UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

DEC 11 2009

SUBJECT: Decision Rationale for Approval of Washington Aqueduct Treatment Changes

FROM: Jennie Perey Saxe, Ph.D., Lead Environmental Scientist, Drinking Water Branch (3WP21)

TO: File

THRU: William S. Arguto, Chief, Drinking Water Branch (3WP21)

1. Purpose

The purpose of this memo is to document EPA Region III's review of and rationale for approval of treatment changes at the Washington Aqueduct's two treatment plants. Several supporting documents are included as attachments to this memo.

2. Background

The Washington Aqueduct is planning to replace its liquid/gas chlorine disinfection process with sodium hypochlorite at both of its treatment plants. At the same time, the Aqueduct will be adding caustic soda capability for fine pH adjustment at the Dalecarlia Treatment Plant and for all pH adjustment at the McMillan Treatment Plant. The schedule for implementation of these treatment changes is as follows:

Treatment Process	**Treatment Plant**	**Implementation timeframe** (*approximate; as of 11/19/09*)
Hypochlorite	Dalecarlia	May 2010
	McMillan	January 2010
Caustic soda	Dalecarlia	April/May 2010
	McMillan	May/June 2010

In June 2006, EPA Region III issued an optimal corrosion control treatment (OCCT) designation to the Washington Aqueduct and the DC Water and Sewer Authority (DCWASA). This designated orthophosphate as the OCCT for these two systems and included water quality parameters (WQPs) for entry point and distribution system monitoring. The WQP designations were final for all parameters except for pH at the Washington Aqueduct; that WQP designation was an interim designation (7.7 ± 0.3 units) until caustic soda treatment was in place. After this treatment change, the final WQP for finished water pH will be 7.7 ± 0.1 units. The Washington Aqueduct and DCWASA have been meeting all interim and final (as applicable) WQPs of the OCCT designation.

3. Primacy agency treatment change review and approval process

Lead and Copper Rule provisions

Per the October 2007 Lead and Copper Rule Short-term Regulatory Revisions and Clarifications ("2007 LCR revisions"), the primacy agency must review and approve any long-term change in water treatment (40 CFR §141.90(a)(3)). The purpose of this process is to allow the primacy agency to evaluate whether the treatment change may have an adverse effect on corrosion control.

LT2 requirements

Also, per the Long Term 2 Enhance Surface Water Treatment Rule (LT2), the system must submit to the primacy agency revised *Giardia* and virus profiles and benchmarks when making a significant change to disinfection treatment (40 CFR §141.708). The purpose of this process is to evaluate whether the treatment change may have an adverse effect on microbial inactivation.

4. Studies to support decisions

Corrosion control impacts

In December 2008, HDR, Inc. (through a subcontract with the Cadmus Group, Inc.) submitted an engineering review of the treatment changes. The review built upon a literature review of treatment change impacts which was performed by Cadmus in 2007. In May 2009, EPA Region III requested that an ORD corrosion scientist (Mike Schock) additionally review the HDR study.

Disinfection impacts (profiles and benchmarks)

In February 2009, EPA Region III requested that the Washington Aqueduct recalculate disinfection profiles and benchmarks which take into account the upcoming treatment change. *Giardia* profiles and benchmarks were submitted in May 2009. Virus profiles and benchmarks were submitted in June 2009. In July 2009, EPA Region III requested that the EPA Office of Ground Water and Drinking Water Technical Support Center (TSC) in Cincinnati review the submitted profiles and benchmark calculations. Derek Losh of the TSC reviewed the data.

5. Study findings

Corrosion control impacts

- Maintenance of the orthophosphate dose and proper pH range will have a greater impact than the changes of converting to sodium hypochlorite as a disinfectant and adding caustic soda for pH control
- Advantages of treatment changes:
    - Same level of disinfection efficiency
    - More consistent finished water pH
    - Oxidation-reduction potential (ORP), dissolved inorganic carbon (DIC), and alkalinity should all remain constant
- Potential issues with treatment changes:
    - Slight increase in sodium levels of finished water
        - Increase is estimated to be 5 – 6 mg/L
        - WA reports sodium levels to DC DOH quarterly, as required by regulation
    - Contaminants (chlorate, chlorite, perchlorate, bromate) may be present (or form) in hypochlorite solution
        - 17 to 23 days of supply will be on hand at each treatment plant; HVAC renovations in hypochlorite storage areas will provide an environment which will minimize solution degradation

Comments from ORD: ORD noted that the two treatment changes planned at Washington Aqueduct are occurring elsewhere in the water industry. ORD did not identify any reasons to disapprove the changes. The review found that implementation of caustic soda would be advantageous and that the replacement of gaseous chlorine with liquid hypochlorite should proceed, provided other operating parameters are accounted for and remain constant.

Also, based on the findings of recent literature, ORD strongly encouraged revisiting the minimum orthophosphate level identified in our OCCT designation for the Aqueduct (i.e., raising the minimum value from 0.5 mg/L to 2 mg/L). Although the minimum permissible orthophosphate level is currently 0.5 mg/L, the Aqueduct is dosing orthophosphate at approximately 2.5 mg/L. ORD noted that there is still significant PbO_2 (lead (IV)) scale in the distributions system pipe scale, possibly due to its coating by aluminum-containing scales; thus, ORD also recommended optimization of coagulant addition and perhaps elimination of lime at the Dalecarlia plant in order to raise the orthophosphate dose without aluminum-phosphate solid precipitation in the distribution system.

Regarding decreased levels of calcium due to reduced lime usage, ORD noted that although there is a good chance the removal of calcium is not going to be an issue, the lead levels must be watched closely for indications of film and protection loss. If the pipe scale surface material is destabilized by lowered calcium, the effect might not show up for months or even a year or more. It would probably be possible to overcome any effects of losing calcium by augmenting the formation of the lead (II) phosphates by an increased orthophosphate dosage.

Additional notes on distribution system monitoring: To meet EPA's request for distribution system monitoring during the first 18 months of implementation, DCWASA has committed to the Washington Aqueduct that DCWASA will share its distribution system ORP measurements and historic and current data for LCR sampling locations for purposes of assessing impacts to the distribution system.

As another way to track distribution system behavior, DCWASA continues to perform lead profile analyses at homes with lead compliance results over the action level and at homes that have high iron levels. Some "customer demand" samples also trigger lead profile analyses, if DCWASA is permitted access to the home to perform the sampling. DCWASA also informed EPA Region III that additional lead service line samples will be sent to Dr. Barry Maynard (University of Cincinnati) for scale analysis.

DC Drinking Water Technical Expert Working Group (TEWG) coordination: These treatment changes have been discussed during TEWG conference calls on August 24, 2007, February 22, 2008, August 22, 2008 and June 5, 2009; most of the TEWG members were present for one or more of these calls. Call notes have been shared with all on the TEWG mailing list.

The only question received during TEWG calls was whether the caustic soda change should be piloted in pipe loops prior to implementation. The Aqueduct noted that caustic soda was originally used in its pipe loops for pH control (ease of dosing) without adverse impacts. The draft pipe loop report prepared by the Aqueduct's contractor did not indicate any issues that arose from the use of caustic soda for pH control and hypochlorite for disinfection in the pipe loops. Dissolved and total lead levels were actually slightly higher and more scattered in the control loop (constant orthophosphate dose, pH 7.7 +/- 0.3, lime for pH control; chlorine for chloramine formation) than in loop 6, which had a constant orthophosphate dose, pH of 7.7 +/- 0.2, and used caustic soda and sodium hypochlorite. Disinfection byproducts and ORP were similar in all pipe loops, except when a chlorine burn was simulated (causing an increase in ORP).

DCWASA also noted that the decrease in calcium (from reduced use of lime) may actually improve distribution system conditions with respect to precipitation and scaling (consistent with findings of the HDR study).

Disinfection impacts (profiles and benchmarks)

The Washington Aqueduct analyzed bihourly data from 2008 to estimate the impact of the planned treatment changes on disinfection efficiency for *Giardia* and viruses. The Aqueduct assumed that a pH increase of 0.3 units through each of the 2 disinfection segments could result from use of sodium hypochlorite and reconstructed disinfection profiles based on this assumption. As can be seen from the summary table below, the Aqueduct will continue to meet the required log inactivation for *Giardia* and viruses. Throughout most of the year, log inactivation values are much higher than what is required.

Summary of Washington Aqueduct Disinfection Benchmark Values (units of "log inactivation")[#]

	Dalecarlia Treatment Plant			**McMillan Treatment Plant**		
	Required inactivation	Current benchmark	Estimated benchmark (post-treatment change)	Required inactivation	Current benchmark	Estimated benchmark (post-treatment change)
Giardia	3	6.6 (actual Cl2) 5.6 (max Cl2)[‡]	6.0 (actual Cl2) 4.8 (max Cl2)[‡]	3	6.8 (actual Cl2) 5.7 (max Cl2)[‡]	6.2 (actual Cl2) 5.2 (max Cl2)[‡]
Viruses	4	184 (actual Cl2) 153 (max Cl2)[‡]	184 (actual Cl2) 153 (max Cl2)[‡*]	4	235 (actual Cl2) 190 (max Cl2)[‡*]	235 (actual Cl2) 190 (max Cl2)[‡*]

(*<u>Benchmark</u>: the lowest mean monthly level of Giardia or virus inactivation.*)

[#] These represent the revised benchmark values received from Washington Aqueduct by email on September 3, 2009 (document dated August 28, 2009) which incorporate corrections to errors identified though the TSC review.

[‡] The Washington Aqueduct calculated the benchmarks in two ways: using the actual disinfectant residual ("actual Cl2") and using the maximum value of 3 mg/L is used, per EPA's guidance manual ("max Cl2").

[*] The CT tables in EPA's 1999 Disinfection Profiling and Benchmarking Guidance Manual show that virus inactivation using free chlorine or chloramines is independent of pH (between pH 6.0 and 9.0); thus, the potential increase of 0.3 pH units taken into consideration for estimating the new *Giardia* benchmark would not have an effect on the benchmark for viruses.

Comments from TSC: The TSC review included a comparison of the Aqueduct's CT calculations against EPA's 1999 Disinfection Profiling and Benchmarking Guidance Manual. The Aqueduct calculated slightly lower values for the required CT than were estimated by the TSC reviewer; the Guidance Manual allows for some flexibility in this calculation. The reviewer noted that the difference was minor (approximately 15% difference) and that the Aqueduct's procedure was reasonable. The TSC log inactivation estimates for *Giardia* and viruses were lower in all cases than those calculated by the Aqueduct; however, the TSC estimates still indicate that the Aqueduct will continue to be capable of achieving the required inactivation values after the treatment changes.

The TSC review identified a few very minor errors in the calculations used to derive the Aqueduct's disinfection profiles and benchmark values. These errors were corrected upon presentation of the TSC review to the Aqueduct.

6. Public notifications

Environmental Assessment

- In April 2007, Washington Aqueduct prepared a draft Environmental Assessment (EA) of the system improvements (treatment changes) under NEPA. Notifications were printed in several area newspapers. In addition, the draft EA was sent to:
    - Elected officials, including: Reps. Norton and Van Hollen, Sen. Cardin, and DC City Councilmembers Cheh and Graham
    - District agencies, including: DDOE and DC DOH
    - Community groups, including: ANC commissioners and other citizen groups
    - Environmental/activist groups, including: DC Appleseed and Clean Water Action
    - County, State, and Federal agencies, including: Arlington County (VA), Montgomery County (MD), MDE, and EPA Region III
- Comments on the draft EA were provided by DDOT, DDOE, DC Historic Preservation Office, National Park Service, Montgomery County (MD) Planning Department, MDE, and Maryland Historic Trust
    - DDOE's comment related to the need to include emergency response and spill prevention in WA's comprehensive emergency response plan.
- Washington Aqueduct finalized the EA and issued a Finding of No Significant Impact (FONSI) for the treatment changes in June 2007

Consumer Confidence Report

- Washington Aqueduct included a statement regarding the upcoming treatment changes in its CCR to its customer systems (DCWASA, Arlington County (VA), and Falls Church (VA))

Website

- A notice regarding the treatment changes (including the final EA and FONSI) remains on the Washington Aqueduct's website: http://washingtonaqueduct.nab.usace.army.mil/hypochlorite.htm

7. Timeline of related activities

April 2007	Washington Aqueduct (WA) sends draft Environmental Assessment on treatment changes to stakeholders
June 2007	WA final Environmental Assessment and FONSI on treatment changes
8/24/07	Preliminary discussion of schedule for treatment changes on TEWG call
11/26/07	Region III amends contract work assignment to include a literature review of the treatment changes with respect to corrosion control
12/31/07	Literature review received from Cadmus
2/22/08	Discussion of treatment changes on TEWG call
3/5/08	WA submits to EPA Region III a technical memorandum describing treatment changes and potential impacts
4/1/08	Region III approves work plan for contract work assignment which includes engineering review ofthe treatment changes with respect to corrosion control
6/18/08	Region III formally requests information from WA for review of treatment changes
8/18/08	Documentation on treatment changes received from WA
8/22/08	Discussion of treatment changes on TEWGcall
12/12/08	Final report on corrosion control impacts received from HDR
12/22/08	Briefing on HDR report for Acting DWB Branch Chief and ODWSWP AD
1/13/09	Region III requests follow-up information on treatment changesfrom WA

2/4/09	WA submits additional information in response to Region III's 1/13/09 request
2/6/09	Region III issues clarification to WA on LT2 requirements and requests *Giardia* and virus profiles and benchmarks
5/8/09	Region III receives *Giardia* profiles and benchmarks from WA (*dated May 1, 2009*)
5/22/09	Report on corrosion control impacts sent to ORD for additional review
5/26/09	Region III receives confirmation from OGWDW that WA must also complete a virus profile and benchmark; requirement reiterated to WA
6/1/09	Comments on corrosion control impacts study received from ORD
6/5/09	Discussion of treatment changes on TEWG call
6/5/09	Virus profiles and benchmarks received from WA (*clarifications received: 6/9/09*)
6/10/09	Briefing for DWB Branch Chief and ODWSWP AD
6/11/09, 6/23/09	Requested additional review of WA profiles/benchmarks
6/12/09	ORC attorney assigned (*Phil Yeany*)
6/15/09	Requested clarifications from WA regarding pH impacts of treatment change and *Giardia* profile data (*clarifications received: 6/16/09*)
6/17/09	Additional comments received from ORD
6/23/09	Discussed notification procedure with OSCR
6/29/09	Comments on draft letter received from ORC
7/2/09	Briefing for WPD Director
7/2/09	Briefing paper sent to OGWDW for review and comment
7/2/09	Draft approval letter sent for additional ORC review (*Stef Shamet*)
7/2/09	Requested OGWDW Technical Support Center (TSC) review of WA profile and benchmark calculations
7/2/09	Informed by WA of error in calculations, leading to an underestimation of CT through the filter segment; revised profiles and benchmark calculations will be sent
7/14/09	Received feedback from OGWDW
7/17/09	Revised profiles received from WA; sent to TSC on 7/20/09
7/31/09	Received TSC review of WA profile and benchmark calculations
8/18/09	Shared TSC comments with WA
9/3/09	WA provided slightly revised benchmark values based on TSC review and recommendations (email dated 9/3/09; document dated 8/28/09)
10/7/09	Received additional comments on draft approval letter from ORC
10/9/09	Information on treatment changes posted to Water Treatment News section of www.epa.gov/dclead

8. Decision

EPA Region III is approving the Washington Aqueduct's implementation of sodium hypochlorite for disinfection and caustic soda for pH control, as described in Section 2 of this memo (Background), based on the information submitted by the Washington Aqueduct and reviews of this information conducted by EPA program staff, technical experts and contractors. These treatment changes are not anticipated to have adverse impacts on corrosion control or disinfection processes. The conversion to hypochlorite for disinfection represents a safety improvement and the addition of caustic soda will improve pH and corrosion control.

9. Attachments

1) EPA Region III request for information on Washington Aqueduct's treatment changes (dated June 18, 2008)
2) Washington Aqueduct's response to EPA Region III request for information on treatment changes (dated August 5, 2008)
3) EPA Region III request for follow-up information on treatment changes (email dated January 13, 2009)
4) Washington Aqueduct's response to EPA Region III follow-up request (dated February 2, 2009)
5) EPA Region III request for revised *Giardia* and virus profiles and benchmarks (dated February 6, 2009)
6) Washington Aqueduct's response to EPA Region III request for revised disinfection profiles and benchmarks (dated May 1, 2009)
7) Washington Aqueduct *Giardia* profiles (July 17, 2009 version)
8) Washington Aqueduct virus profiles (July 17, 2009 version)
9) Cadmus literature review of treatment changes (dated December 31, 2007)
10) HDR engineering review of treatment changes (dated December 12, 2008)
11) ORD review of HDR corrosion control impacts study (dated June 1, 2009)
12) EPA TSC review of disinfection profile and benchmark data (dated July 31, 2009)

Attachment 1: EPA Region III request for information on Washington Aqueduct's treatment changes

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

JUN 18 2008

Thomas P. Jacobus
General Manager
Washington Aqueduct Division
U.S. Army Corps of Engineers
5900 MacArthur Boulevard, NW
Washington, DC 20016-2514

Dear ~~Mr. Jacobus~~ Tom:

The U.S. Environmental Protection Agency (EPA) Region III office is aware of the Washington Aqueduct's planned installation of facilities to provide disinfection with sodium hypochlorite and to provide fine adjustment of pH using caustic soda (sodium hydroxide). Per the October 2007 Lead and Copper Rule Short-Term Regulatory Revisions and Clarifications (72 FR 57782), water systems deemed to have optimized corrosion control must submit written documentation describing long-term treatment changes so that the primacy agency may review and approve the treatment changes prior to implementation of the changes (40 CFR §141.90(a)(3)).

The regulations do not explicitly state the documentation that must be provided; however, as primacy agency for the Public Water System Supervision Program in the District of Columbia, EPA Region III requests that the Washington Aqueduct submit the following information in support of the upcoming treatment changes:

1) A description of the upcoming treatment changes, including:
    a) The rationale for changes,
    b) A timeline for implementation of the changes, and
    c) Revised treatment process schematics,
2) Certificate of Analysis for the sodium hypochlorite product to be used,
3) Any studies performed by (or on behalf of) the Washington Aqueduct to examine the impact of these treatment changes on corrosivity of the water or other facets of water quality,
4) The completed checklist from page 2-2 of EPA's LT2/Stage 2 Simultaneous Compliance Guidance Manual (EPA 815-R-07-017, March 2007) which is available online at:
http://www.epa.gov/safewater/disinfection/stage2/pdfs/guide_st2_pws_simultaneous-compliance.pdf,

5) A supplemental monitoring plan for the first 6 months of implementation of the treatment changes that includes:
    a) Monitoring of oxidation-reduction potential at representative sites in the distribution system,
    b) Monitoring of dissolved and particulate lead levels at representative sites in the distribution system, and
    c) Weekly monitoring of sodium in finished water from the Dalecarlia and McMillan treatment plants, and

6) Any additional documentation which you believe would be beneficial for us to consider in our review.

In addition, this may be an appropriate time to consider decreasing the in-plant chlorine dose. The July 2005 report *Disinfection Byproduct Evaluation of The Washington Aqueduct U.S. Army Corps of Engineers* ("DBP Evaluation") included the following recommendation:

> "Manage free chlorine and total chlorine CT such that the log *Giardia lamblia* inactivation is close to each plant's disinfection benchmark (or alternatively, WA's established goal of 1.0 log inactivation) on a year-round basis. This can be done by making adjustments in the free chlorine dose, the water's pH during free chlorine contact time, and/or the point of application of ammonia. It is essential to consider all disinfection segments when calculating compliance and considering process control (e.g., free chlorine through the filters, free chlorine through the first clearwell and chloramines from the point of ammonia addition)."

Please provide us with your plans to consider this recommendation of the DBP Evaluation.

Please submit the requested materials no later than 60 days from the date of this letter. If you have any questions, please feel free to contact me (rogers.rick@epa.gov; 215-814-5711) or Dr. Jennie Saxe (saxe.jennie@epa.gov; 215-814-5806).

Sincerely,

Richard A. Rogers, Chief
Drinking Water Branch

cc: Lloyd Stowe, Washington Aqueduct

Attachment 2: Washington Aqueduct's response to EPA Region III request for information on treatment changes

[illegible]
Rec'd OGWDW 8/18/

DEPARTMENT OF THE ARMY
WASHINGTON AQUEDUCT
U.S. ARMY CORPS OF ENGINEERS, BALTIMORE DISTRICT
5900 MACARTHUR BOULEVARD, N.W.
WASHINGTON, D.C. 20016-2514

5 August 2008

Jennie Perey Saxe, Ph.D.
Water Protection Division
Drinking Water Branch
EPA Region III, 3WP21
1650 Arch Street
Philadelphia, PA 19103-2029

Dear Dr. Saxe:

In response to EPA Region III's letter dated June 18, 2008, Washington Aqueduct is hereby submitting for your review and approval the requested documentation of our planned long-term treatment change to a sodium hypochlorite disinfection system and to use of sodium hydroxide for fine pH adjustment.

We would like to note that we are submitting potential specification requirements for the sodium hypochlorite in lieu of your request for a certificate of analysis because we are not able to predict which supplier will be awarded the contract once the system is constructed and we are ready to begin purchasing the chemical.

Also, as you know, Washington Aqueduct does not own a distribution system. Thus, we request clarification on your request for a supplemental monitoring plan for the first 6 months of implementation at representative sites in the distribution system.

If you have any questions about this submittal, please feel free to contact me or Lloyd Stowe, Operations Branch Chief, at 202-764-2702.

Sincerely,

Thomas P. Jacobus
General Manager

Enclosures

Description of Treatment Changes

Rationale for Changes

Washington Aqueduct, a Division of the U.S. Army Corps of Engineers (USACE), Baltimore District, operates the Dalecarlia and McMillan Water Treatment Plants (WTPs) in Washington, D.C., serving potable water to approximately one million persons in the District of Columbia and northern Virginia. Washington Aqueduct withdraws water from the Potomac River, treats and disinfects the water, and distributes the finished water to the metropolitan service area. Washington Aqueduct has decided to modify two components of the treatment process – disinfection and control of pH – at both the Dalecarlia WTP and the McMillan WTP to enhance the reliability of the production of safe drinking water and to reduce operational risk.

Disinfection

Bulk liquid chlorine, created by compressing pure chlorine gas, has been used throughout the history of disinfection at the Dalecarlia WTP and the McMillan WTP. Due to the hazardous nature of the liquid chlorine, engineering and management controls are employed to minimize risks associated with its handling and use. As an alternative to using liquid chlorine, chlorine as aqueous sodium hypochlorite, an inherently safer form, is commercially available and frequently used in the water treatment industry. Washington Aqueduct has decided to convert the disinfection process at the Dalecarlia WTP and the McMillan WTP from using bulk liquid chlorine to using aqueous sodium hypochlorite for disinfection in order to eliminate the inherent risks associated with storing and handling liquid chlorine.

pH Control

In 2004, in the interest of managing corrosion observed in parts of the District of Columbia water distribution system, EPA Region III approved a Washington Aqueduct plan to take steps to modify the water treatment process. The initial step taken was to introduce a chemical corrosion inhibitor, phosphoric acid. In addition, the acceptable range for pH in finished water was modified. Washington Aqueduct has decided to use caustic soda for pH control to supplement lime, which is currently used at both the Dalecarlia WTP and the McMillan WTP. Washington Aqueduct also determined that sulfuric acid may be needed periodically to control pH at the McMillan WTP.

