-15-7	SERV1	04-Oct-89	0.001		0.00	0.11	
OK-03-15-7	SERV2	04-Oct-89	0.002		0.00	0.10	
OK-04-15-7	SERV3	04-Oct-89	0.000		0.00	0.10	

PEACH ORCHARD DATA

SAMPID	CODE	SAMPDT	CA mg/l	MG mg/l	MN mg/l	PH	ALK mg/l
OK-01-15-3	MFD	01-Aug-89	111.00	34.0	0.02		
OK-02-15-3	SERV1	01-Aug-89	112.00	34.0	0.10		
OK-03-15-3	SERV2	01-Aug-89	106.00	34.0	0.10		
OK-04-15-3	SERV3	01-Aug-89	112.00	34.0	0.07		
OK-01-15-5	MFD	20-Sep-89	111.60	45.5	0.28		
OK-02-15-5	SERV1	20-Sep-89		45.0	0.23		
OK-03-15-5	SERV2	20-Sep-89		45.0	0.32		
OK-04-15-5	SERV3	20-Sep-89		45.0	0.29		
OK-01-15-6	MFD	27-Sep-89	102.30	40.4	0.00		
OK-02-15-6	SERV1	27-Sep-89		41.2			
OK-03-15-6	SERV2	27-Sep-89		38.4			
OK-04-15-6	SERV3	27-Sep-89		40.8			
OK-01-15-7	MFD	04-Oct-89	97.80	44.0	0.03		
OK-02-15-7	SERV1	04-Oct-89		43.2			
OK-03-15-7	SERV2	04-Oct-89		42.8			
OK-04-15-7	SERV3	04-Oct-89		42.4			

APPENDIX D

Peach Orchard Observations about each House

House 1; Cu service line: Sample was taken from an inside spigot could account for high lead levels if the spigot is not used often. House has a water softener.

House 2; Cu service line: Sample was taken from a basement tap. House has a water softener.

House 3; Cu service line: Some morning first draw samples had lead concentrations >0.01 mg/L and the service line samples were all <0.01 mg/L. This indicates the lead source is probably the faucet or plumbing. House has water softener. Rounds 5, 6, and 7 were samples of softened water.

House 4; Pb service line: Service line sample lead concentrations exceeded 0.01 mg/L in one round before service line replacement and in one round after lead service line replacement. These results lead me to ask if we really obtained service line samples each time. It seems LSLR reduced the lead levels at the tap.

House 5; Pb service line: The lead concentration was always <0.01 mg/L at the tap with a lead service line and new faucet. House has water softener.

House 6; Pb service line: Morning first draw samples had extremely high lead concentrations (>0.05 mg/L). The lead service line samples had high lead concentrations >0.01 mg/L before LSLR and <0.01 mg/L after LSLR. LSLR reduced lead at the tap for service line samples but not for morning first draw. This indicates a major source of lead is in the faucet or plumbing. House has water softener.

House 7; Pb service line: House had lead service line and a new faucet. The plumbing information sheet indicates the sample was taken at the hot water kitchen tap. The source of high lead in the morning first draw samples is most likely the faucet. LSLR did not reduce the lead concentration at the tap. House has water softener.

House 8; Pb service line: Results indicate the water softener was on during all sample rounds except Round 1. Sample was taken at the basement bath sink. Morning first draw lead concentrations were >0.01 mg/L. There was not a significant change in lead levels at the tap after LSLR.

House 9; Cu service line: House had copper plumbing with Pb/Sn solder. Lead concentrations were low in all samples. House has water softener.

House 10; unknown: House had copper plumbing with Pb/Sn solder. Results indicate the water softener was on for all water samples. The lead concentrations were <0.01 mg/L for all samples except one main sample. The main samples were taken from an outside spigot.

APPENDIX D (cont)

House 11; Pb service line: Samples were taken at a bar sink which has some copper plumbing. All the morning first draw samples had lead concentrations >0.01 mg/L. LSLR did not significantly decrease lead concentrations at the tap. House has water softener.

House 12; Pb service line: Samples were taken from the rear outside spigot. LSLR did not appear to affect the lead concentrations at the tap. House has water softener.

House 13; Cu service line: Data is unclear.

House 14; Cu service line: All samples had lead concentrations <0.01 mg/L. House has water softener.

House 15; Cu service line: Samples were taken from faucet in master bathroom. Lead concentrations were <0.01 mg/L. House has water softener.