Highlights of the Revised Treatment Process and Facilities

- Design, construction and operation of bulk sodium hypochlorite storage and feed systems at both the Dalecarlia WTP and the McMillan WTP.

- Design, construction, and operation of a caustic soda storage and feed system in order to trim pH following pH adjustment with lime at the Dalecarlia WTP.

- Design, construction, and operation of caustic soda and sulfuric acid storage and feed systems for the control of pH at the McMillan WTP.

- Construction of a new structure adjacent to an existing storage building at the Dalecarlia WTP, and no new structures at the McMillan WTP.

Timeline for Implementation of Changes

Following is the tentative timeline for implementation of the changes described in this letter. However, construction start and completion dates are subject to change based on a variety of factors, many of which are not under the direct control of Washington Aqueduct.

Construction Contract Presolicitation Notice: Posted on FedBizOpps on July 3, 2008
Estimated Construction Start Date: October 2008
Estimated Construction Completion Date: April 2010

Revised Treatment Process Schematics

Treatment process schematics not posted on www.epa.gov/dclead.

Key Specification Requirements for Sodium Hypochlorite

Washington Aqueduct intends to use AWWA Standard B300-04 as the basis for our chemical specification for sodium hypochlorite, with modifications as needed to accommodate specific purchasing requirements. The following table lists several potential specification requirements aimed at reducing the potential for undesirable contaminants (e.g., chlorate, chlorite, perchlorate, or bromate) to occur or form in the purchased hypochlorite. These or similar requirements to limit the degradation of strength or quality of the hypochlorite product will be considered carefully, but the details may need to be adjusted to ensure that manufacturers are capable of meeting the requirements.

Desired concentration	Shall contain not less than 100 g/L available chlorine (12 trade percent); total free alkali shall not exceed 1.5 percent by weight (expressed as NaOH)
pH	>12
Ni2+ concentrations	< 0.05 mg/L
Cu2+	< 0.05 mg/L
Chlorate concentration	< 1.5 g/L
Delivery deadline	within 72 hours of production
Storage temperature prior to delivery	< 20 degrees C
Certification	Certified as suitable for contact with or treatment of drinking water in accordance with NSF/ANSI Standard 60. Certification shall be at a minimum Maximum Use Level of 10 ppm (as chlorine)

Supplemental Monitoring Plan—Sodium in Finished Water
First 6 Months of Sodium Hypochlorite/ Caustic Soda Implementation

Washington Aqueduct will monitor sodium once per week at the following locations:

JS (McMillan WTP Finished Water)
18 (Dalecarlia WTP Finished Water)

Washington Aqueduct will collect samples each Tuesday.

Completed Checklist from page 2-2 of EPA's LT2/ Simultaneous Compliance Guidance Manual (March 2007)

Exhibit 2.1 Checklist for Identifying Key Operational and Simultaneous Compliance Issues

Yes No

☐■ ***Will you be getting less CT (measured as log inactivation) for any regulated microorganism (i.e. viruses, Giardia, or Cryptosporidium) as a result of the treatment change?*** If you answered "yes" and are a surface water system, you must conduct disinfection benchmarking and profiling. If you are a ground water system required to meet 4-loginactivation, you must continue to meet 4-log inactivation.

☐■ ***Will the treatment change cause an increase (seasonal or permanent) in organic carbon at any point before disinfectant addition?*** If yes, you could potentially have problems complying with the Stage 1 DBPR, the Stage 2DBPR, or the TCR.

☐■ ***Will the treatment change the pH and/or alkalinity of your finished water?*** If yes, your finished water could be more corrosive and you could have problems complying with the LCR.

☐■ ***Will you be using a different residual disinfectant or a different concentration of residual disinfectant?*** Disinfectant residual changes can impact TCR and LCR compliance.

☐■ ***Will the treatment change affect the quality of water being filtered?*** A change in coagulation or pre-disinfection could affect filter performance and compliance with the LT1ESWTR or IESWTR.

■☐ ***Will the treatment change result in higher or lower concentrations of inorganics, such as manganese, iron, aluminum, sulfate, chloride, or sodium in your finished water?*** If yes, your water could become more corrosive and you could have problems complying with the LCR. You could also have aesthetic problems.

☐■ ***Will the treatment change cause an increase in production of waste residuals (e.g., enhanced coagulation could cause your system to produce more sludge)?*** This will not typically cause any rule violations but may require increased land disposal area, and increased residual production can present operational challenges for your system.

Studies of Impacts on Water Quality of Proposed System Improvements of the Dalecarlia WTP and the McMillan WTP for Disinfection and pH Control

- TM: Conversion from Chlorine Gas to Sodium Hypochlorite and Implementation of Caustic Soda Feed to Control pH: Analysis of Impacts on Lead and Copper Corrosion and Other Processes (Attached)

Technical Memorandum
To: Washington Aqueduct
Prepared by: Vernon L. Snoeyink
Reviewed by: Glenn Palen/CH2M HILL
Phil Hecht/CH2M HILL
Jennifer Armstrong/CH2M HILL

Title: Conversion from Chlorine Gas to Sodium Hypochlorite and Implementation of Caustic Soda Feed to Control pH: Analysis of Impacts on Lead and Copper Corrosion and Other Processes

Date: March 4, 2008

Purpose of this Document

Washington Aqueduct is planning to convert to sodium hypochlorite for disinfection and to implement the use of caustic soda to trim the pH. Construction of new facilities is anticipated. The Lead and Copper Rule Short Term Regulatory Revisions (October 2007, 72 FR 57782) require that a water system deemed to have optimized corrosion control, such as Washington Aqueduct, which is considering a long-term change in water treatment shall submit to the primacy agency for approval written documentation describing the change. The purpose of this document is

- To present the planned long-term changes in treatment,
- To analyze the impact of these treatment changes on the corrosiveness of the treated water to lead and copper,
- To request approval from the primacy agency, USEPA Region III, for the proposed changes

Conversion from Liquid Chlorine to Sodium Hypochlorite as the Source of Chlorine

Washington Aqueduct plans to convert from liquid chlorine to sodium hypochlorite because of the health hazards associated with liquid chlorine and the greatly reduced hazard associated with shipping and handling sodium hypochlorite solution. This change will not affect disinfection efficiency because the same pH and the same chlorine dose, in mg/L as Cl_2, will be used for sodium hypochlorite as has been used for liquid chlorine. The active disinfection species are the same for both chlorine and sodium hypochlorite and they are controlled only by pH. For example, chlorine addition to water results in the following reactions:

1. $Cl_2 + H_2O \rightarrow HOCl + H^+ + Cl^-$
2. $HOCl \rightarrow OCl^- + H^+$

Addition of NaOCl to water results in the following reactions

3. $NaOCl \rightarrow Na^+ + OCl-$
4. $OCl^- + H_2O \rightarrow HOCl + OH^-$

The equilibrium constants that govern reactions 2 and 4 control the ratio of $HOCl/OCl^-$, and this ratio is a function only of pH. The concentrations of HOCl and OCl^- are controlled by the dosage, which will not change after the switch is made. Thus, disinfection efficiency, the concentrations of disinfection by-products that will form, the reaction with ammonia to form monochloramine which serves as a secondary disinfectant, and the oxidation potential which can affect the type of lead corrosion scales, will not change as a result of the conversion to sodium hypochlorite. Also, it is important to note that less Cl^- and less H^+ is added to the water when sodium hypochlorite is used in place of liquid chlorine.

Use of Caustic Soda (NaOH) to control the pH of the Water Entering the Distribution System

Currently, hydrated lime ($Ca(OH)_2$) is used by Washington Aqueduct to adjust the finished water pH to the finished water goal of 7.7 ± 0.1. Plans are being made to make the final pH adjustment step with NaOH, because it can be fed with greater accuracy and it will enable the treatment plants to achieve a more constant pH than can be obtained with lime. Only NaOH will be used at the McMillan plant, whereas $Ca(OH)_2$ followed by NaOH will be used at Dalecarlia to meet the larger demand for base more cost effectively.

Impact of the Treatment Changes on Corrosion of Lead and Copper

Analysis of the potential impacts of the treatment changes requires an analysis of the impact of the changes on the water quality parameters that affect corrosion and the release of metal ions from existing corrosion scales. For the changes that will be made, these parameters include pH, Cl^- concentration as reflected in the chloride to sulfate mass ratio (CSMR), the calcium concentration, and the alkalinity concentration.

- **pH Effect:** No change will be made in the pH goal for the treated water, and the use of NaOH, in place of $Ca(OH)_2$, to trim the pH just prior to distribution will enable the treatment goal to be reached with less variability. A more constant pH is beneficial with respect to distribution system water quality and reducing corrosion because it enables the formation of more stable scales on lead, copper and iron pipes. More stable scales have a lower tendency to release metal ions to the water being distributed, and thus lower concentrations of iron, lead and copper at the tap are expected because of this change.

- **Chloride Concentration and Chloride to Sulfate Mass Ratio (CSMR) Given Current Coagulation Practice:** A recent paper by M. Edwards (*JAWWA 99*(7), 96, 2006) raises the possibility that increasing chloride concentrations can cause release of lead from lead/tin solder. Although this effect requires much more research to determine the effect of parameters such as alkalinity, inhibitor concentration, pH, duration of the effect in the presence of phosphate inhibitor, etc, we can use the information in this paper to help us evaluate whether a change in treatment might cause a problem. Edwards found that a CSMR of less than approximately 0.6 did not cause a problem, and that a CSMR greater than 0.6 could result in higher concentrations of tap water lead. Calculation of the CSMR requires knowledge of the finished water chloride and sulfate concentrations, both of which are determined by the concentrations in the water supply and in the treatment chemicals that are employed.

The effect of changing from liquid chlorine to sodium hypochlorite was analyzed by investigating the change in CSMR for the average, minimum and maximum values of chloride and sulfate in Washington Aqueduct's finished water. The 2006 data were assumed to be typical of the data we can expect in the future. The average/minimum/maximum values of Cl^- during 2006 in Dalecarlia finished water were 28/22/34 mg/L, and the corresponding values of SO_4^{2-} were 48/39/56 mg/L. The CSMR values based on these values are 0.6/0.6/0.6. Given reactions 1 and 3 above, assuming that no sodium chloride is present in the sodium hypochlorite, and no change in coagulant type or dose, the CSMR will decrease slightly because less Cl^- is added to the water when sodium hypochlorite is used in place of liquid chlorine.

The average/minimum/maximum values of Cl^- during 2006 in McMillan finished water are 28/23/33 mg/L, and the corresponding values of SO_4^{2-} are 50/40/59 mg/L. The CSMR values based on these values are also 0.6/0.6/0.6, and similar to Dalecarlia, no significant change is expected in CSMR when the change in source of chlorine is made.

- **Chloride Concentration and Chloride to Sulfate Mass Ratio assuming that Coagulation could be Conducted at a Lower pH, or with a Chloride Based Coagulant, to Enhance the Removal of Organic Matter in the Future:** It is often observed that enhanced removal of organic matter can be achieved by coagulating at a pH that is well below that of the distributed water. The lower pH for coagulation can be achieved through the addition of a higher concentration of alum, or by the use of sulfuric acid in combination with alum. If either approach is used, followed by adjustment of pH to the target value of 7.7, a lower value of the CSMR would result, which is beneficial with respect to release of lead from lead/tin solder. However, the lower the pH that is used, the greater the increase in total dissolved solids will be, as discussed below.

  It is sometimes observed that better removal of organic matter, or smaller amounts of treatment residue (sludge) can be achieved if a coagulant other than alum is used. However, if PACl or ferric chloride were to be used in place of alum, there would be an adverse impact of the coagulant as indicated by the CSMR. For example, we can estimate this effect if we assume that the typical alum dose of 35 mg/L as $Al_2(SO_4)_3.14H_2O$ is replaced with an equal dose, based on Al, of PACl. If we further assume that each ion of Al in this typical coagulant is associated with 2 ions of Cl^- and one ion of OH^-, the SO_4^{2-} concentration will be decreased by 17 mg/L and the Cl^- concentration will be increased by 8 mg/L in the finished water because of this change. Using the 2006 average values for Cl^- and SO_4^{2-} concentrations, the new CSMR will be 1.1 (CSMR = Cl^- (28 +8)/SO_4^{2-} (50 -17) = 1.1). The use of ferric chloride instead of alum or PACl would likely increase the CSMR to a value larger than 1.1 because three Cl^- ions are associated with each Fe^{3+}.

The use of a Cl^- based coagulant in place of alum results in a substantial increase in the CSMR. Therefore, replacing alum with a PACl or $FeCl_3$ has the potential of significantly increasing the lead release. Unless research is done to show that this will not happen, it is recommended that Washington Aqueduct not replace alum with PACl or another chloride based coagulant.

- **Calcium Concentration Change:** With the conversion from hydrated lime ($Ca(OH)_2$) to caustic (NaOH) for pH adjustment a slight decrease in calcium concentration will occur. For example, with an average alum dose of 35 mg/L, 12.4 mg/L of $Ca(OH)_2$ would be required to raise the pH to 7.7 after coagulation. This dose of hydrated lime contains 6 mg/L of Ca. If NaOH only is used instead of $Ca(OH)_2$, as is planned for McMillan, 13.5 mg/L of NaOH containing 7 mg/L of Na is added to the water. The average finished water Ca will be reduced from 35 mg/L to 29 mg/L. This change is considered to be relatively minor and should have essentially no effect on the release of lead or copper from corrosion scales. At Dalecarlia, the change will be less because a combination of hydrated lime and caustic will be used.

- **Salt Concentration Increase:** A large increase in salt concentration can increase corrosion. However, if the only changes in treatment involve the replacement of liquid chlorine with sodium hypochlorite, and the use of NaOH instead of $Ca(OH)_2$ to increase pH to the existing target of 7.7, only a minor change, if any, will occur in the current average finished water total dissolved solids (198 mg/L at Dalecarlia and 214 mg/L at McMillan in 2006).

  However, if the pH of coagulation is lowered to 6.6, a typical value that might be used to increase the removal of organic matter during coagulation, a larger increase in total dissolved solids will occur. Under average raw water conditions, a coagulation pH of 6.6 could be achieved by increasing the alum dose from 35 to 58 mg/L. Assuming the pH would be raised to 7.7 using NaOH after coagulation, the net effect would be to increase the concentration of both Na^+ and SO_4^{2-}, and the total dissolved solids would increase by 16 mg/L. The same change in total dissolved solids is expected if sulfuric acid is used in conjunction with alum to reduce the pH. This is less than a 10 percent increase in total dissolved solids and this change should not have a significant effect on corrosion, other than that discussed above with respect to the CSMR

- **Alkalinity:** Alkalinity has important effects on corrosion. However, no significant change in alkalinity will take place as a result of treatment and the proposed changes in treatment. Use of acidic chemicals, such as Cl_2, alum and sulfuric acid, will remove alkalinity, and basic chemicals such as sodium hydroxide and sodium hypochlorite will increase alkalinity when they are added. However, the target pH of 7.7 will be the same after the treatment changes as it is now. Alkalinity is a function only of pH and the concentration of carbonate species (CO_2, H_2CO_3, HCO_3^-, CO_3^{2-}.). The concentration of carbonate species does not change during treatment, and since the finished water pH does not change, alkalinity should not change.

Other Issues

Users of hypochlorite must be aware that trace contaminants of concern can be present in some types of commercially available sodium hypochlorite products. Substances such as chlorite, chlorate, perchlorate and bromate can be present, and their presence depends upon the raw materials and process conditions that are used to make the hypochlorite. This issue can be dealt with by specifying the levels of these contaminants that may be present. Also, research that is to be initiated soon by the American Water Works Association (AWWA) and Awwa Research Foundation (AwwaRF) (RFP WITAF #712 / AwwaRF #4147 "Hypochlorite—An Assessment of Factors That Influence the Formation of Perchlorate and Other Contaminants") will examine the potential presence of identified contaminants or impurities of concern in hypochlorite at concentrations of concern. The project will also examine the factors that influence the formation of these contaminants. Washington Aqueduct should follow the progress of this research project and implement its findings, as appropriate to avoid problems from such contaminants.

Attachment 3: EPA Region III request for follow-up information on treatment changes

Jennie Saxe/R3/USEPA/US
01/13/2009 03:11 PM

To Lloyd.D.Stowe@wad01.usace.army.mil
cc
bcc
Subject a few questions about treatment changes

Hi Lloyd -

We've done our first review of the materials you submitted for the conversion to NaOCl and addition of NaOH capability and have reviewed our contractor's report on potential impacts of the treatment changes. We have a few questions before we start working on our decision:

* Has anyone quantified the sodium increase in finished water due to addition of sodium-containing treatment chemicals? I ask because WA is occasionally close to (and sometimes just over) the 20 mg/L sodium advisory for individuals on low salt/sodium restricted diets.

* How much NaOCl supply (number of days supply) do you plan to keep on-site at each treatment plant?

* Have you considered providing advance notice of the treatment changes, perhaps asking your customers to provide notice via their CCRs?

Also - a note about the distribution system monitoring. In our letter to you, our intention was for WA and DCWASA (and perhaps your Virginia customers) to collaborate on a way to use/analyze existing monitoring data as an early indicator of any potential negative consequences of the treatment changes. Our review does not indicate that unintended consequences (e.g., on corrosion control) will occur, but we know that DCWASA does a lot of "above and beyond" monitoring in the distribution system which might prove doubly beneficial. We'll work with WA and DCWASA on developing some sort of distribution system monitoring for the period right after the treatment changes.

If you could provide information on the 3 questions above in the next week or so, I'd appreciate it.

Thanks!
Jennie

Attachment 4: Washington Aqueduct's response to EPA Region III follow-up request

DEPARTMENT OF THE ARMY
WASHINGTON AQUEDUCT
U.S. ARMY CORPS OF ENGINEERS, BALTIMORE DISTRICT
5900 MACARTHUR BOULEVARD, N.W.
WASHINGTON, D.C. 20016-2514

February 2, 2009

Jennie Perey Saxe, Ph.D.
Water Protection Division
Drinking Water Branch
EPA Region III, 3WP21
1650 Arch Street
Philadelphia, PA 19103-2029

Dear ~~Dr.~~ Jennie Saxe:

In your email of January 13, 2009 you requested additional documentation regarding our planned long-term treatment change to a sodium hypochlorite disinfection system and to use of sodium hydroxide for fine pH adjustment. The following information is submitted in fulfillment of this request.

- The anticipated sodium increase in finished water due to addition of sodium-containing treatment chemicals is 5 to 6 mg/L, based on a conservative historical chlorine dose (8 mg/L) and the typical caustic soda dose projected for the McMillan WTP (4.8 mg/L). Sodium levels will be slightly lower at the Dalecarlia WTP because lime will be used along with caustic soda. Washington Aqueduct finished water sodium levels have fluctuated over the years, and (as you note) have at times exceeded the 20 mg/L health advisory level. We report sodium levels and the sodium health advisory information to our customer systems for their use in their CCRs.

- The number of days of NaOCl supply storage at each treatment plant is as follows, based on the maximum month chlorine usage in 2008:
  Dalecarlia WTP: 17 days
  McMillan WTP: 23 days

- We have provided advance notice of the planned treatment changes to our customer systems and will suggest that they consider using their CCRs to inform their customers of upcoming changes.

- At our June 26, 2008 quarterly water quality meeting, we informed DC WASA (and our Virginia customers) of your request to develop distribution system monitoring enhancements for an early indication of any potential negative consequences of the treatment changes. We understand that DC WASA is developing a proposed monitoring program and will forward it to your office when it is complete.

Regarding Washington Aqueduct monitoring of finished water, we request that you revisit your previous suggestion of monitoring ORP, given that in the evaluation of our treatment change, Cadmus/HDR found that "no change in the oxidation reduction potential (ORP) of the water should be realized with the switch to sodium hypochlorite, therefore current lead based corrosion scales in the distribution and premise system should not be impacted by ORP changes" (Cadmus EP-C-08-015).

Cadmus/HDR also noted that EPA believes that the health advisory level of 20 mg/L is probably low and has therefore listed sodium as a research priority on the CCL in order to evaluate and revise the guidance. We would appreciate any update that you can provide on the status of the sodium health advisory.

If you have any questions about this submittal, please feel free to contact me or Lloyd Stowe, Operations Branch Chief, at 202-764-2702.

Sincerely,

Thomas P. Jacobus
General Manager

Attachment 5: EPA Region III request for revised *Giardia* and virus profiles and benchmarks

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

FEB 0 6 2009

Thomas P. Jacobus
General Manager
Washington Aqueduct Division
U.S. Army Corps of Engineers
5900 MacArthur Boulevard, NW
Washington, DC 20016-2514

Dear Mr. Jacobus:

The U.S. Environmental Protection Agency (EPA) Region III office is in the process of reviewing the documentation dated August 5, 2008, regarding the Washington Aqueduct's planned installation of facilities to provide disinfection with sodium hypochlorite and to provide fine adjustment of pH using caustic soda (sodium hydroxide).

During our review, we noticed an error in the checklist which we asked you to complete and provide as part of the treatment change documentation package. The first item on the checklist located on page 2-2 of EPA's LT2/Stage 2 Simultaneous Compliance Guidance Manual ("guidance manual", EPA 815-R-07-017, March 2007, http://www.epa.gov/safewater/ disinfection/stage2/ pdfs/guide_st2_pws_simultaneous-compliance.pdf) states the following:

> ***Will you be getting less CT (measured as log inactivation) for any regulated microorganism (i.e. viruses, Giardia, or Cryptosporidium) as a result of the treatment change?*** If you answered "yes" and are a surface water system, you must conduct disinfection benchmarking and profiling. If you are a ground water system required to meet 4-log inactivation, you must continue to meet 4-log inactivation.

Even though the Washington Aqueduct indicated that the treatment plants would not be getting less CT with the change to sodium hypochlorite disinfection, this letter is to clarify that the Washington Aqueduct is required to create a disinfection profile and calculate a disinfection benchmark for *Giardia lamblia* and viruses.

The guidance manual checklist appears to be misleading in that the regulations at 40 CFR §141.708 state that "Following the completion of initial source water monitoring under §141.701(a) [LT2], a system that plans to make a significant change to its disinfection practice...must develop disinfection profiles and benchmarks for *Giardia lamblia* and viruses as described in §141.709." A "significant change in disinfection practice" could be a change in the disinfectant used or a change in the disinfection process (§141.708(b)). Although the guidance manual does not explicitly address requirements for systems converting to sodium hypochlorite for disinfection, EPA Region III has determined that the upcoming conversion to sodium hypochlorite for disinfection constitutes a significant change in disinfection practice, as it is a change in the disinfectant used as well as a change in disinfection process.

To develop the profile and benchmark values, 12 months of new data may be collected (§141.709(a)) or up to three years of existing data may be used (§141.709(c)). Please let us know how you intend to meet this requirement within two weeks of receipt of this letter. We would like to review the disinfection profile and benchmark prior to our approval of these changes under 40 CFR §141.90(a)(3).

We have brought the error in the guidance manual, as it relates to the regulatory language of §141.701(a), to the attention of our counterparts at EPA Headquarters and have encouraged development of an errata sheet to address this discrepancy. If you have any questions regarding the disinfection benchmarking or profiling requirements, please contact Nick Tymchenko (tymchenko.nick@epa.gov; 215-814-2022) or Dr. Jennie Saxe (saxe.jennie@epa.gov; 215-814-5806) of my staff.

Sincerely,

William S. Arguto, Chief
Drinking Water Branch

cc: Lloyd Stowe, Washington Aqueduct

Attachment 6: Washington Aqueduct's response to EPA Region III request for revised disinfection profiles and benchmarks

Recd 8 May 2009

DEPARTMENT OF THE ARMY
WASHINGTON AQUEDUCT
U.S. ARMY CORPS OF ENGINEERS, BALTIMORE DISTRICT
5900 MACARTHUR BOULEVARD, N.W.
WASHINGTON, D.C. 20016-2514

MAY 1, 2009

Jennie Perey Saxe, Ph.D.
Water Protection Division
Drinking Water Branch
EPA Region III, 3WP21
1650 Arch Street
Philadelphia, PA 19103-2029

Dear Dr. ~~Saxe:~~ Jennie

In your letter of February 6, 2009, you requested that we create a disinfection profile and calculate a disinfection benchmark for *Giardia lamblia* as part of our planned sodium hypochlorite conversion. The disinfection profiles and benchmarks for the Dalecarlia and McMillan WTPs are attached.

The disinfection chemistry of sodium hypochlorite and gaseous chlorine is the same, so the same tables or equations are used to find the required CT for these two disinfectants. However, addition of sodium hypochlorite raises the pH of the water. Various other treatment chemicals we use, such as aluminum sulfate, phosphoric acid, ammonia, fluoride, lime, and sodium hydroxide also change the pH The pH impact of these chemicals on the inactivation of microorganisms changes as the location of the respective chemical addition point varies with operational needs.

We analyzed the potential effect of sodium hypochlorite addition on the disinfection process by assuming that its use would result in a pH increase of 0.3 standard units. We then reconstructed the disinfection profiles for each plant using the modified pH.

- For the Dalecarlia WTP, the 2008 benchmark for disinfection of *Giardia lamblia* is 5.5 log inactivation. We project that the change to sodium hypochlorite could lower this number to 4.9.
- For the McMillan WTP, the 2008 benchmark for disinfection of *Giardia lamblia* is 6.3 log inactivation. We project that the change to sodium hypochlorite could lower the number to 5.7.

We received a letter from DC WASA, dated March 2, 2009, describing its proposed plan for distribution monitoring following hypochlorite implementation. DC WASA intends to share specific lead and ORP data for six months following the conversion to sodium hypochlorite, as spelled out in its letter, which we have attached. Washington Aqueduct will review this information and submit it to EPA Region III as received.

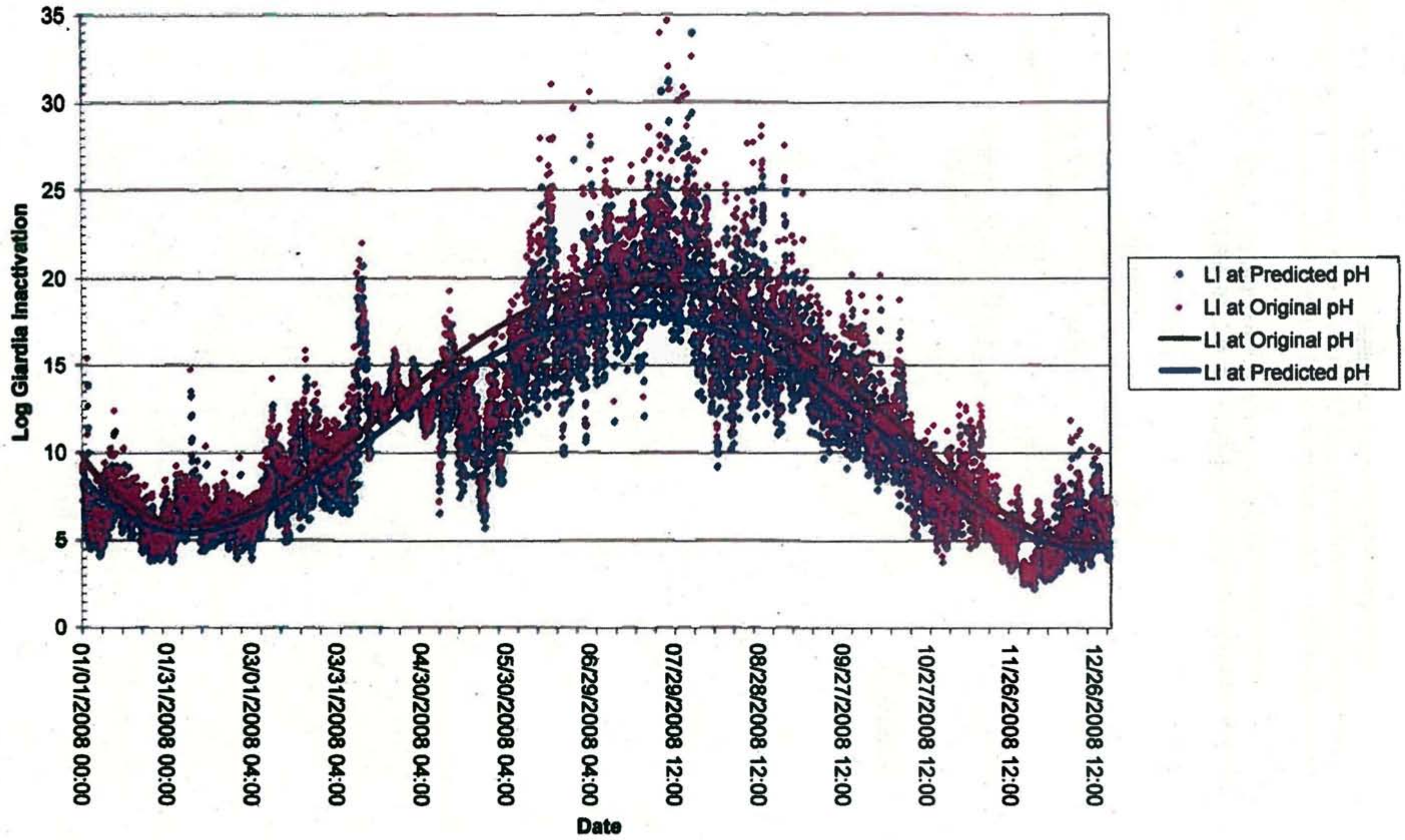
We believe we have now submitted all of the information you have requested with regard to the sodium hypochlorite conversion project so that EPA Region III may proceed with the determination of whether to allow the conversion.

If you have any questions about this submittal, please feel free to contact me or Lloyd Stowe, Operations Branch Chief, at 202-764-2702.

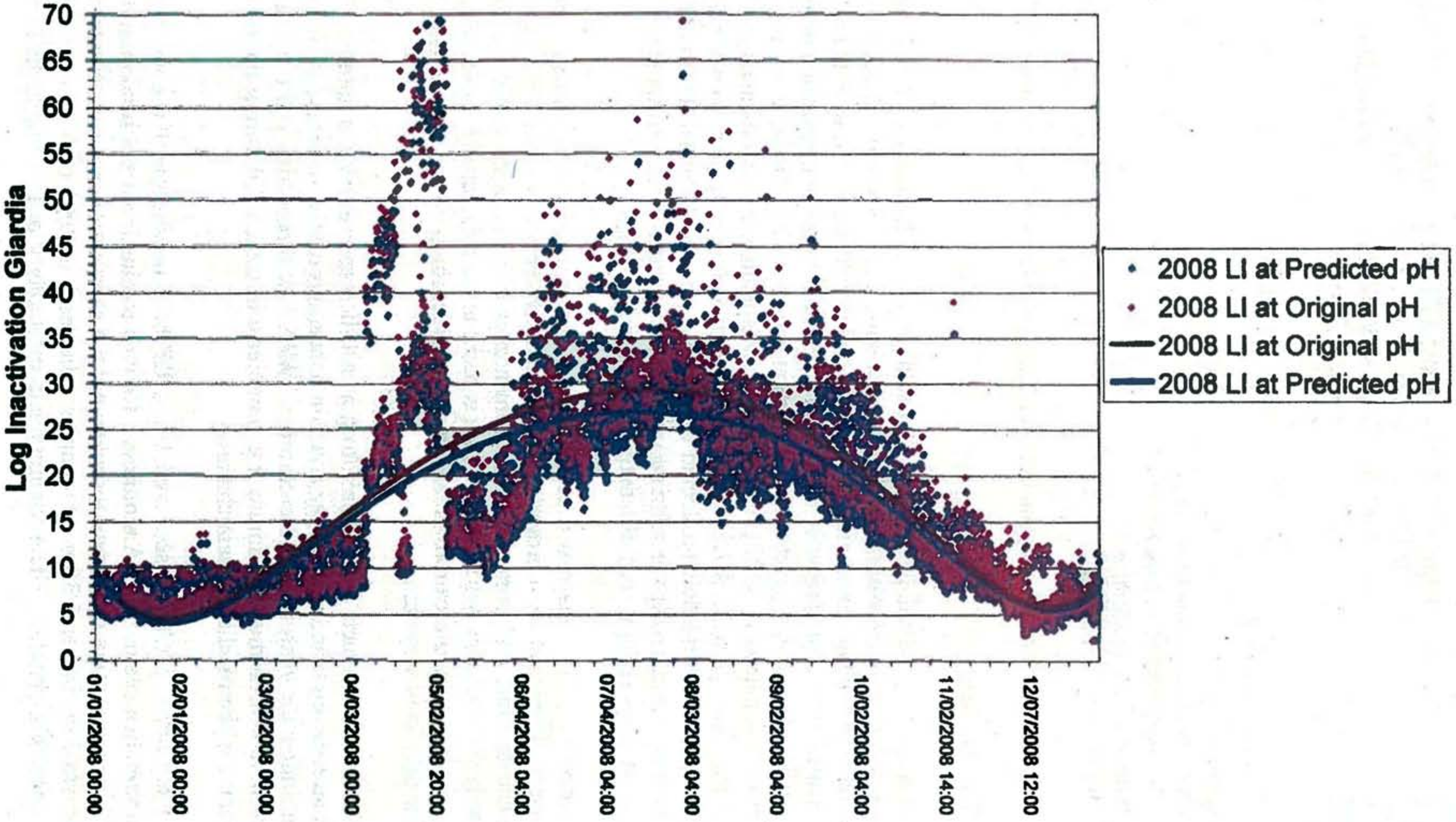
Sincerely,

Thomas P. Jacobus
General Manager

Enclosures



Log Inactivation Dalecarlia 2008



Log Inactivation McMillan 2008

DISTRICT OF COLUMBIA WATER AND SEWER AUTHORITY
DEPARTMENT OF WATER SERVICES
301 BRYANT STREET, N.W. WASHINGTON DC 20021
March 2, 2009

Thomas P. Jacobus
General Manager
Washington Aqueduct Division
U.S. Army Corps of Engineers
5900 MacArthur Blvd, NW
Washington, DC 20016

Re: Supplemental Monitoring Plan for Change to Liquid Sodium Hypochlorite

Dear Mr. Jacobus,

In a letter from EPA, Region III, dated June 18, 2008, to you, Mr. Richard Rogers requested that the Washington Aqueduct submit to EPA several documents for review related to the upcoming switch from gas chlorine to liquid chlorine at the Dalecarlia and McMillan treatment plants. Item number 5 lists a 6-month supplemental monitoring plan which includes entry point and distribution monitoring for lead, copper and oxidation reduction potential (ORP). Although the Washington Aqueduct does not operate the distribution system, WASA can provide lead and copper monitoring data from our pipeloops and sample data collected under the Lead and Copper Rule (LCR) to assist the Aqueduct in meeting the distribution system monitoring requirements identified by EPA for up to six months from the date of the chemical switch.

Currently WASA uses two pipe loops to monitor daily lead leaching rates from lead service lines that were removed from the distribution system in 2004. These pipe loops provide similar lead concentrations from homes that sample under the LCR. Samples collected twice per week before and six months after the change to liquid chlorine should provide a good indication of "real-time" lead leaching rates for the majority of homes in the distribution system.

WASA also conducts LCR monitoring at 100 homes every six months. Most of these homes have historic lead, copper and iron data and can be an effective comparison before and after the switch to liquid chlorine. WASA will report to you the historic and most current data on individual homes that participate in the LCR during the six-month period after the chemical disinfectant change.

In the letter, EPA has also asked that ORP be monitored at the entry point and the distribution system. WASA monitors ORP on a routine basis at schools and daycares and ORP values remain consistent throughout the distribution system. The average monthly standard deviation is 35 mv for samples collected in 2008 under the school and daycare monitoring program. The variability is most likely due to slight disinfectant residual changes or probe error as ORP is not an exact measurement and can vary as much as 10% in the same sample. WASA will continue to monitor ORP values under the non-regulated school and daycare monitoring program and report those values to you on a monthly basis.

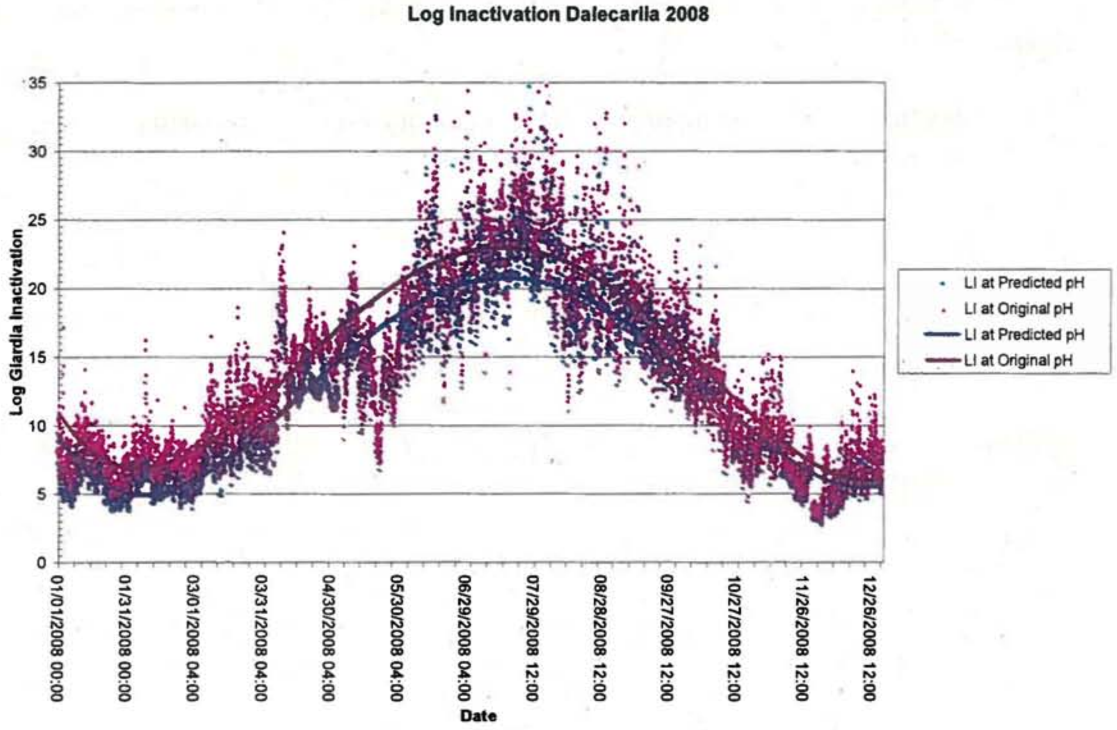
If you have any questions regarding this month's monitoring period, feel free to contact me at 202-612-3441.

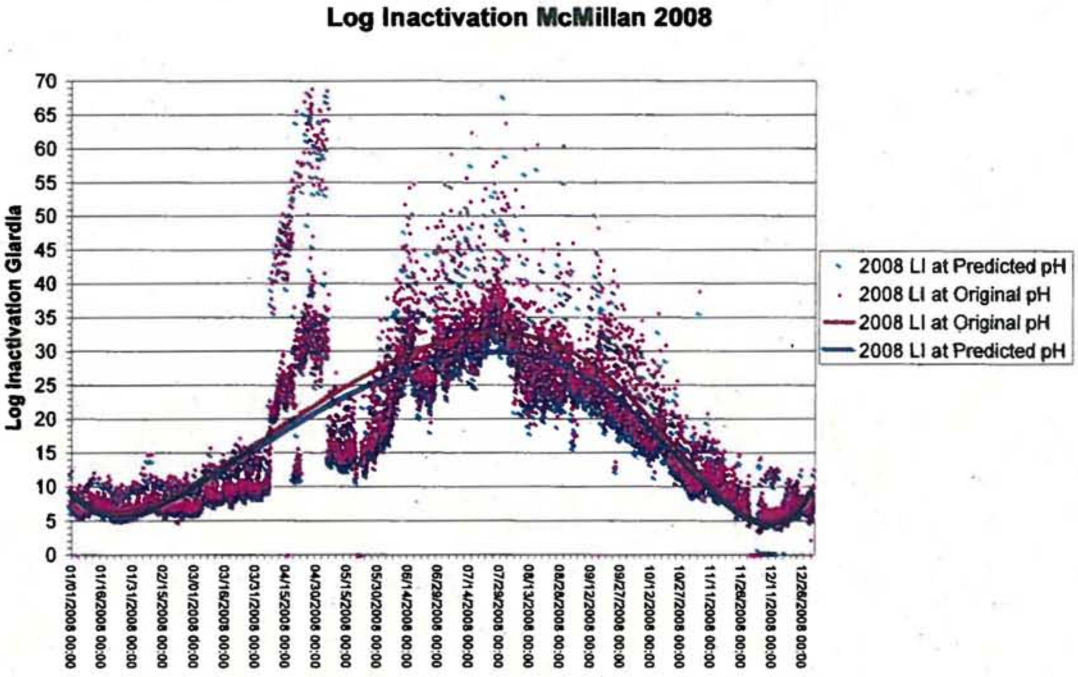
Sincerely,

R. Giani

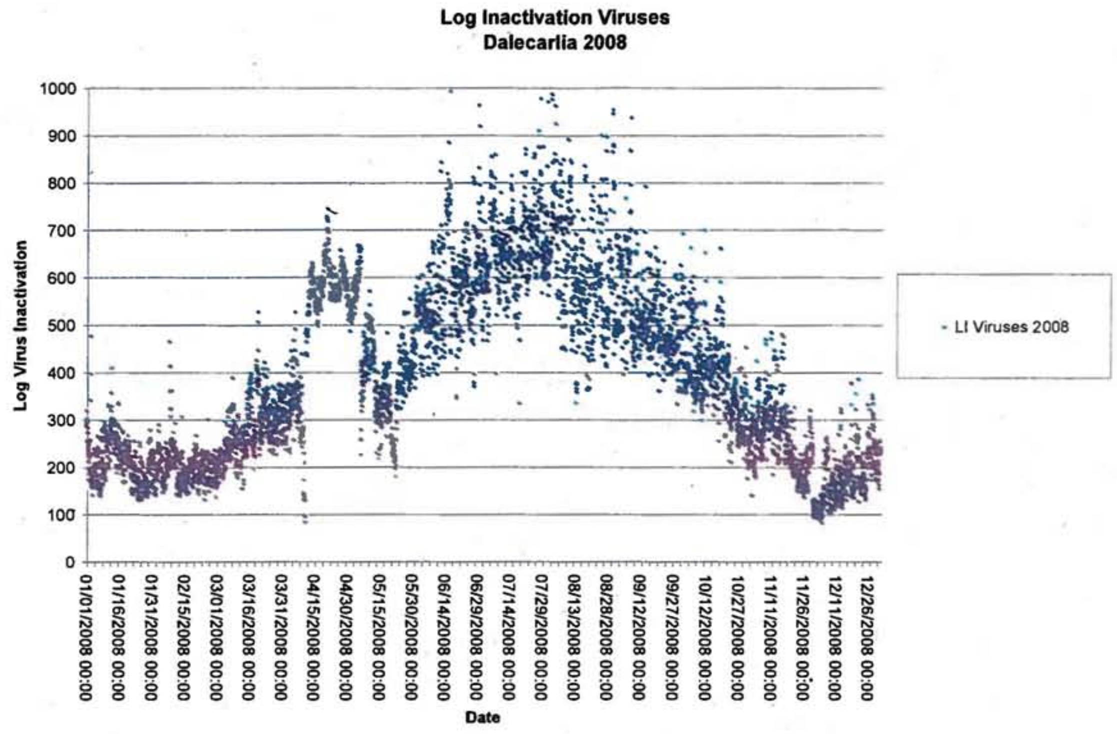
Rich Giani
Manager, Water Quality

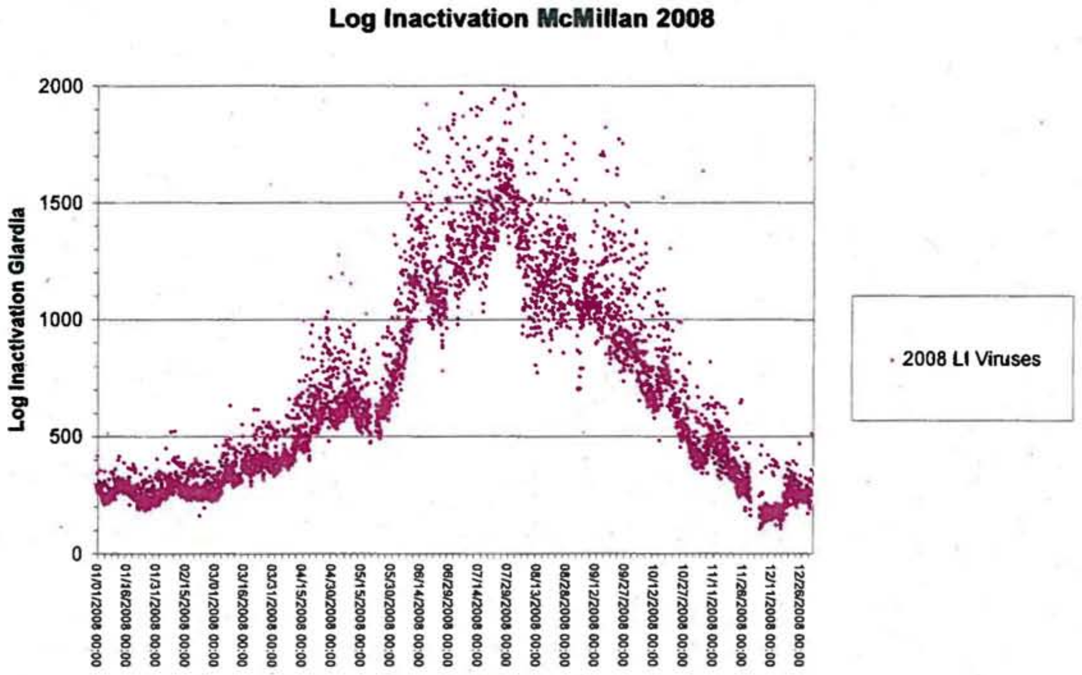
Attachment 7: Washington Aqueduct *Giardia* profiles





Attachment 8: Washington Aqueduct virus profiles





<u>Attachment 9: Cadmus literature review of treatment changes</u>

TECHNICAL MEMORANDUM

TO: George Rizzo and Jennie Saxe, EPA Region 3

FROM: Laura Dufresne and Ken Klewicki, the Cadmus Group, Inc.

DATE: December 31, 2007

REGARDING: Deliverable for Contract No. 68-C-02-069, Work Assignment 4-47, Amendment 2, Task 4: *Review of Drinking Water Utility Research Plans*

This technical memorandum provides the results of a literature review of three technical topics identified in the statement of work for Work Assignment 4-47, Task 4. Advantages, potential issues, and technical references are provided for each topic.

1. Converting from Alum to Poly Aluminum Chloride (PACl) for Coagulation

Advantages

- PACL performs better than alum in cold weather. (Janay and Edzwald 2001, Exall and Van Loon 2000)

- PACl has higher charge and can reverse charge on colloids better. This results in better coagulation. (Sinha et al. 2000, Ruehl 1998)

- PACl has shown to give equal or lower turbidity at lower coagulant doses than alum. This can reduce filter run times and lower the amount of required backwash water. (Ruehl 1998, Soucie and VanHeirseele 1999, Charlton and Kohl 2006, Janay and Edzwald 2001)

- In some cases PACl may remove more organics than alum. (Furrey et al. 1997, Exall and Vanloon 2000)

- PACl is less acidic and doesn't reduce the pH as much as alum. This can reduce the chemical dose needed to raise the pH prior to introduction in the distribution system. (Soucie and VanHeirseele 1999, Janay and Edzwald 2001)

- PACl can produce sludge with higher weight percent solids, resulting in less sludge production. (Charlton and Kohl 2006)

Potential Issues

- PACl increases the chloride to sulfate ratio of the treated water. This can lead to corrosion problems and leaching of lead from plumbing materials. (Triantafyllidou and Edwards 2006, USEPA 2006)

- PACl is less acidic than alum. A higher pH may result in lower disinfectant efficiency. (USEPA 2006)

- Some studies have shown lower organic and particulate removal with PACl. (Charlton and Kohl 2006, Soucie and VanHeirseele 1999)

- PACl has a higher freezing point than alum. May crystallize if pH is too high in holding tank. (DeWolfe et al. 2003)

- Any change in coagulants can cause problems such as turbidity spikes, formation of sludges, and other problems. A careful transition plan including testing, monitoring, consultation with regulators and other issues should be prepared. (DeWolfe et al. 2003)

References

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Wang, D. Z. Luan, and H. Tang. 2003. Differences in Coagulation Efficiencies Between PACl and PICl. *J. AWWA*. Vol. 95. No. 1. Denver: AWWA.

2. Converting from Gaseous Chlorine to Hypochlorite for Disinfection

Advantages

- Chlorine gas has been implicated in dangerous gas releases. These gas leaks have caused an increase in public awareness about the chemical and has been a major reason that water systems have switched from gaseous chlorine to hypochlorite. (Joslyn and Gaddis, 2001; Damron et.al. 2002; White, 1999)

- The Northern Kentucky Water District's insurance carrier decreased insurance premiums slightly when they switched from gaseous chlorine to hypochlorite (Joslyn and Gaddis, 2001)

- Gaseous chlorine has high costs to meet EPA/OSHA requirements. USEPA requires users of chlorine gas to develop and complete a Risk Management Plan (RMP) for facilities storing 2,500 pounds or more of chlorine. States may have additional requirements. Many systems have decided to switch to hypochlorite to avoid implementing an RMP. (American Chemistry Council, 2007; Sloane and Branch, 2001; Joslyn and Gaddis, 2001; Abraham et.al., 2002; Damron et.al. 2002)

- The delivery and management of empty cylinders for chlorine gas is more complex than the delivery of hypchlorite (Joslyn and Gaddis, 2001; Damron et.al. 2002).

- Hypochlorite reduces the pH of the water less than gaseous chlorine. (Mackey et.al., 2003; Abraham et.al., 2002; Damron et.al. 2002)

Potential Issues

- Sodium hypochlorite is corrosive and requires special handling. (American Chemistry Council, 2007; Damron et.al., 2002)

- Vapor locking can occur with the decomposition of hypochlorite into oxygen, chlorine gas and other byproducts. The pockets of air and chlorine that form can accumulate and affect the feed rate or bind air to the pump so that the pump has no output. (Joslyn and Gaddis, 2001; Stannard, 2001)

- Venting is necessary for NaOCl feed lines between storage tanks and metering pumps. Venting should be at all high points so that as chlorine degrades, the chlorine gas that forms has a way to escape to the outside. Storage tanks should also be vented to the outside. Otherwise even small quantities of chlorine gas can cause corrosion problems of exposed metal surfaces or electronic equipment. (Abraham et.al. 2002; White, 1999)

- Incompatibility of sodium hypochlorite with most materials, such as metals, can lead to contamination of disinfectant. This situation leads to accelerated bleach decomposition. All metals should be avoided except titanium, silver, gold and platinum. Metals such as stainless steel, Hastalloy, Monel, brass or copper should be avoided at all costs in pumps, pump seals, water flush lines, electrodes in magnetic flow tubes, diaphragm seals for gauges and switches, temperature wills, and common piping elements such as hose connections and valves. Tanker trucks for delivery must be lined with materials resistive to sodium hypochlorite. The liners include rubber, FRP, PVC, Halar, Tefzel, and other non-metallic materials. (Stannard, 2001; Abraham et.al. 2002; Gordon, 2001; Joslyn and Gaddis, 2001, White, 1999)

- When using ball valves, gas can build up in cavity of valve and cause a small explosion. If PVC or CPVC ball valves are used one side of the ball should be drilled or the valves should be predrilled to allow release of NaOCl from inside the ball when the valve is in the closed position. (Joslyn and Gaddis, 2001; Abraham et.al. 2002; Stannard, 2001; White, 1999)

- Chlorine gas can be produced from sodium hypochlorite mixing with acids commonly found in water treatment plants, ex. Ferric sulfate and hydrofluosicilic acid. Separating these chemicals can complicate storage areas (Joslyn and Gaddis, 2001) Hypochlorite can also lead to explosions or release large quantities of chlorine gas if it is pumped into the wrong tank or mixed with the wrong chemical. (Stannard, 2001; White, 1999)

- Bulk sodium hypochlorite systems can become clogged with salt precipitate, and injectors must be removed and cleaned with acid to remove scale. A sequestering agent can also be added to reduce scale. Water softening can help, but approaches to reduce scale can be time consuming and require additional capital costs to meet an acceptable bleach quality standard. (Mackey et.al., 2003; Gordon, 2001; Stannard, 2001; Abraham et.al. 2002)

- Hypochlorite degrades over time, so optimum temperature may require use of a heating, ventilation and air conditioning system. The degradation of hypochlorite reduces its strength, and results in the same byproducts as chlorine gas plus bromate and chlorate. (Mackey et.al., 2003; Abraham et.al. 2002; American Chemistry Council, 2007; Stannard, 2001)

- In a chlorine gas system, a leak is readily detected because of the irritation it causes on operators respiratory systems, the sounding of alarms, operators' desire to avoid calling a HazMat team, and because operators respect chlorine gas. In a hypochlorite system, leaks are common because the high pH can compromise the glue of PVC joints, so leaks form after a short period. Spilled hypochlorite corrodes pumps, and is a potential health and fire hazard. (Stannard, 2001).

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3. Increased use of Caustic Soda for pH Control

Advantages

- Caustic is easier to feed. Lime can clog feed equipment and requires more expensive feed equipment. Lime must also be stored in dry environments and can contain higher levels of metals such as manganese and aluminum. (AWWA 1999, AWWARF and DVGW-TZW, 1996
- Caustic won't change the dissolved inorganic carbon levels. (AWWARF and DVGW-TZW, 1996)
- Caustic soda won't increase calcium concentrations, so calcium carbonate precipitation and increased turbidity are less likely. (AWWARF and DVGW-TZW, 1996)

Potential Issues

- If alkalinity is low (less than 5 mg/L) pH may be hard to control with caustic alone. (US EPA 1999, Kirmeyer et al. 2000)

- Lime is cheaper than caustic soda. (AWWA 1999, Rice 1994)

- Lime is most effective if pH is less than 7.2, calcium is less than 60 mg/L, iron is less than 0.2 mg/L, manganese is less than 0.05 mg/L, and alkalinity is less than 100 mg/L. (US EPA 1999)
- Both caustic and lime increase alkalinity which can potentially increase copper corrosion. (Edwards et al. 1996)

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Attachment 10: HDR engineering review of treatment changes

CADMUS EP-C-08-015

District of Columbia Water System
Direct Implementation Support (WA 4-47)

Evaluation of Washington Aqueduct Treatment Changes Final Report

Prepared by HDR
December 12, 2008

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1.0 INTRODUCTION

1.1 Background

The U.S. Army Corps of Engineers (USACE) operates the Washington Aqueduct (the Aqueduct), which delivers water to Washington D.C. and suburban areas. Water is diverted from the Potomac River and treated at two water treatment plants, Dalecarlia and McMillan. Both water treatment plants provide finished drinking water to the District of Columbia Water and Sewer Authority (DCWASA) service area.

Historically, full conventional treatment has been provided using aluminum sulfate (alum) for coagulation, gravity filtration, free chlorine for disinfection, fluoride addition for dental health, and lime addition for reducing corrosion (USACE, 2008). On November 1, 2000, the Aqueduct converted from using free chlorine to chloramines at both plants to provide a residual disinfectant in the distribution system less likely to form regulated disinfection byproducts. In August 2004, orthophosphate was added at both plants for corrosion control and pH levels were adjusted to accommodate this new chemical treatment. The U.S. Environmental Protection Agency (USEPA) Region III designated optimal corrosion control treatment (OCCT) for the Aqueduct consisting of application of orthophosphate system-wide, subject to stated conditions and water quality parameters (WQPs), as shown in Appendix A. This designation requires a finished water pH of 7.7 ± 0.1, with an interim requirement of 7.7 ± 0.3 (until caustic soda feed is operational at both treatment plants) and an orthophosphate dose in the range of 0.5 – 5.0 mg/L as dissolved orthophosphate.

1.2 Purpose of Study

The Aqueduct is planning two treatment changes in late 2009: 1) a conversion from liquid chlorine to hypochlorite for disinfection, and 2) use of caustic soda for pH control. The Aqueduct submitted documentation of these treatment changes to USEPA Region III in a letter dated August 5, 2008 (Jacobus 2008). A technical memorandum was prepared by the Cadmus Group, Inc. on December 31, 2007 which summarized advantages and disadvantages of these potential Washington Aqueduct treatment changes, which included a list of pertinent literature (Dufresne 2007). The purpose of this study is to expand on the literature review completed under the previous contract and examine advantages and potential issues (excluding operational and maintenance issues) of implementing these two changes at the Washington Aqueduct.

1.3 Approach

The approach for the study was to:

- Review available water quality data since startup of orthophosphate treatment for corrosion control (2005 – 2008)
- Review the Washington Aqueduct letter to USEPA Region III dated August 5, 2008, submitted for approval of proposed treatment changes (sodium hypochlorite for disinfection and sodium hydroxide for pH adjustment) (Jacobus 2008a)
- Review of other related reports and data pertaining to the Washington Aqueduct's operations and finished and distributed water quality, including sanitary surveys for both the Washington Aqueduct and the DCWASA (Cadmus Group 2006; 2008), and

correspondence between the Washington Aqueduct and USEPA Region III (USEPA 2008a, Jacobus 2008b).

- Evaluation and integration of the updated data and information with the previously completed literature review (Dufresne 2007) to identify advantages and potential issues of the proposed treatment changes.

2.0 STUDY FINDINGS

The key study findings are identified below in terms of advantages and potential issues associated with the planned treatment changes at the Washington Aqueduct. The planned treatment changes are (1) conversion from free chlorine to hypochlorite for disinfection and (2) use of caustic soda for pH control.

2.1 Advantages of Planned Treatment Changes

- Use of sodium hypochlorite in place of liquid chlorine will provide the same level of disinfection efficiency as long as the finished water chlorine concentration and pH remain the same.
- No change in the oxidation reduction potential (ORP) of the water should be realized with the switch to sodium hypochlorite, therefore current lead based corrosion scales in the distribution and premise system should not be impacted by ORP changes.
- Use of sodium hypochlorite for disinfection will reduce the amount of Cl^- added to the water when compared to liquid chlorine, potentially resulting in slightly lower chloride to sulfate mass ratios (CSMR). Literature indicates that a lower CSMR may be less likely to release lead.
- Reduced use of lime will reduce calcium levels in the finished water, reducing the calcium carbonate precipitation potential, thereby minimizing scaling potential in the system.
- More consistent finished water pH can be obtained with use of caustic soda addition than with use of lime alone. Use of caustic soda will not change the finished water pH, alkalinity and dissolved inorganic carbonate (DIC) levels. Distribution pH, alkalinity and DIC levels are expected to be similar to current levels in the distribution system. Accordingly, optimal corrosion control treatment requirements can continue to be met and operational control improved, resulting in continued compliance with the Lead and Copper Rule (LCR).

2.2 Potential Issues

- Sodium content of the water may be increased slightly with use of sodium hypochlorite
- Contaminants may be present in the sodium hypochlorite solution (chlorate, chlorite, perchlorate, and bromate) and the solution can degrade to form chlorate and perchlorate.
- While not directly related to these two treatment changes, if the use of polyaluminum chloride (PACl) is increased, the chloride levels in finished water will increase, potentially resulting in higher CSMR which may negatively impact lead levels in the system. More research is needed in this area.

3.0 ORGANIZATION OF REPORT

This report is organized into two major sections:

- Treatment and Distribution System. This section summarizes information about the Washington Aqueduct treatment system, DCWASA's distribution system, and trends in water quality parameters of interest in evaluating the impact of the proposed treatment changes.
- Description and Evaluation of Planned Treatment Changes. This section summarizes the planned changes to the Washington Aqueduct's treatment system, and it contains an evaluation of potential Issues and unintended consequences of these changes.

4.0 TREATMENT AND DISTRIBUTION SYSTEM

This section provides a description of treatment and the distribution system served by the Washington Aqueduct, a discussion of corrosion related parameters and OCCT requirements for the Washington Aqueduct, and an evaluation of water quality data relative to the OCCT.

4.1 Description of Treatment and Distribution System

The Washington Aqueduct provides an average of 180 million gallons per day (MGD) of drinking water to over one million residents of the District of Columbia; Arlington County, Virginia; the City of Falls Church; and approximately 36 square miles of Fairfax County, Virginia, via the City of Falls Church. The Washington Aqueduct is controlled and managed by the United States Army Corps of Engineers. The USACE manages the operations of the Washington Aqueduct, and the distribution of water treated by the Aqueduct is the responsibility of the local governments.

Source water for the Washington Aqueduct is the Potomac River, which is treated at two major water treatment plants (WTPs): Dalecarlia and McMillan. The combined capacity of these plants is approximately 400 MGD. Conventional treatment is employed at both Dalecarlia and McMillan WTPs, including coagulation, flocculation, sedimentation, filtration and disinfection. At both Dalecarlia and McMillan, the primary coagulant is liquid alum. Lime is used for pH adjustment of the filter effluent prior to entering the clearwell, and can also be added prior to coagulation, if needed, to ensure proper coagulation. Phosphoric acid is added for corrosion control, at a dose of 2.9 mg/L as PO_4 to achieve 2.4 mg/L PO_4 leaving the plant. Chloramines are utilized for secondary disinfection. (Cadmus Group, 2006)

The DCWASA distribution system includes eight pressure zones, five pumping stations and eleven storage reservoirs that serve these pressure zones. Water is provided through nearly 1,300 miles of water distribution mains ranging from 4-inches to 78-inches in diameter. Eighty-seven percent of the water mains are cast iron, eight percent are ductile iron, with lesser amounts of steel and pre-stressed reinforced concrete. (Cadmus Group, 2008).

As of July 5, 2007, a total of 12,657 lead service lines (371,723 feet) had been replaced in public space and 1,892 lead service lines (34,308 feet) had been replaced on private property since 2003. This is approximately 80% of the lead service lines encountered in the system (DCWASA 2008). As of September 30, 2008, the inventory of lead service lines in the DCWASA system was 15,113 lead and 22,926 of unknown material (Benson 2008).

4.2 Corrosion Related Water Quality Parameters

Corrosion of lead and copper is impacted by the pH, alkalinity, DIC, orthophosphate concentrations, and buffer intensity of the water (USEPA, 2003). The pH of water can vary significantly as water moves through the distribution system and it is important to maintain the target pH throughout distribution.

DIC is the sum of total carbonates in the form of carbon dioxide gas (CO_2 or H_2CO_3), bicarbonate ion (HCO_3^-), and carbonate ion (CO_3^{2-}) in water. It is related to alkalinity and can be estimated from the pH and alkalinity of a water. It is also related to the buffering capacity of the water and affects the stability of pH in the distribution system. Maintaining sufficient buffering and consequently a stable pH in the distribution system is very important when using orthophosphate for lead control, which typically requires a pH of 7.2–7.8 to be effective. Even if the pH of the water leaving the treatment plant is within OCCT goals, the pH may change in the distribution system, resulting in less effective corrosion control. Therefore, understanding current corrosion control conditions in the system, and the impact that these two treatment changes may have on these key parameters that impact corrosion control, is of key interest.

OCCT for the Washington Aqueduct includes maintaining a pH of 7.7 ± 0.1 entering the distribution system (with an interim range of 7.7 ± 0.3 until caustic soda feed is operational at the treatment plants) and an orthophosphate level of 0.5 – 5.0 mg/L (dissolved orthophosphate), specified as the dose necessary to reach this residual in tap samples. In the distribution system, pH must be ≥ 7.2 and orthophosphate residual between 0.5 – 5.0 mg/L. Free ammonia nitrogen and nitrite nitrogen must be monitored and reported. Based on meeting WQPs for 1 year, DCWASA reduced WQP monitoring from 25 sites every 6 months to 10 sites every 6 months (USEPA 1991))

4.3 Evaluation of Water Quality Data Relative to OCCT

The following sections describe trends in finished and distributed water quality parameters of interest when evaluating the impact of the proposed treatment changes at the Washington Aqueduct. Emphasis was placed on parameters listed in the current OCCT requirements for both finished and distributed water quality parameters, and on distributed water quality conditions that can directly affect release of lead and copper from lead-bearing materials in the system.

4.3.1 Finished Water Quality Trends (Washington Aqueduct)

Finished water pH levels produced by the Washington Aqueduct are displayed in Figures 1 through 4. Figures 1 and 2 show the average-monthly and the average-daily finished water pH values, respectively, for the Dalecarlia Plant. Similarly, Figures 3 and 4 show the average monthly and the average daily finished water pH, respectively, for the McMillan WTP.

The current finished water pH OCCT requirement for both the Dalecarlia and the McMillan water treatment plants is an interim pH requirement of 7.7 ± 0.3, with a final pH requirement of 7.7 ± 0.1 (once caustic is implemented for pH control). Examination of average monthly finished water pH for both plants (Figures 1 and 3) under current conditions indicates that the future OCCT requirement is being met (7.65 – 7.75). Daily average pH measurements for July 2007 through July

2008 (Figures 2 and 4) indicate that both plants were meeting their interim requirements for OCCT (7.7 ± 0.3) during this time frame.

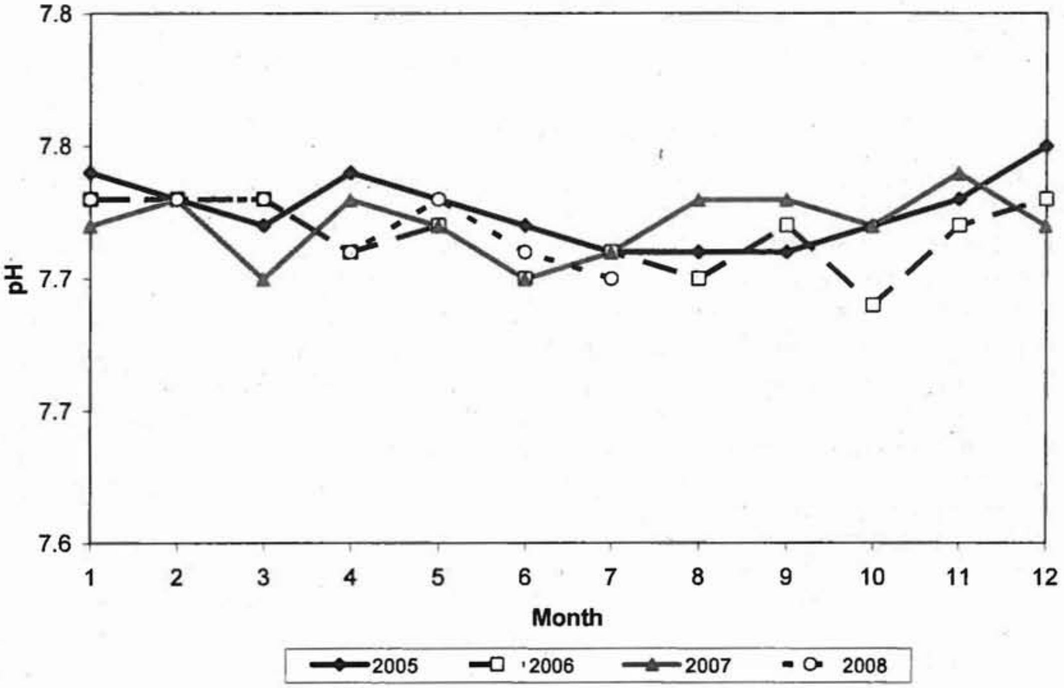

Figure 1. Dalecarlia Average Monthly Finished Water pH (2005–2008)
(Data Source: WA Operational Data.xlw)

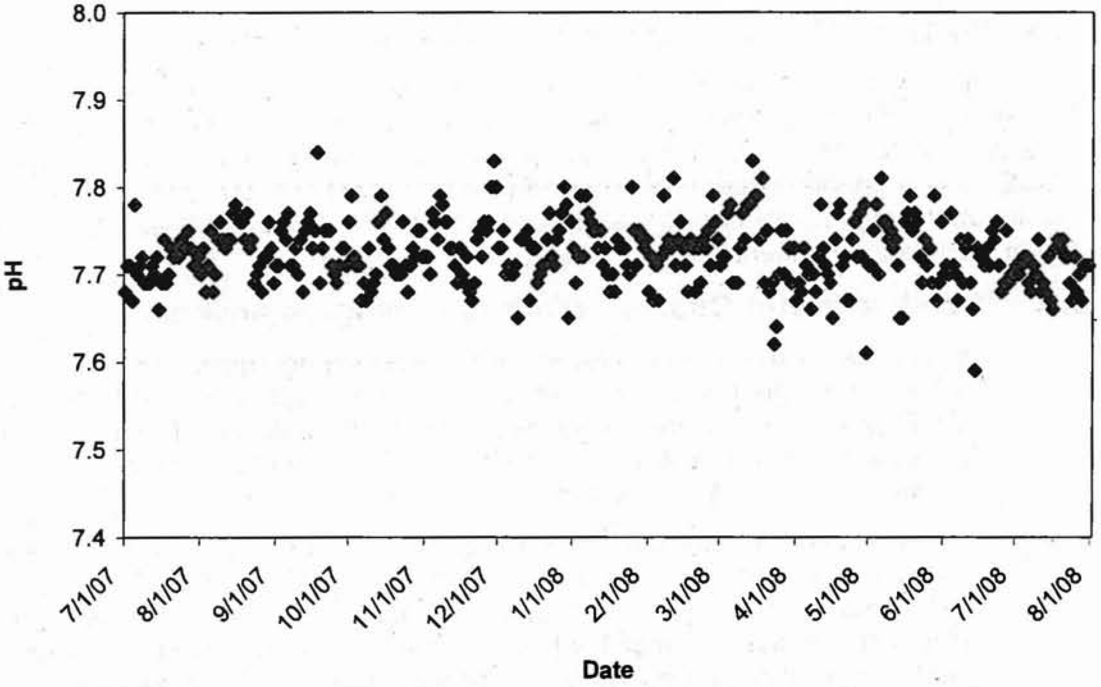

Figure 2. Dalecarlia Average Daily Finished Water pH (July 07 - July 08)
(Data Source: entry point WQP tracking for OCCT.xlw)

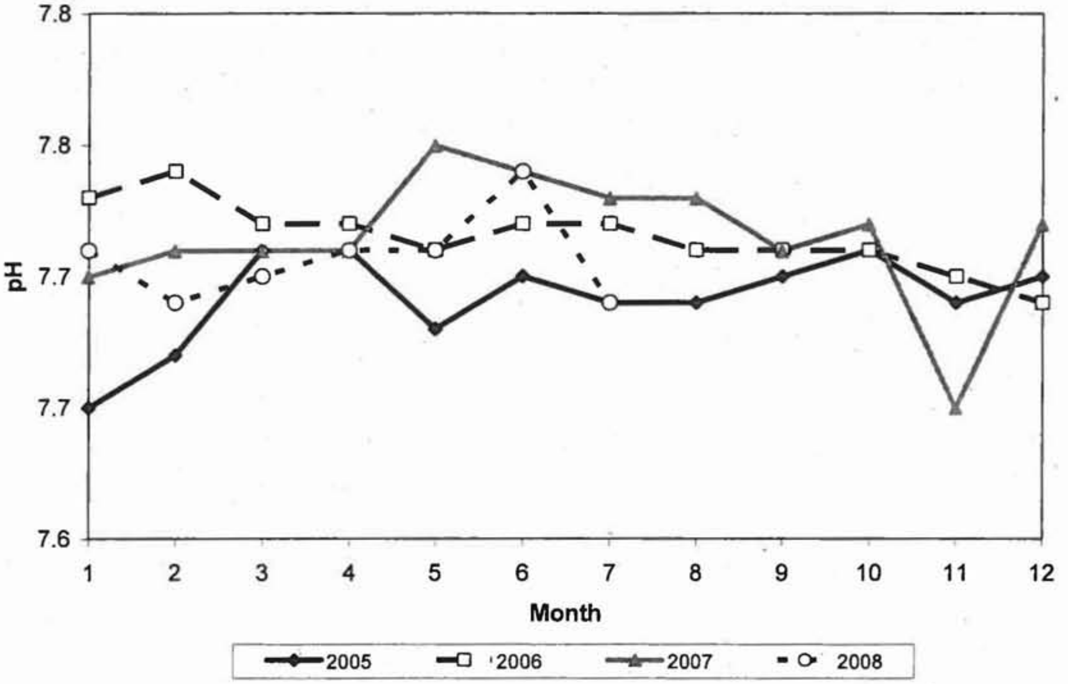

Figure 3. McMillan WTP Average Monthly Finished Water pH (2005-2008)
(Data Source: WA Operational Data.xlw)

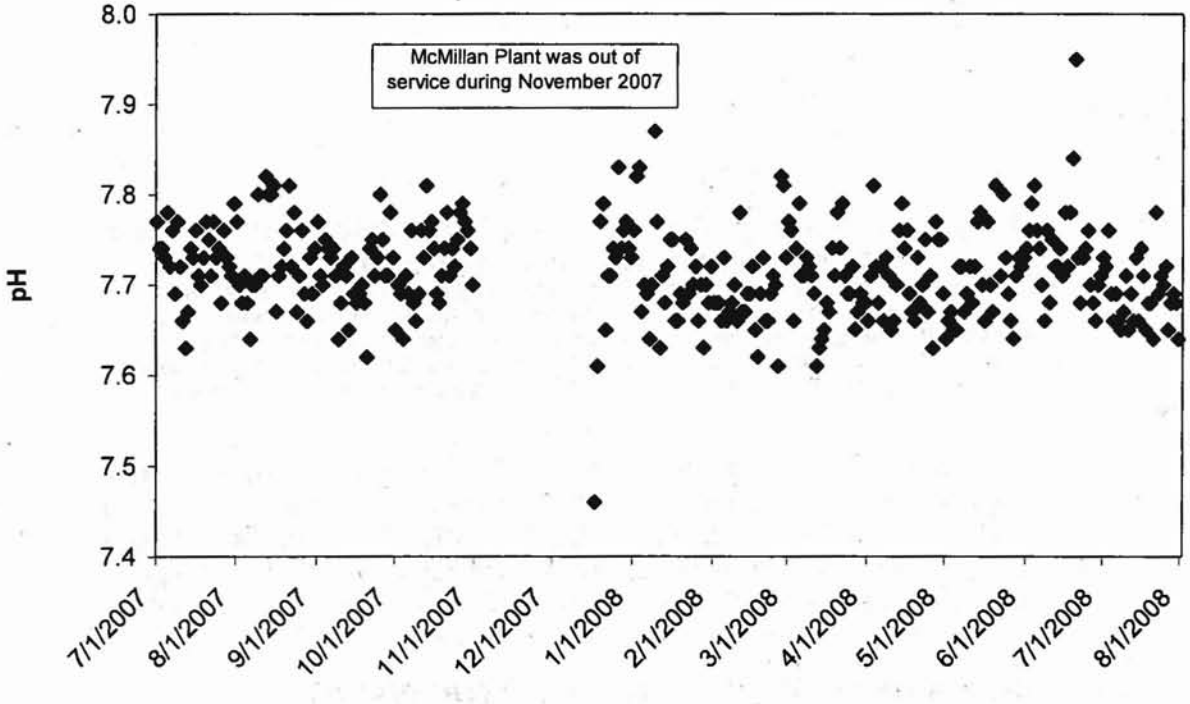

Figure 4. McMillan Average Daily Finished Water pH (July 07 - July 08) – Note that McMillan Plant was out of service during November 2007.
(Data Source: entry point WQP tracking for OCCT.xlw)

Finished water alkalinity produced by the Washington Aqueduct for July 2007 through July 2008 is displayed in Figure 5. Levels range from 115 mg/L as $CaCO_3$ to 45 mg/L as $CaCO_3$, with higher levels measured from June through December. There are no OCCT requirements for alkalinity. Based on these alkalinity and pH levels, dissolved inorganic carbonate levels are estimated to be 10-25 mg C/L.

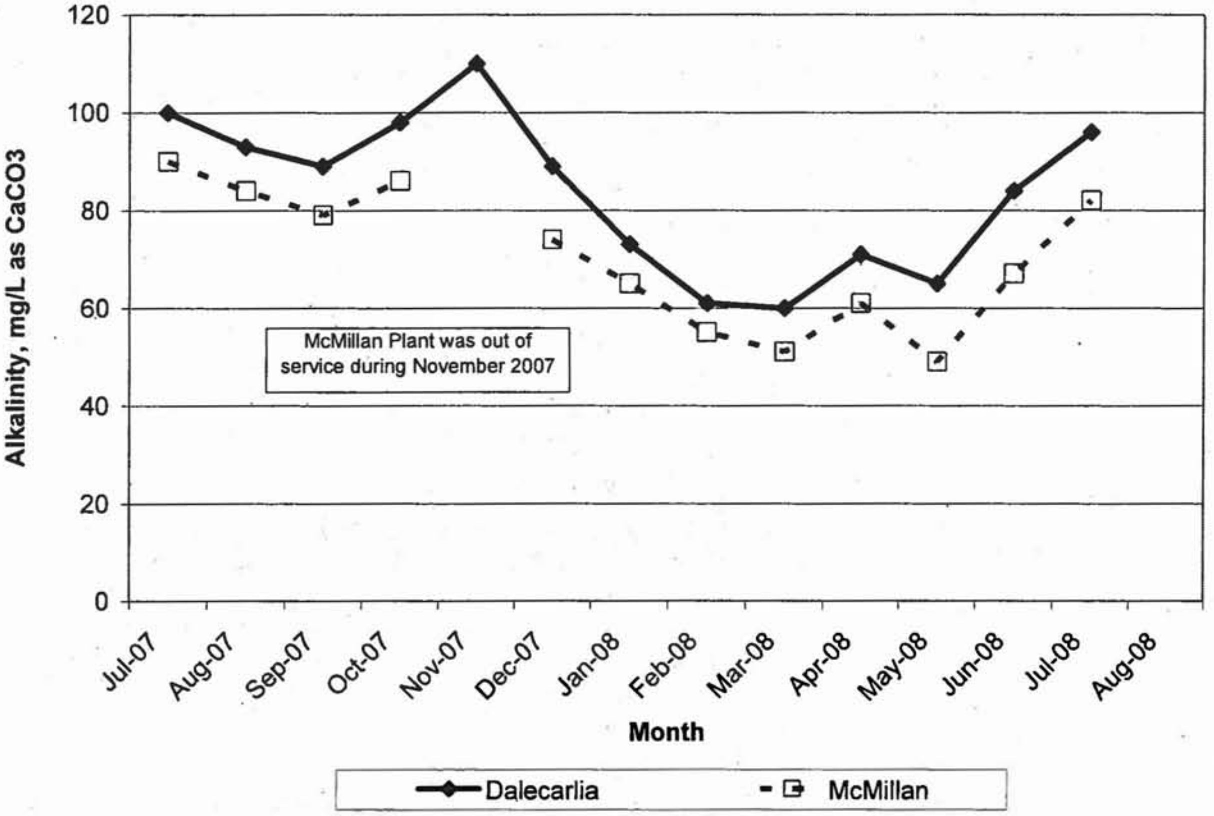

Figure 5. Average Finished Water Alkalinity (July 2007 – July 2008) – Note that McMillan Plant was out of service during November 2007.

(Data Sources: Monthly Water Quality Reports from Washington Aqueduct to USEPA Region 3, contained in following files: December EPA report 2007.pdf; EPA report 2007(July).pdf; EPA report April 2008.pdf; EPA report August 2007.pdf; EPA report July 2008.pdf; EPA report June 2008.pdf; EPA report March 2008.pdf; EPA report May 2008_revised.pdf; EPA report November 2007.pdf; February EPA report 2008.pdf; January EPA report 2008.pdf; October EPA report 2007.pdf; September EPA report 2007.pdf)

Finished water dissolved orthophosphate levels produced by the Washington Aqueduct for the time period July 2007 through July 2008 are displayed in Figures 6 and 7 for the Dalecarlia and the McMillan WTPS, respectively. Finished water orthophosphate levels were generally in the range of 2.25 to 2.5 mg/L, which is within the required OCCT range of 0.5 to 5.0 mg/L (specified as the dose necessary to reach this residual in tap samples).

4.3.2 Distributed Water Quality Trends (DC WASA)

Distribution system water quality trends for parameters of interest are displayed in Figures 8 through 20. Included parameters are pH, alkalinity, total and free chlorine, orthophosphate, and chloride and sulfate levels. Ninetieth percentile lead data collected for the Lead and Copper Rule are shown in Figure 21.

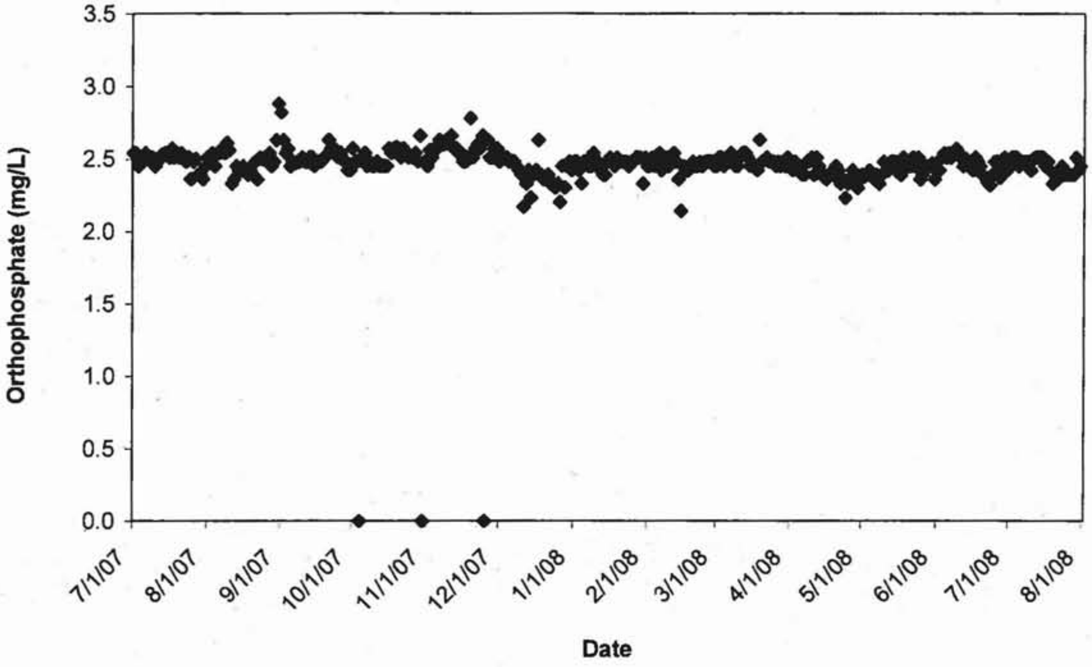

Figure 6. Dalecarlia Daily Finished Water Orthophosphate Residual (July 2007 – July 2008)

(Data Source: entry point WQP tracking for OCCT.xlw)

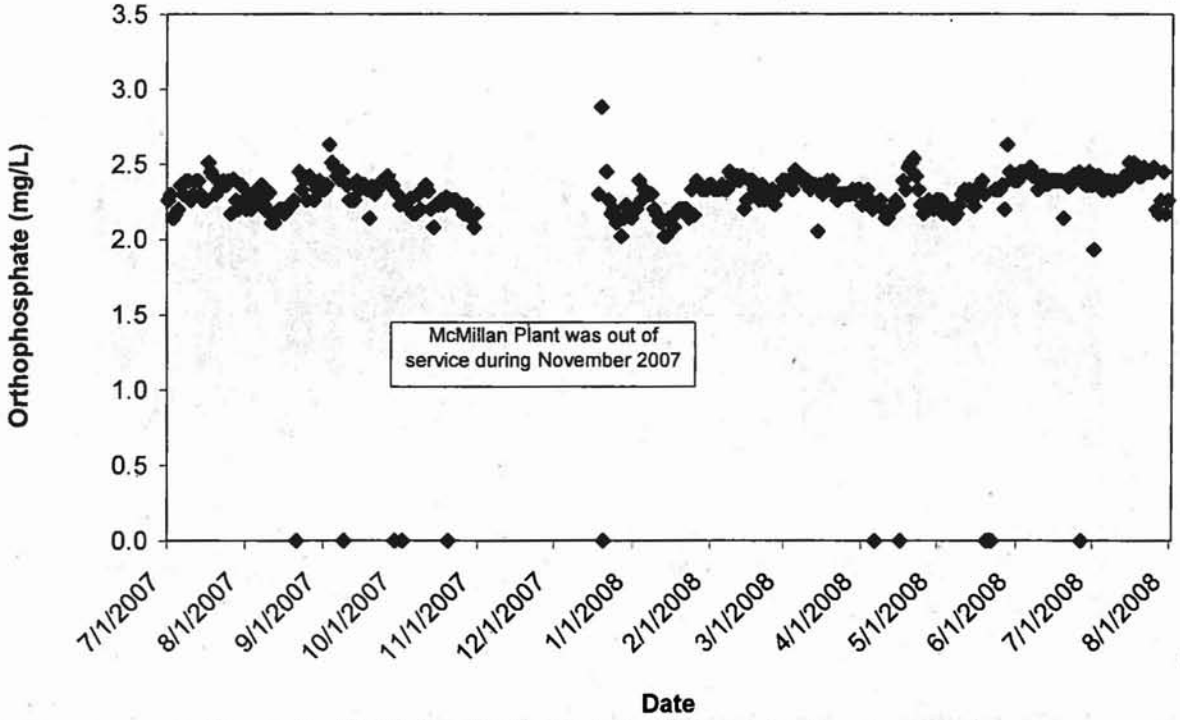

Figure 7. McMillan Daily Finished Water Orthophosphate Residual (July 2007 - July 2008) – Note that McMillan Plant was out of service during November 2007.

(Data Source: entry point WQP tracking for OCCT.xlw)

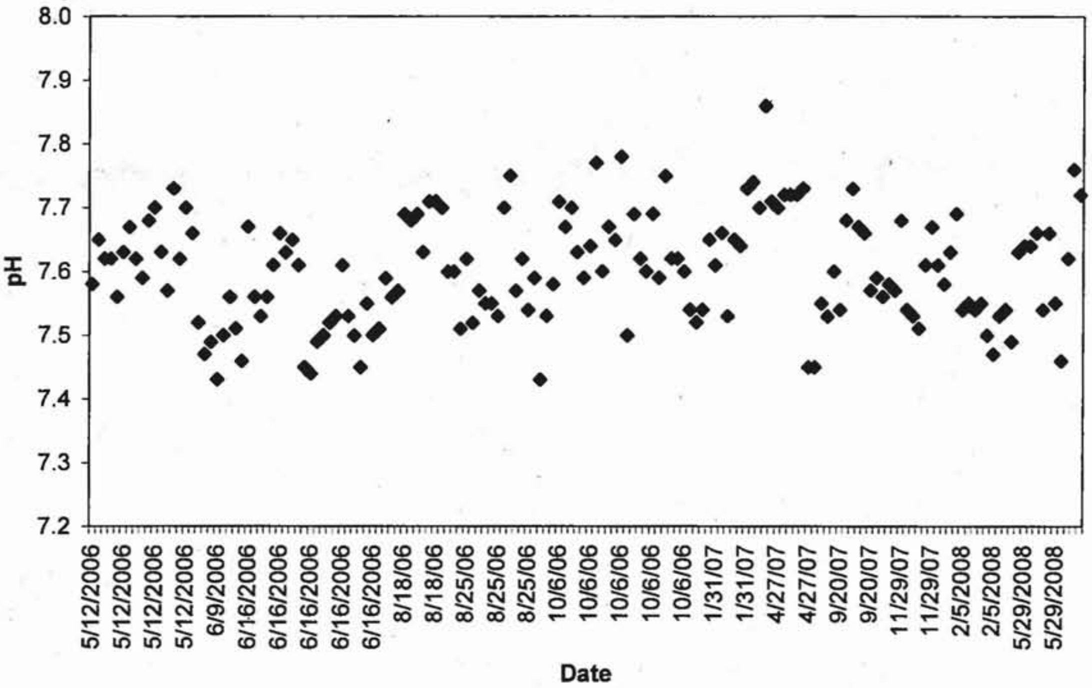

Figure 8. Distribution System pH (OCCT Sites) (2006-2008)
(Data Sources: OCCT Jan – June 2006.xlw; OCCT July-Dec06 jps.xlw; OCCT Jan-Jun 07 jps.xlw; OCCT Jul-Dec 07 jps.xlw; OCCT Jan-Jun 2008 results.xlw)

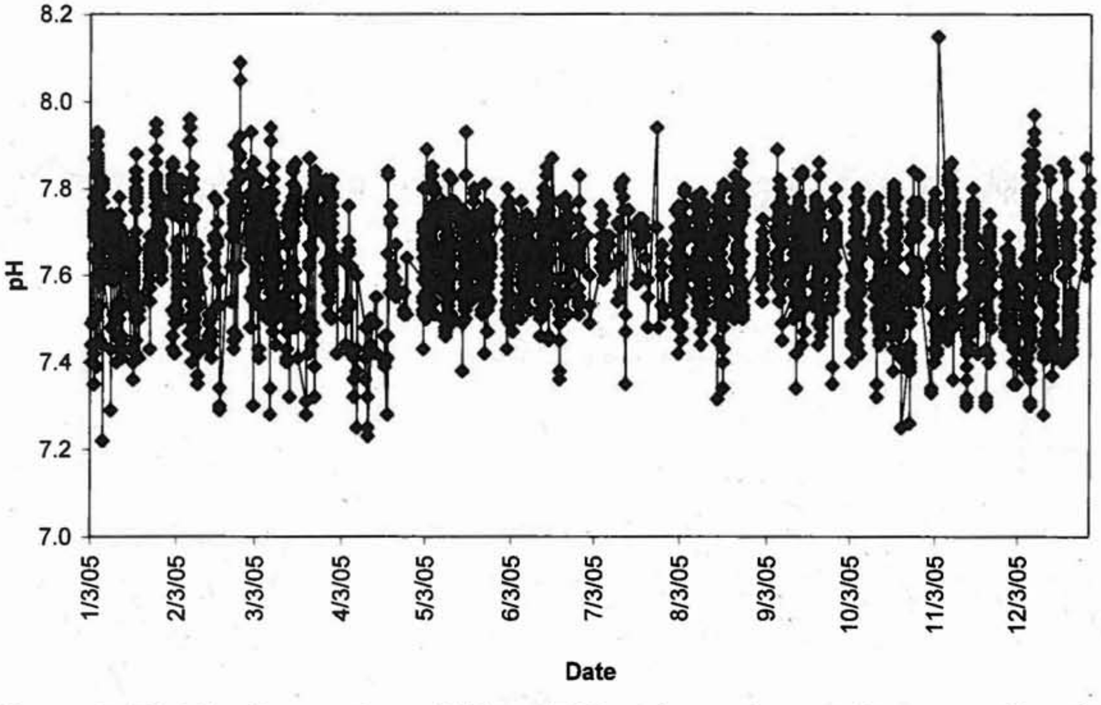

Figure 9. Distribution system pH (from TCR and supplemental tap sampling sites) (2005)
(Data Source: DCWASA Monitoring.mdb)

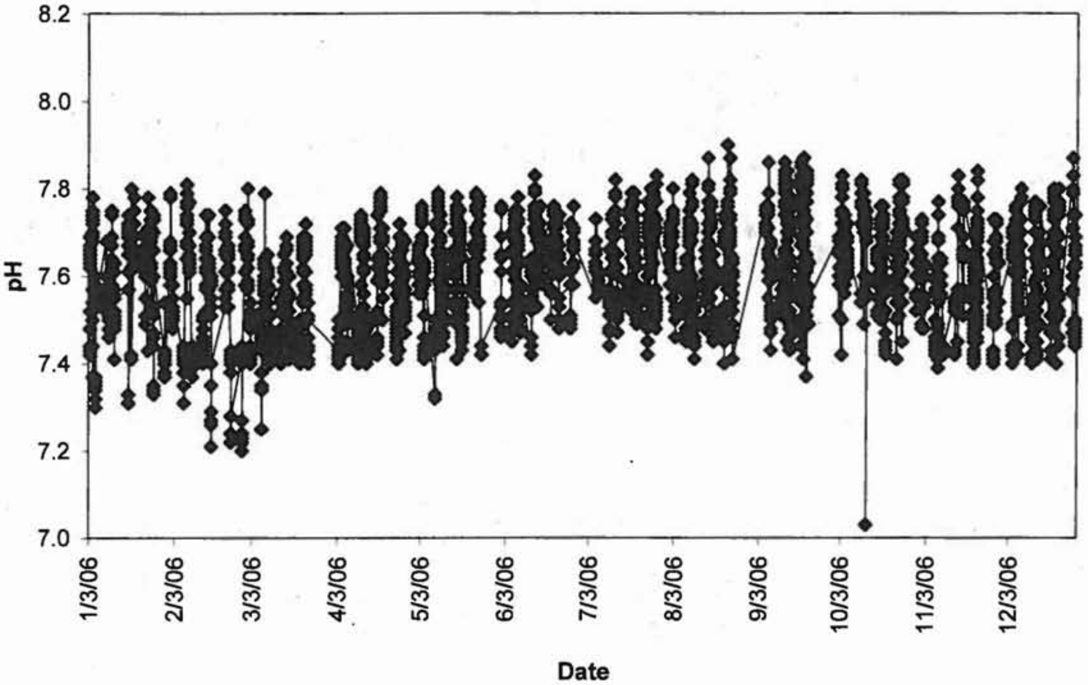

Figure 10. Distribution System - pH (from TCR tap sampling sites) 2006
(Data Source: DCWASA Monitoring.mdb)

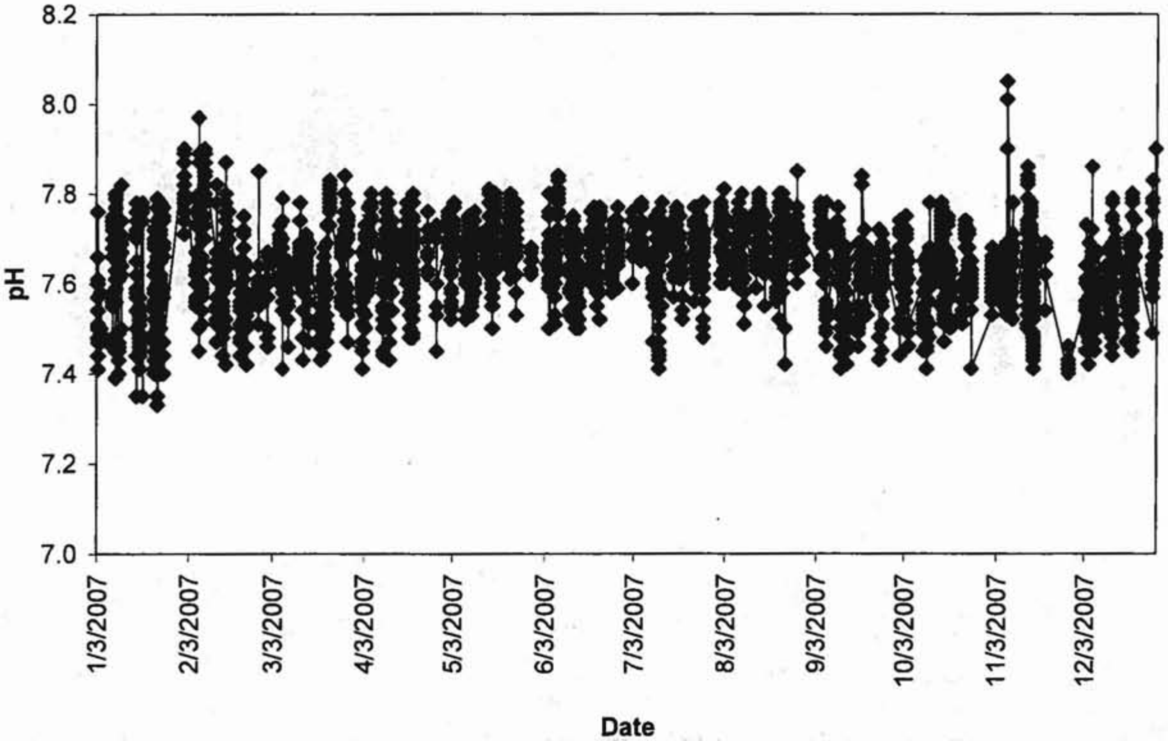

Figure 11. Distribution System pH (from TCR tap sampling sites) (2007)
(Data Source: DCWASA Monitoring.mdb)

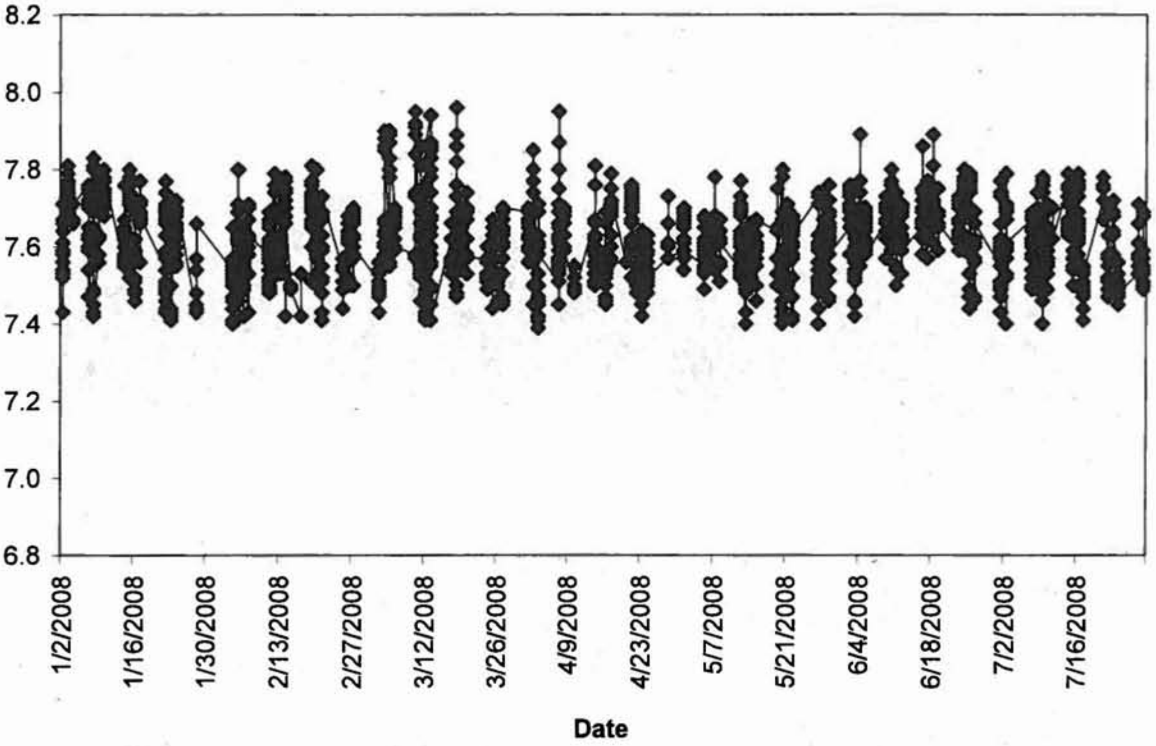

Figure 12. Distribution System pH (from TCR tap sampling sites) (2008)
(Data Source: DCWASA Monitoring.mdb)

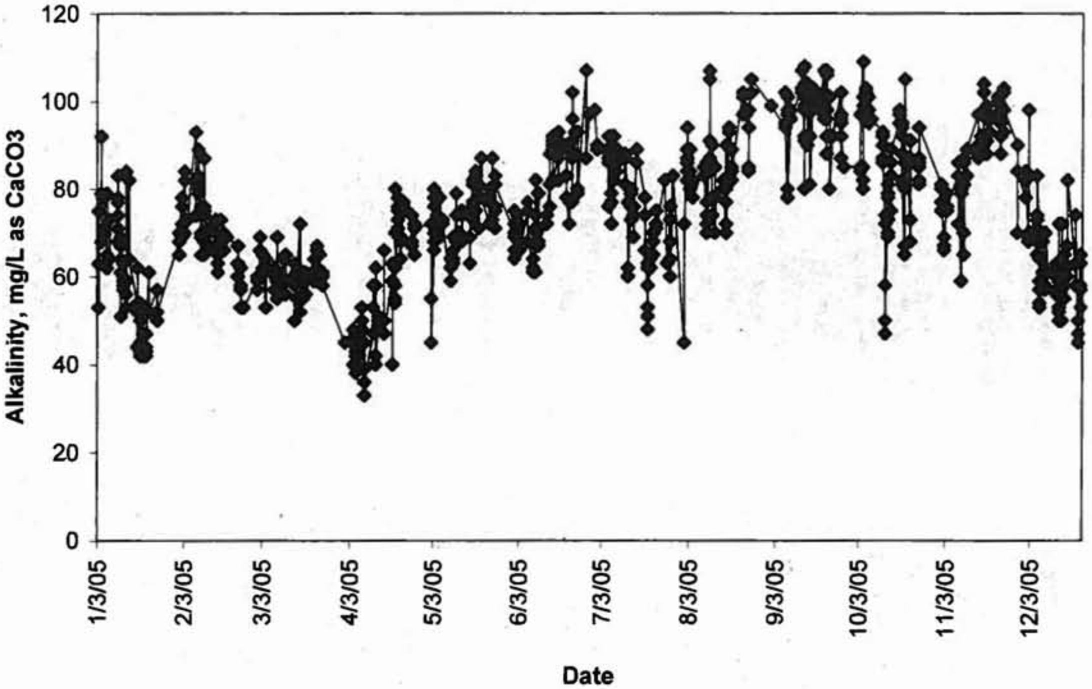

Figure 13. Distribution System Alkalinity (from TCR and supplemental tap sampling sites) (2005)
(Data Source: DCWASA Monitoring.mdb)

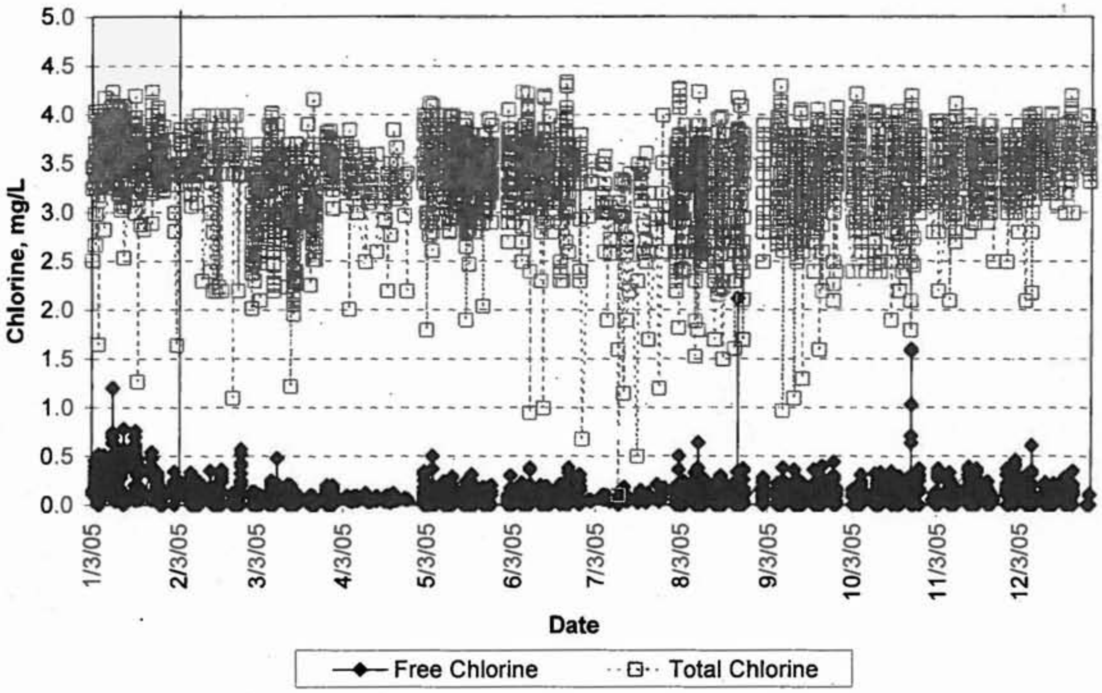

Figure 14. Distribution System Total and Free Chlorine (from TCR and supplemental tap sampling sites) (2005)

(Data Source: DCWASA Monitoring.mdb)

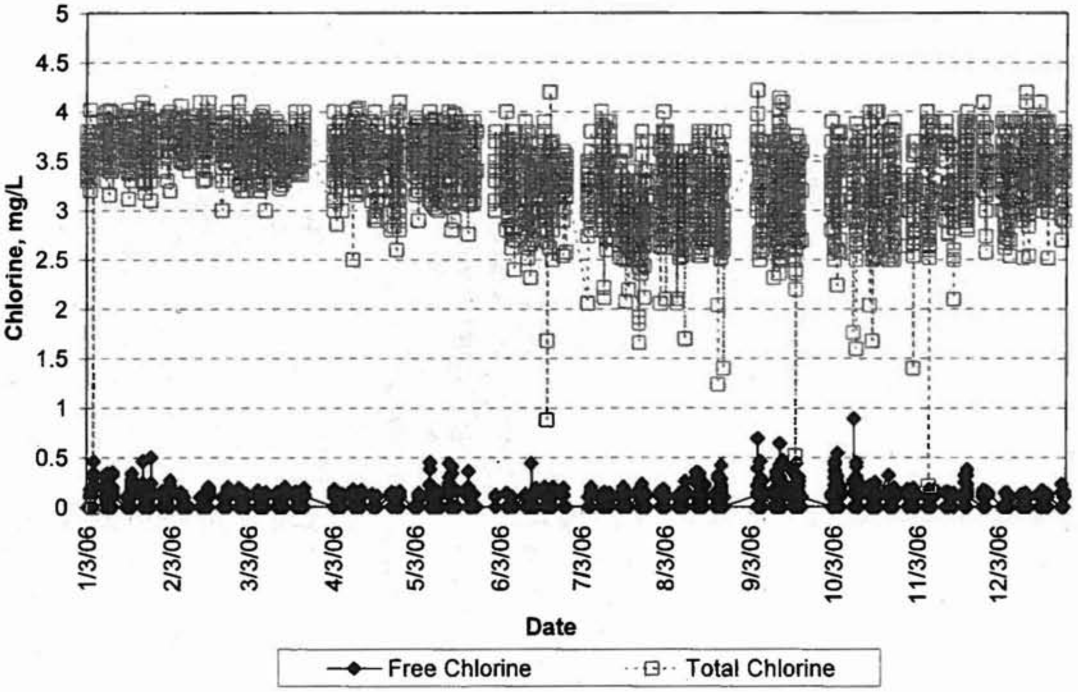

Figure 15. Distribution System Free and Total Chlorine (from TCR tap sampling sites) (2006)

(Data Source: DCWASA Monitoring.mdb)

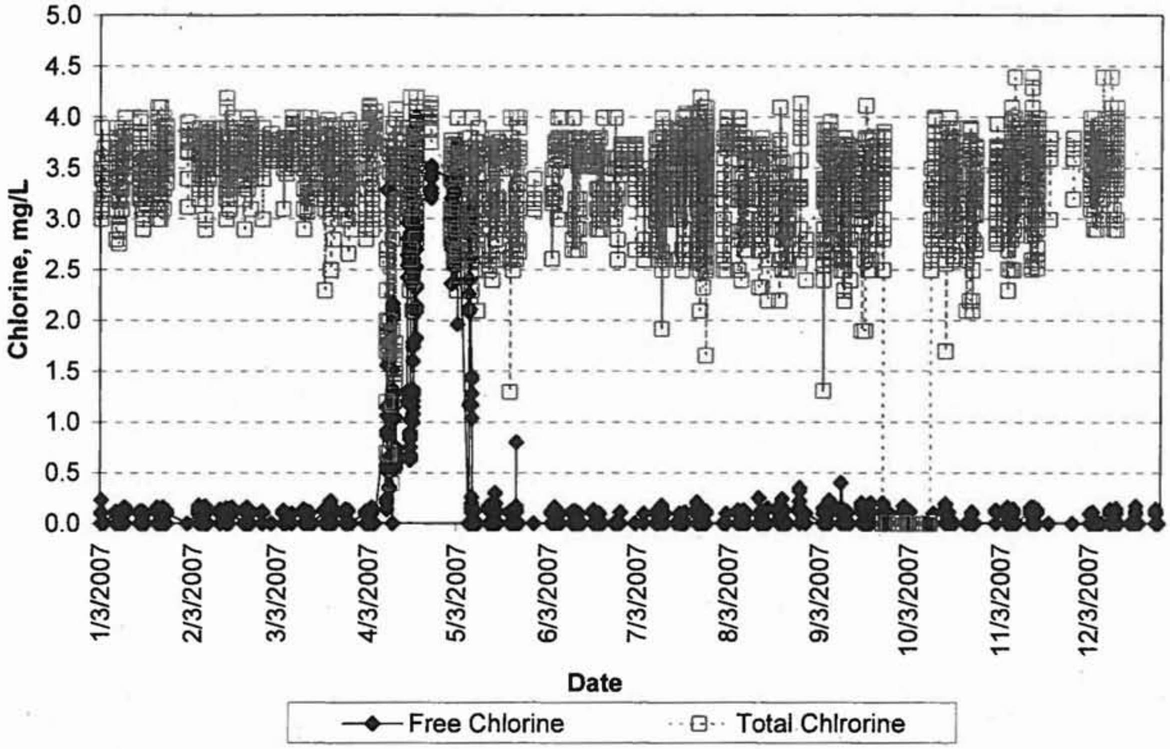

Figure 16. Distribution System Free and Total Chlorine (from TCR tap sampling sites) (2007)

(Data Source: DCWASA Monitoring.mdb)

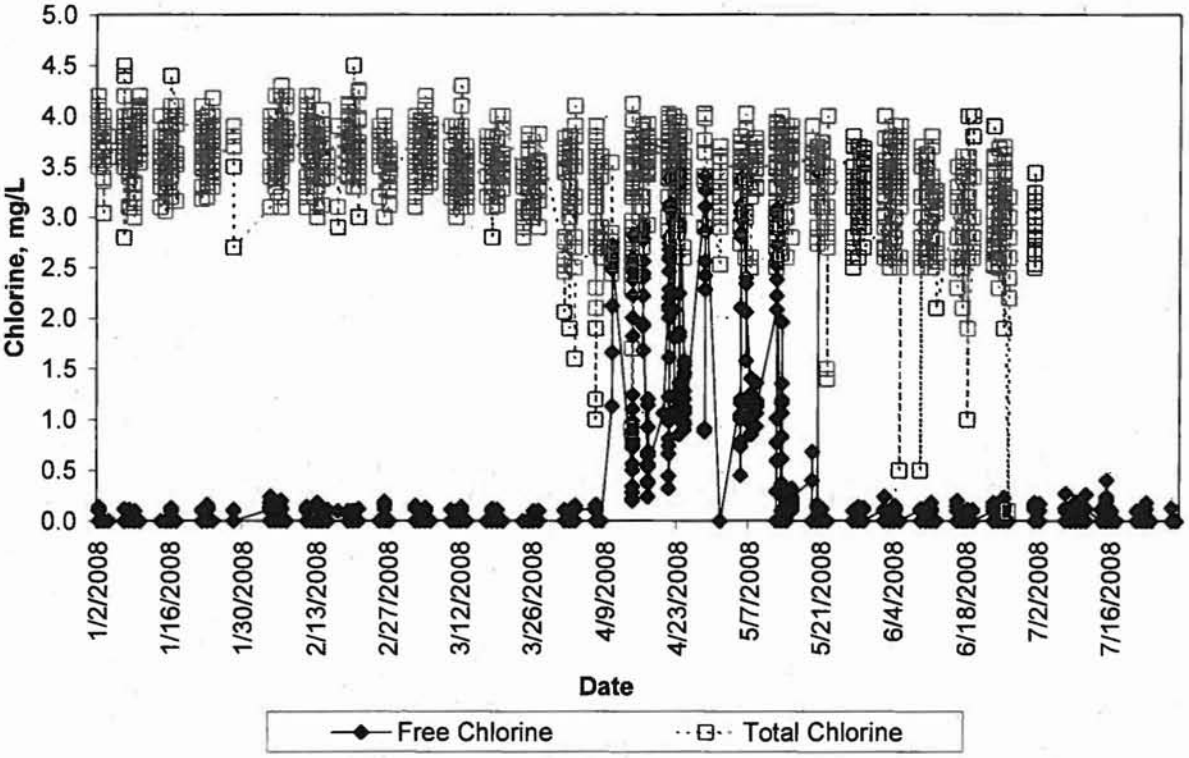

Figure 17. Distribution System Free and Total Chlorine (from TCR tap sampling sites) (2008)

(Data Source: DCWASA Monitoring.mdb)

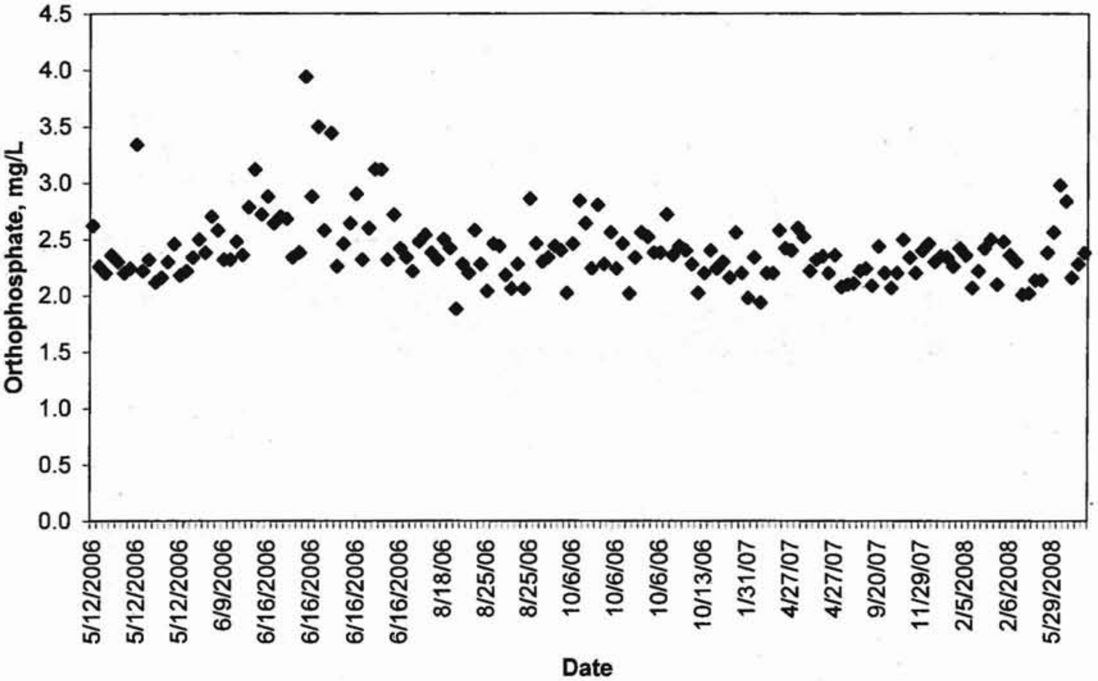

Figure 18. Distribution System Orthophosphate (OCCT Sites) (2006-2008)
(Data Sources: OCCT Jan – June 2006.xlw; OCCT July-Dec06 jps.xlw; OCCT Jan-Jun 07 jps.xlw; OCCT Jul-Dec 07 jps.xlw; OCCT Jan-Jun 2008 results.xlw)

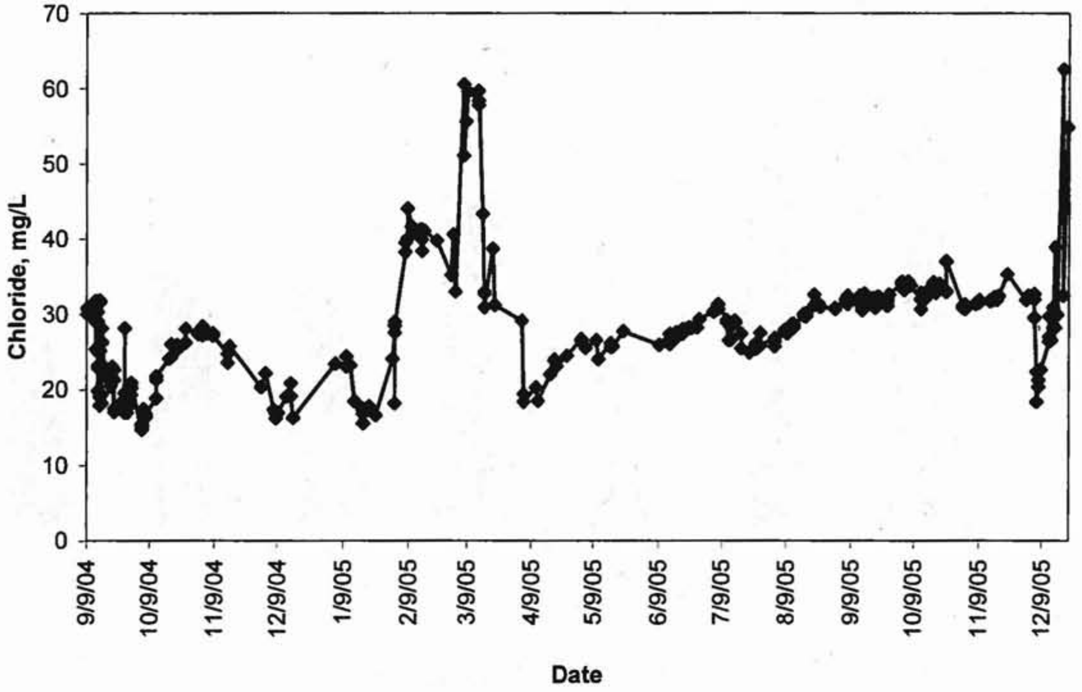

Figure 19. Distribution System Chloride (2004-2005)
(Data Source: DCWASA Monitoring.mdb)

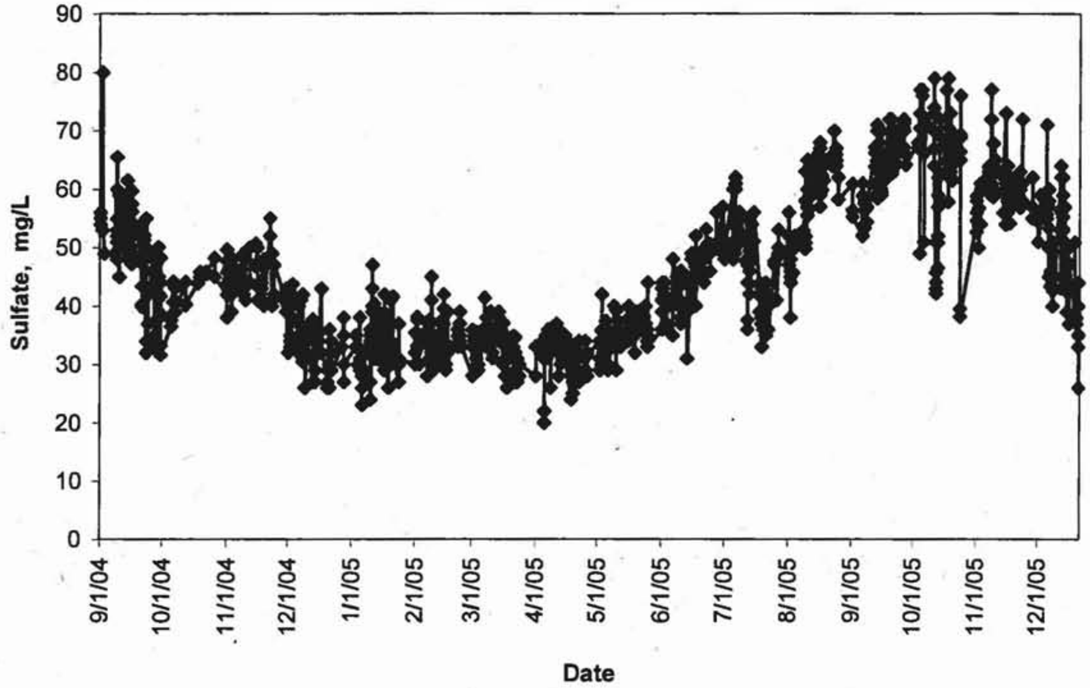

Figure 20. Distribution System Sulfate (2004-2005)
(Data Source: DCWASA Monitoring.mdb)

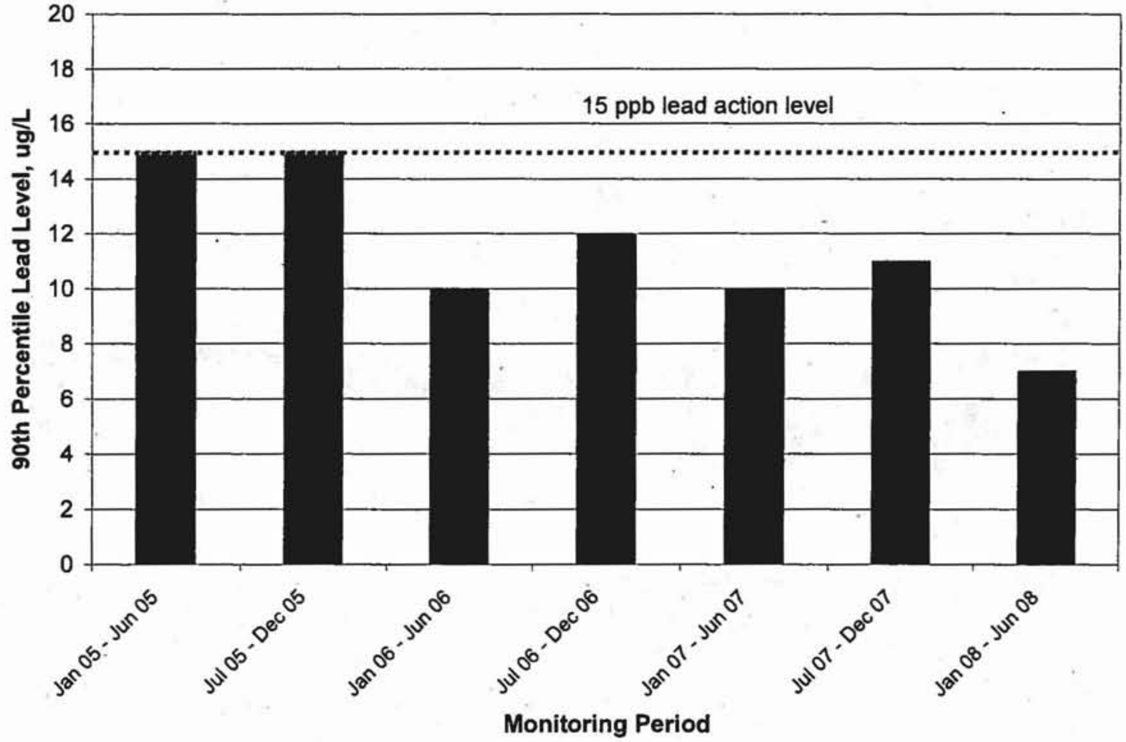

Figure 21. 90th percentile Lead Levels
(Data Source: historical 90th % v3-saxe.xlw)

Figure 8 displays pH measured from OCCT sites in the distribution system during 2006 through 2008. Figures 9 through 12 display pH measured at TCR sampling sites in the distribution system during the period from January 2005 through July 2008. The pH levels measured during this timeframe meet the OCCT requirement of >7.2, with the exception of one measurement in October 2006 (Figure 10) which was collected from a TCR location (not a designated WQP location) and therefore did not count towards compliance with the WQPs designated as part of the final OCCT designation (Capacasa 2004a and 2004b).

The pH of water in the distribution system can be different than the pH of water measured at the entry point to the distribution system depending on water quality, size of the distribution system, flow rate, and age and type of piping materials, and this change in pH in the distribution system can impact lead and copper release from lead based materials in the system. Based on the available data, the difference between average finished water pH measured at the Aqueduct water treatment plants and pH measured in the DCWASA distribution system from OCCT sites ranges from approximately 0.1 to 0.3 pH units. The range is slightly wider for the difference between average finished water pH and pH measured from additional tap sampling sites (0.4 - 0.7 pH units).

Distribution system alkalinity measurements for the year 2005 are shown in Figure 13. Levels ranged from 33-109 mg/L as $CaCO_3$, with an average of 75 mg/L as $CaCO_3$, with higher levels generally measured in the summer months. This data was collected as part of a supplemental monitoring program specified under the interim OCCT designation for DCWASA. This requirement ended as of January 2006.

Free and total chlorine measured in the distribution system from January 2005 through July 2008 are shown in annual increments in Figures 14 through 17. Total chlorine levels were generally maintained at 3.0 – 3.5 mg/L in the distribution system, with some daily variation.

Distribution system orthophosphate levels measured at OCCT sites ranged from approximately 2.0 to 4.0 mg/L (Figure 18) from May 2006 through May 2008. These levels are within OCCT requirements.

Chloride and sulfate levels were measured at distribution system sites in 2004 and 2005, and results are shown in Figures 19 and 20, respectively. Levels ranged from 14 to 62 mg/L for chloride and 20 to 80 mg/L for sulfate, with generally higher sulfate levels in the summer and fall when compared to the winter and spring. As with alkalinity, this data was collected as part of a supplemental monitoring program specified under the interim OCCT designation for DCWASA, which ended as of January 2006. Chloride was not listed as a requirement, but was monitored in addition to the required sulfate

Ninetieth percentile lead levels measured for LCR compliance for DCWASA are displayed in Figure 21. These 90th percentile lead levels have met the action level of 0.015 mg/L (15 μg/L) from 2005 through the first half of 2008. Copper levels measured for LCR compliance were well below the action level of 1.3 mg/L for 2005 through the first half of 2008, ranging from 0.004 to 0.373 mg/L Cu.

5.0 DESCRIPTION AND EVALUATION OF PLANNED TREATMENT CHANGES

The Washington Aqueduct's planned conversion from liquid chlorine to hypochlorite for disinfection, and use of caustic soda for pH control are evaluated and discussed below. A brief discussion is also provided regarding other water quality issues that potentially could impact lead and copper corrosion in the Aqueduct service areas.

5.1 Conversion from Liquid Chlorine to Hypochlorite

The conversion from liquid chlorine to hypochlorite is planned for both the Dalecarlia and McMillan WTPs. The Aqueduct's rationale for this conversion is to eliminate the inherent risks associated with storing and handling liquid chlorine (Jacobus 2008a). The impact of switching disinfectants on disinfection efficiency, oxidation reduction potential, chloride-to-sulfate mass ratio, sodium levels, and chlorate and chlorite formation are discussed below.

5.1.1 Disinfection Efficiency and Oxidation Reduction Potential

Sodium hypochlorite is a commonly used disinfectant for drinking water. Both liquid chlorine and sodium hypochlorite form hypochlorous acid, which dissociates into H^+ and OCl^-. The chemical formulas for these reactions are the following:

Liquid chlorine: $Cl_2 + H_2O \rightarrow HOCl + H^+ + Cl^-$

Sodium hypochlorite: $NaOCl + H_2O \rightarrow HOCl + NaOH$

Disinfection with both products is aimed at the formation of hypochlorous acid (HOCl), which is a strong disinfectant. As shown above, chlorine dissolves in water to form hypochlorous acid, hydrogen and chloride ion, and sodium hypochlorite forms hypochlorous acid and sodium hydroxide. In both cases, the HOCl that is formed dissociates into H^+ and OCl^-. The ratio of HOCl to OCl^- is pH dependent. At a pH of 7.3 there is roughly a 50-50 concentration of HOCl and OCl^-. As pH increases, the OCl^- predominates, resulting in less effective disinfection. Use of sodium hypochlorite may raise the pH of water, reducing its disinfectant effectiveness (Abraham et al, 2002); however, as long as chlorine dose is maintained and finished water pH is maintained at current OCCT levels, there should be no impact to switching disinfectant chemicals on pH or disinfectant efficiency. Either chemical will provide the same level of disinfection efficiency provided that the finished water chlorine concentration and pH remain the same.

The oxidation reduction potential of the water can be impacted by what type of disinfectant is used, with stronger oxidants such as ozone and free chlorine resulting in higher oxidation potentials than weaker oxidants such as chloramines or dissolved oxygen. Oxidation reduction potential can have an impact on the type of lead-based corrosion scales that may develop in the distribution and premise system, and the characteristics of these scales are factors in release of lead. Switching from liquid chlorine to sodium hypochlorite for disinfection will not change the oxidation reduction potential of the water as long as the chlorine dose remains the same, therefore the types of lead-based corrosion scales formed in the system should not be changed.

5.1.2 Chloride to Sulfate Mass Ratio

There may be a relationship between the ratio of chloride to sulfate levels in the water and lead release from lead based plumbing materials. Some research has been conducted that indicates a link between higher CSMR and elevated levels of lead being released through galvanic corrosion of lead-tin solder at copper pipe joints and brass faucets and fittings (Britton and Richards, 1981; Oliphant 1983; Gregory 1985; Edwards 1999; Edwards and Triantafyllidou 2007). It has been theorized that CSMR values greater than 0.5 may increase galvanic corrosion of lead solder connecting copper pipe (Gregory 1985) and exacerbate release of lead (Edwards and Triantafyllidou 2007), although more research is needed on this relationship.

The chloride sulfate mass ratios for finished water from the Dalecarlia and McMillan WTPs for 2005 through 2008 are displayed in Figures 22 and 23, respectively, with average values summarized in Table 1 for summer and winter from July 2007 through July 2008 at both treatment plants. The ratio is generally higher (>0.60) in the winter months than the summer months (<0.50), and in both circumstances is close to the ratio identified in the literature as having the potential to exacerbate lead release from lead sources in the distribution and premise system. Using sodium hypochlorite for disinfection will reduce the amount of Cl^- added to the water when compared to liquid chlorine (see equations above), which could result in slightly lower CSMR values than those displayed for historical data from the Aqueduct (which were measured using liquid chlorine). Literature indicates that a lower CSMR may be less likely to leach lead. Other treatment changes, such as increased use of polyaluminum chloride (PACl), could impact the CSMR. Appendix B contains a brief discussion of the potential impacts of increased PACl use on the CSMR ration and lead release.

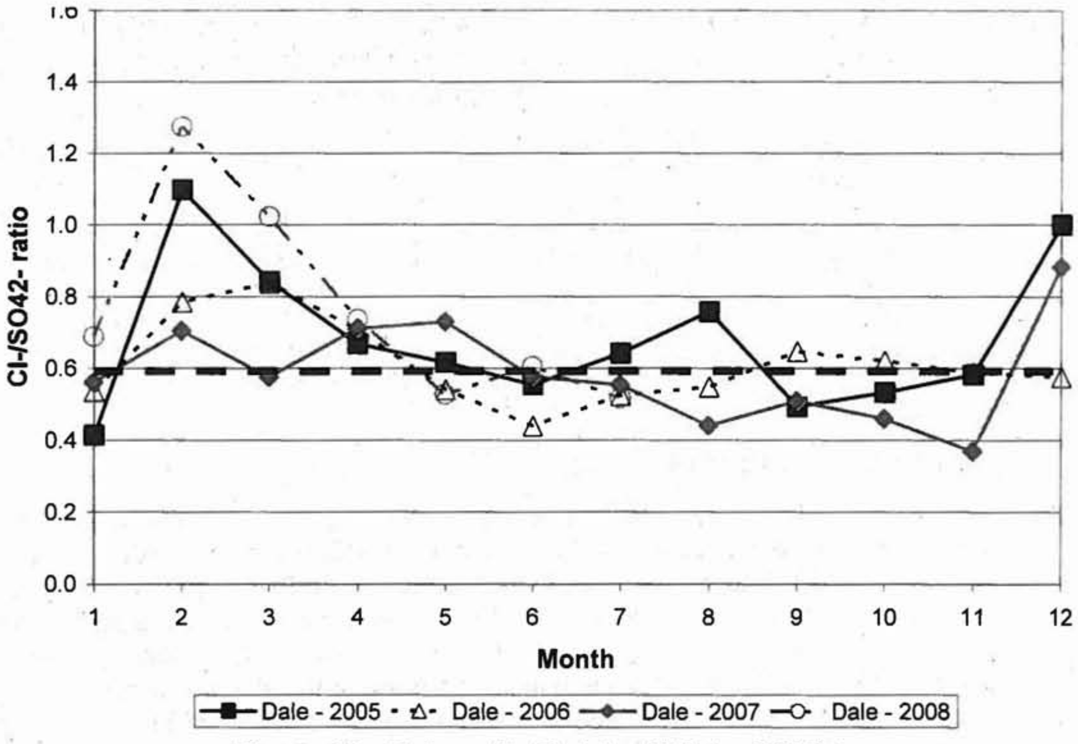

Figure 22. Dalecarlia Finished Water CSMR

(Data Source: chloride-sulfate ratio.xlw)

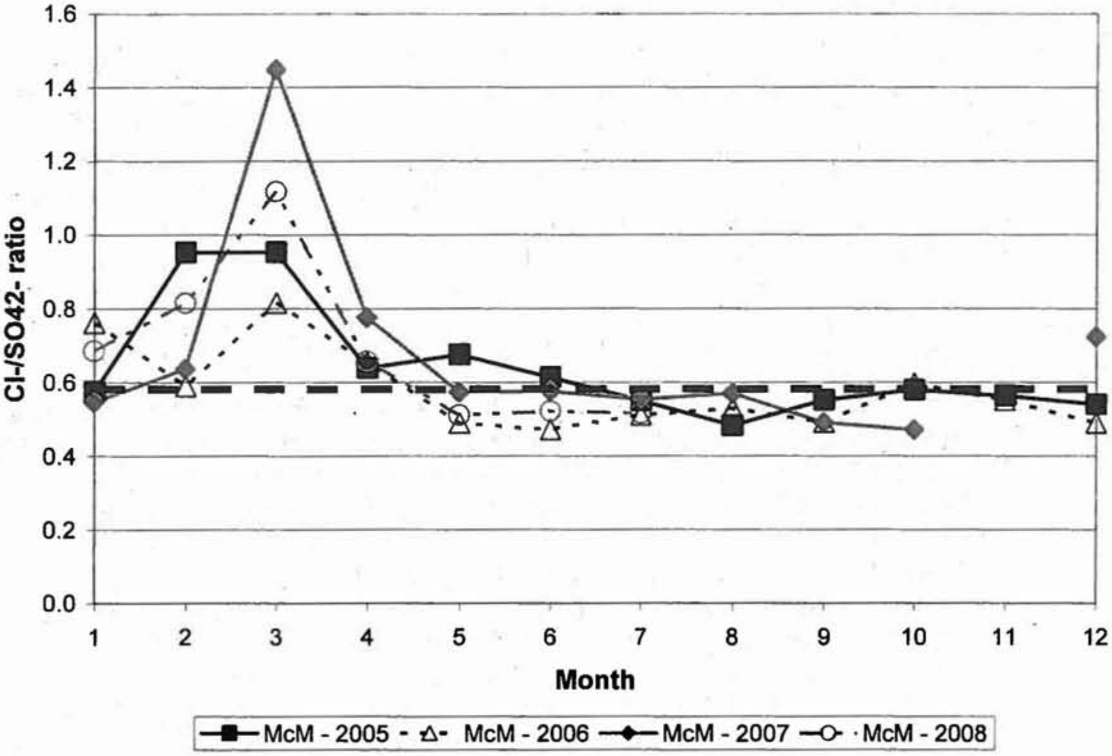

Figure 23. McMillan Finished Water CSMR – Note that McMillan Plant was out of service during November 2007.

(Data Source: chloride-sulfate ratio.xlw)

Table 1. Average Chloride and Sulfate Levels and Chloride Sulfate Mass Ratio in Finished Water from July 2007 through July 2008 for the Dalecarlia and McMillan WTPs

Season*	Chloride	Sulfate	CSMR
Dalecarlia WTP			
Summer	28.7	56.9	0.51
Winter	38.3	50.2	0.76
McMillan WTP			
Summer	29.0	55.9	0.52
Winter	39.4	49.8	0.79

*summer = May through October; winter = November through April

5.1.3 Sodium Content of Water

The sodium content of water may be slightly increased with use of sodium hypochlorite when compared to liquid chlorine (Damron et al, 2002). If there is an equal molar addition of sodium and chlorine, about 0.65 mg/L of sodium will be added per mg/L of chlorine added. Sodium is currently not regulated in drinking water; however it has been included on the Drinking Water Contaminant Candidate List (CCL) which is a list of contaminants which may require regulations under the Safe Drinking Water Act (SDWA). The current USEPA guidance level for sodium is a Drinking Water Equivalency Level (DWEL) or guidance level of 20 milligrams per liter. The agency believes this level is probably low, and has listed sodium as a research priority on the CCL in order to evaluate and revise this guidance (USEPA 2008a). The Aqueduct has plans to monitor sodium in the finished water at both plants with a frequency of once per week to track changes in sodium levels that may occur with the proposed switch to sodium hypochlorite for disinfection.

5.1.4 Chlorite and Chlorate Formation

Sodium hypochlorite can degrade to form chlorate and chloride ions. In addition, other contaminants may be present in sodium hypochlorite solutions, including chlorite, perchlorate, and bromate (Mackey et al, 2003; Abraham et al, 2002; American Chemistry Council, 2007). Recent research has indicated that perchlorate levels my increase in sodium hypochlorite solutions over time (Greiner et al, 2008). There is currently no maximum contaminant level (MCL) for chlorate or perchlorate (USEPA 2008b), however it would be prudent to take measures to minimize decomposition of the hypochlorite solution and insure that contaminants are not present in the chemical supplied. The Washington Aqueduct indicated that it will use AWWA Standard B200-04 for their specification for sodium hypochlorite, which is aimed at reducing the potential for chlorate, chlorite, perchlorate or bromate contamination from occurring.

5.2 Caustic Soda for pH Control

The Washington Aqueduct plans to use caustic soda at the Dalecarlia WTP to further control pH following pH adjustment with lime. At the McMillan WTP, caustic soda and sulfuric acid will be used for control of pH. The rationale for this change is to 'enhance the reliability of the production of drinking water' (Jacobus 2008a).

5.2.1 Finished Water Quality

Use of caustic soda will not change the DIC levels of the finished water (AWWARF and DVGW-TZW, 1996), and will not change the pH and alkalinity of the finished water, given that the same target pH is utilized in determining chemical doses. In addition, use of caustic soda will not increase calcium concentrations, so calcium carbonate precipitation and increased turbidity are less likely (AWWARF and DVGW-TZW, 1996). The *Rothberg, Tamburini, & Winsor Model for Corrosion Control and Process Chemistry* (RTW Model) was used to demonstrate this chemistry.

The RTW Model is a spreadsheet model that uses calcium carbonate chemistry to evaluate water stability and can predict changes in water stability and other characteristics. This model was used to demonstrate that pH, alkalinity, and DIC would remain constant when different pH adjustment chemicals are used Average summer and winter values for source water parameters (Washington Aqueduct, 2007) were input to the model. These parameters included pH, temperature, total dissolved solids, alkalinity, hardness, calcium, chloride, and sulfate. The model was run using current pH adjustment conditions (lime addition) versus planned pH adjustment (lime and caustic at Dalecarlia, caustic at McMillan). Model outputs demonstrated that pH, alkalinity, and DIC remained the same under planned pH adjustment scenarios when compared to the current pH adjustment method (see Table 2). Calcium levels were estimated to be lower with the addition of caustic for pH control, as the amount of lime used would be reduced at both plants. This also reduces the calcium carbonate precipitation potential CCPP of the finished water, which may be beneficial with respect to minimizing calcium carbonate scaling in the system. Although the RTW Model is widely used and results are generally considered predictable, bench-scale testing and/or field sampling would need to be conducted to verify these water quality predictions.

Since there will be no change in the pH goal for treated water with use of caustic for pH control, levels of lead and copper measured in LCR tap samples should be similar to levels currently measured under optimal corrosion control treatment. In addition, the finished water pH target can be achieved more reliably and with less variability with the use of caustic soda, and the potential for calcium carbonate precipitation and consequent scaling in the distribution system is likely to be reduced.

Table 2. Simulated pH Adjustment Using RTW Model

	Dalecarlia WTP			
	Summer*		**Winter***	
	Current Conditions (Lime Only)	**Future Conditions (Lime plus Caustic)**	**Current Conditions (Lime Only)**	**Future Conditions (Lime plus Caustic)**
pH	7.7	7.7	7.7	7.7
Alkalinity	99	99	84	84
Calcium	56	53	49	45
DIC	204	204	176	176
CCPP	+.91	+.77	-3.6	-3.8
	McMillan WTP			
	Summer*		**Winter***	
	Current Conditions (Lime Only)	**Future Conditions (Caustic Only)**	**Current Conditions (Lime Only)**	**Future Conditions (Caustic Only)**
pH	7.7	7.7	7.7	7.7
Alkalinity	99	99	84	84
Calcium	56	37	48	35
DIC	204	204	176	176
CCPP	+.79	-.57	-4.1	-4.8

*summer = May through October; winter = November through April

5.2.2 Distribution System Water Quality

Based on review of historical pH data (Figures 1 through 4 and 8 through 10), the difference between finished water pH measured at the Aqueduct water treatment plants and pH measured in the DCWASA distribution system ranges from approximately 0.1 to 0.3 pH units (with minimal measurements outside this range). This is a relatively small change in pH measured in the distribution system, and appears to have little impact on the 90th percentile lead and copper levels measured at the tap for LCR compliance, which are currently below the action levels. Since finished water pH, alkalinity, and DIC will not change with the planned use of caustic for pH control and this variation in pH in the distribution system is expected to be the same or narrower, the effectiveness of orthophosphate based corrosion control could potentially be improved.

In addition, the alkalinity of Aqueduct's finished water provides good buffering capacity, allowing a strong ability to resist pH changes in the distribution system. Use of caustic and lime can increase the alkalinity of the water, which may impact copper corrosion (Edwards et al 1996.). However, historical use of lime by the Washington Aqueduct has resulted in copper levels well below the Lead and Copper Rule action level (current LCR copper levels are < 0.5 mg/L). The planned change in pH adjustment chemicals will not change the pH and alkalinity of the finished water, therefore increases in copper corrosion should not be a concern

5.2.3 Lead and Copper Corrosion Evaluation

The 90th percentile lead levels measured at taps in the DCWASA distribution system for the LCR have been below the action level since 2005 (see Figure 21) and copper levels are well below the action level of 1.3 mg/L (ranging from 0.004 to 0.373 mg/L). The current finished water and distributed water OCCT requirements for pH and orthophosphate are being met, and have resulted in lead and copper levels that are below the action level per the LCR. As discussed previously, changing the pH adjustment method at the Aqueduct's water treatment plants will not change these finished water pH, alkalinity, or DIC conditions, and therefore, lead and copper levels in the distribution system should not be impacted, as long as orthophosphate levels and pH are maintained at optimal conditions. Maintenance of optimal orthophosphate corrosion control treatment (adequate dosage at the proper pH range) will have a greater impact on lead and copper corrosion than the proposed treatment changes planned at Aqueduct (switch to sodium hypochlorite for disinfection and use of caustic for pH control).

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Appendix A – Optimal Corrosion Control Designation for the Washington Aqueduct[1]

Water Quality Parameter Monitoring and Reporting for Optimal Corrosion Control Treatment Designated June 14, 2006

Washington Aqueduct

Water quality parameters (WQPs) for water entering the distribution system:

	WQP	
pH	7.7 ± 0.1	(interim: 7.7 ± 0.3[‡])
Orthophosphate	0.5 – 5.0 mg/L[*]	

‡ EPA expects that the Washington Aqueduct will comply with the final pH WQP once caustic soda feed is operational at both treatment plants. Until that time, the interim pH WQP applies to the Aqueduct.
* Dose necessary to reach this residual (as dissolved orthophosphate) in tap samples. Any deviations from this range will be evaluated on a case-by-case basis. Reports shall indicate whether the applied dose is measured as total or dissolved orthophosphate.

Monitoring shall be conducted according to the frequency and other requirements in 40 CFR §141.87. The Washington Aqueduct is directed to submit to EPA the sampling schedule that will be used for WQP monitoring within two weeks of the date of this letter. Compliance shall be assessed pursuant to 40 CFR §141.82(g).

WQP excursions shall be reported to EPA no later than 10 days after the end of the month in which the excursion occurs. WQP reports shall be submitted to EPA within ten (10) days of the end of each six-month monitoring period.

DC WASA

Water quality parameters for locations in the distribution system selected pursuant to 40 CFR §141.87:

	WQP
pH	≥ 7.2
Orthophosphate residual	0.5 – 5.0 mg/L

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[1] USEPA. 2006. Letter to Thomas P. Jacobus and John T. Dunn, Washington Aqueduct, from Jon M. Capacasa, USEPA Region III. Dated June 14, 2006. Designating Optimal Corrosion Control Treatment for the Washington Aqueduct. Accessed from Appendix C, *Final Environmental Impact Statement for System Improvements of the Dalecarlia WTP and McMillan WTP for Disinfection and pH Control.* Prepared by the U.S. Army Corps of Engineers. June 2007.

Free ammonia nitrogen	Monitor & report
Nitrite nitrogen	Monitor & report

Orthophosphate shall be measured as dissolved orthophosphate. Any deviations from the orthophosphate WQP range will be evaluated on a case-by-case basis.

Monitoring shall be conducted at no less than 25 sampling locations and at a frequency of no less than two times every six month period, according to the requirements in 40 CFR §141.87.

DC WASA shall submit within two weeks of the date of this letter to EPA for review and comment a WQP monitoring plan consisting of a list of the distribution system sampling sites and the sampling schedule that will be used for WQP monitoring. Only samples taken pursuant to this WQP monitoring plan will be considered for purposes of determining compliance with 40 CFR §141.82 and §141.87. DC WASA shall notify EPA in the event that DC WASA must change any of the distribution system WQP sites during a monitoring period.

Compliance shall be assessed pursuant to 40 CFR §141.82(g).

WQP excursions shall be reported to EPA no later than 10 days after the end of the month in which the excursion occurs. WQP reports shall be submitted to EPA within ten (10) days of the end of each six-month monitoring period.

Appendix B – Other Water Quality Issues

While not a planned treatment change subject to evaluation in this technical memorandum, the use of polyaluminum chloride at both plants is discussed briefly, to raise the issue of potential impacts on lead release with higher chloride levels in the finished water. Currently, PACl is used at both plants on a seasonal and/or intermittent basis. According to the sanitary survey for the Washington Aqueduct (Cadmus Group 2006), PACl is typically added during warmer weather conditions and is not needed during colder weather. Increased use of PACl by the Aqueduct could potentially increase the chloride content of the finished water, and elevate the CSMR of the finished water above what is currently measured (typical average values of 0.5 to 0.8). Although more research needs to be completed on the relationship between CSMR and lead release, it has been theorized that CSMR values greater than 0.5 may increase galvanic corrosion of lead solder connecting copper pipe (Gregory 1985) and exacerbate release of lead (Edwards and Triantafyllidou, 2007).

Attachment 11: ORD review memo of corrosion control impacts

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
NATIONAL RISK MANAGEMENT RESEARCH LABORATORY
CINCINNATI, OHIO 45268

MEMORANDUM

DATE: June 1, 2009

SUBJECT: Review of Washington Aqueduct treatment changes and Cadmus EP-C-08-015

FROM: Michael R. Schock Michael R. Schock
Research Chemist, TTEB, WSWRD, NRMRL, ORD

TO: Jennie Saxe
USEPA Region 3

I have completed reviewing the document you sent me, outlining the contractor evaluation of the proposed treatment changes by Washington Aqueduct for their two plants: substitution of sodium hypochlorite for gaseous chlorine, and the use of caustic soda either instead of or in conjunction with lime (depending on the treatment plant). The general concepts of replacement of gaseous chlorine and the use of caustic are well-established both in chemistry theory and in widespread utility practice in the US, though there are some specific details which require attention. There are several interacting water quality and treatment issues that I think also need to be integrated into this proposal before implementation.

The report is generally acceptable, though there are some areas where there are possibly incomplete documentation or misleading conclusions. These are noted in the summary table of comments below.

Though there may be some periods where the chloride to sulfate mass ratio does move into a range identified as of possible concern, I concur with the report that more research is needed. The imprecision of the guidelines and the current inability to precisely define the mechanism behind the suggested values makes it difficult to justify strict adherence to the guidelines at this time. An additional possible mechanism for the impacts of coagulant changes could also be the destabilization of protective aluminum-based scales that had accumulated in the piping, along with or instead of, the chloride effect. For both reasons, there should be continued monitoring vigilance in this distribution system, because there definitely has been accumulation of aluminum in the pipe scales. Although we have previously forwarded more complete data on the elemental composition observed in more than 20 lead pipe scale samples from the DC WASA system, I am including Figure 1 below as an example of a subset of this data that shows that there are large amounts of non-Pb material involved in the coating of the pipes, and that it must be considered to have some impact on improving lead release. Given other evidence in the presentation from WASA (cited in the table) on the formation of turbidity and particulate material containing Al, Ca, Fe and P after phosphate addition at 3 mg/L was initiated, continued monitoring should take into account the possibility that the loss or disruption of this scale could cause spikes in particulate lead release (associated with the non-Pb coating).

The place where I am most uncomfortable, and which was not indicated to be under consideration for change, is with the Water Quality Parameter operating range set for orthophosphate residual, both at the entry points to the distribution system, and in the system itself. The continued use of lime at the Dalecarlia plant, along with high possible aluminum residual through coagulation and entering the distribution system, creates a continuing issue with placing an upper limit of 5.0 mg/L as PO_4 on the feasible dosage of orthophosphate, and in determining the actual mechanism that is providing improved performance against lead release. That, in turn, jeopardizes the ability of this system to meet the OCCT/WQP requirement of the current (and likely, future) LCR. More importantly, further conflict with the OCCT requirement of the LCR is the allowance of only 0.5 mg/L as PO_4 as the minimum WQP floor for orthophosphate residual. This level is far too low, and appears to be without any justification in either actual published experimental or utility practice in successfully minimizing lead release from pipes. Figure 1 below shows the solubility of one of the lead orthophosphate solids found in lead pipe deposits from this system, at a DIC concentration towards the lower end of the seasonal range. At 0.5 mg/L, the lead solubility is 4 times higher than at 4-5 mg/L dosages, which definitely does not qualify as optimal, nor is it consistent with the intent of the LCR. Additionally, recent papers published by Hayes (Hayes *et. al.*, 2008) and Cardew (Cardew, 2009) on the experiences of phosphate dosing in the UK clearly show that their field experiences mirror the predictions of the solubility curves quite well, and that minimum effective dosages must be at least 2 mg/L or higher on this concentration scale to even approach the point of diminishing returns. The data from Cardew (2009) clearly showed that dosages equivalent to 0.5 mg/L as PO_4 as specified here resulted in Pb results triple their regulatory limit of 10 μg/L for even random daytime first liter samples, a less stringent requirement than a 6 hour stagnation time.

Table 1. Summary of specific comments for parts of the report.

1.1 P1.	Background	See text discussion on problems the OWQP operating range for orthophosphate.
2.2	Potential Issues	Here, there should be a mention of the possibility of DS turbidity and precipitation from particulates containing phosphate, aluminum and calcium. This phenomenon was presented at a conference (Tesfai, F., Constant, P., Reiber, S., Giani, R. and Donnelly, M. Precipitate Formation in the Distribution System Following Addition of Orthophosphate. Proc. AWWA Water Quality Technology Conference, Denver, CO, November 5-9, 2006. Whether this is more or less of a factor would depend on the PAlCl dosage chosen at different times.

4.1, p. 3	Description of Treatment and DS	At the bottom of the page, the whole last paragraph is poorly written, and must be revised. The report is not clear about the correct number of lead service lines replaced fully, as opposed to LSL's that were partially replaced. The percentage given as 80% needs to be explicitly related to either the number of whole lines replaced, or possibly the number of lines for which there was either a total or partial replacement. On the next page, the "unknown" percentage doesn't make sense, because if there are still 15,000+ LSLs, left, it doesn't clearly state if those are wholly Pb or partially Pb. If a line is partially replaced, both the remnant Pb and the new material must be known.
Figure 17		From early April to mid-May of 2008, the free chlorine is highly erratic, which wouldn't behave this way if a "chlorine burn" was *really* put into operation, like in 2007 or 2004. What is going on here?
Figure 18		All of these reported orthophosphate residuals are over 2 mg/L, so there is little loss of phosphate during transmission. Therefore, system-wide demand is probably satisfied, so there is no justification here to require lower orthophosphate levels than this out in the distribution system, given the target dosage is enough over 2 mg/L to provide allowance for some modest loss to the unlined iron piping and reaction with the aluminum, calcium, etc.
5.1.1, p. 17	Disinfection Efficiency...	Last paragraph, the switch to hypochlorite won't affect ORP as long as any changes in reaction stoichiometry with the ammonia are accounted for, and as long as the chlorine to ammonia ratio stays equivalent.
Appendix A		The WQP operating range for orthophosphate for both the entry into the distribution system and for DC WASA are in conflict with §141.82.f(3), where the residual concentration is substantially below that required to be "...necessary to form a passivating film on the interior walls of the pipes of the distribution system," as well as the definition of OCCT itself in §141.2.

In conclusion, with respect to the evaluation of treatment changes under consideration, I offer the following recommendations, consistent with both known lead chemistry, and the experiences of many other utilities in the US and abroad.

- Conversion to caustic from lime is advantageous, and should be extended to replace lime at the Dalecarlia plant as soon as possible.

- I concur with that the replacement of gaseous chlorine feed with sodium hypochlorite solution should proceed, in conjunction with setting tight specifications for procurement of batches of chemical with minimal unwanted contaminants, such as chlorite, chlorate, and perchlorate, and the setup of a testing and monitoring program for the bulk chemical at receipt and during storage.

- I concur that the added sodium from hypochlorite addition and replacement of lime with caustic soda does not constitute a corrosive level, and there are vast numbers of water systems with natural sodium levels higher than this.

- I recommend that it is necessary to raise the WQP minimum requirement for both the orthophosphate concentration entering the distribution system and for the residual in the distribution system from 0.5 to 2.0 mg PO_4/L, to be consistent with established corrosion control chemistry and the definition of OCCT pertaining to large systems under the LCR. The upper end of 5.0 mg PO_4/L may cause some deposition problems as previously encountered, without improvements in aluminum residual and reductions in calcium hardness.

- Optimization of polyaluminum chloride coagulation conditions to prevent accumulation of aluminum-containing scales in the distribution system, and their long-term replacement with lead(II) orthophosphate passivating films.

- Because substantial PbO_2 remains in the lead pipe scales, providing an extensive reservoir for elevated lead levels, monitoring must assure that sufficient orthophosphate continues to be present throughout the distribution system, to allow the ongoing active repair of any currently-protective pipe scales damaged or changed through either secondary chemical reactions (such as Al or other compound dissolution) or through hydraulic or physical disturbances.

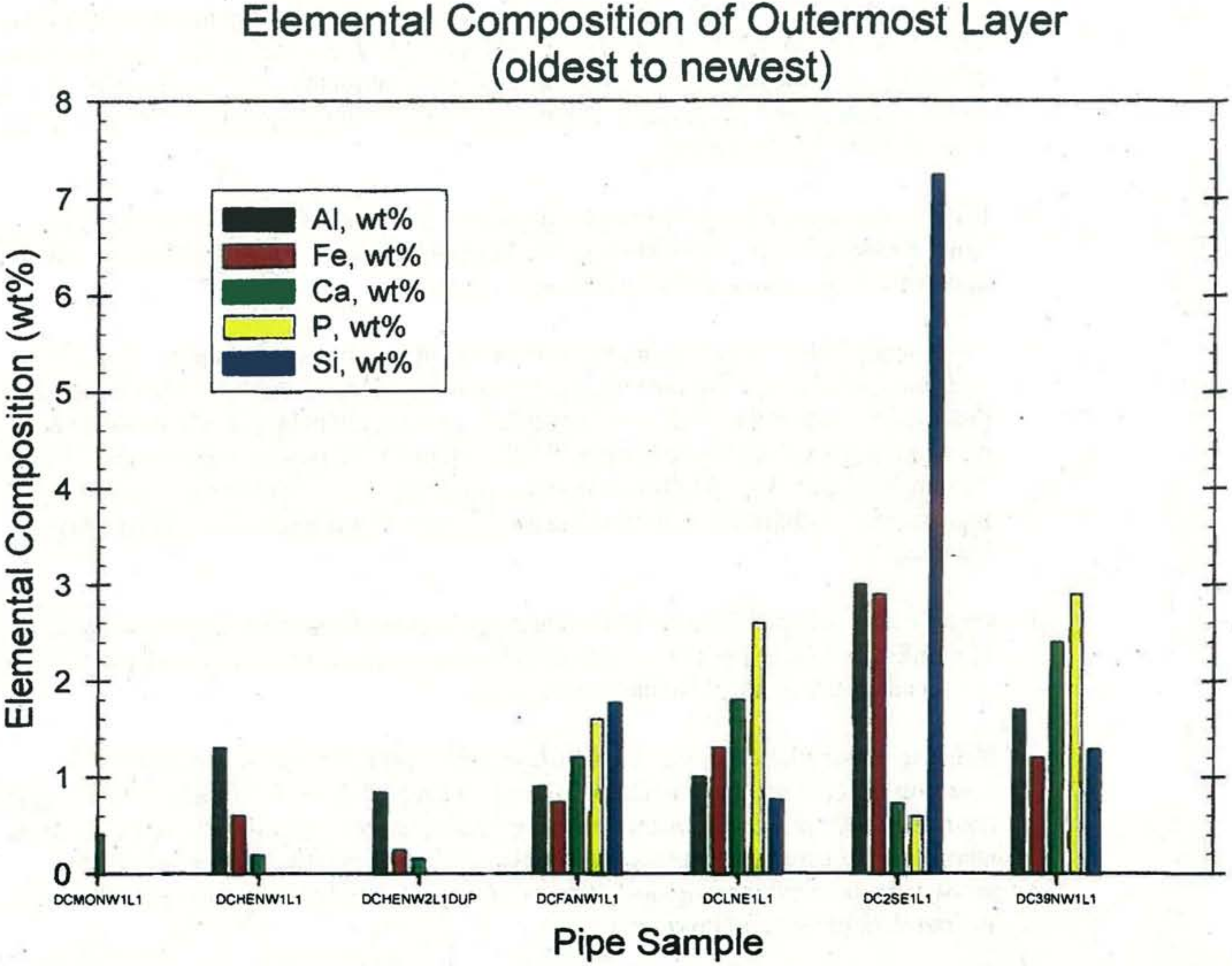

Figure 1. Subset of scale analysis results showing considerable (nearly a percent or more) aluminum on the pipe scales before and after phosphate treatment began.

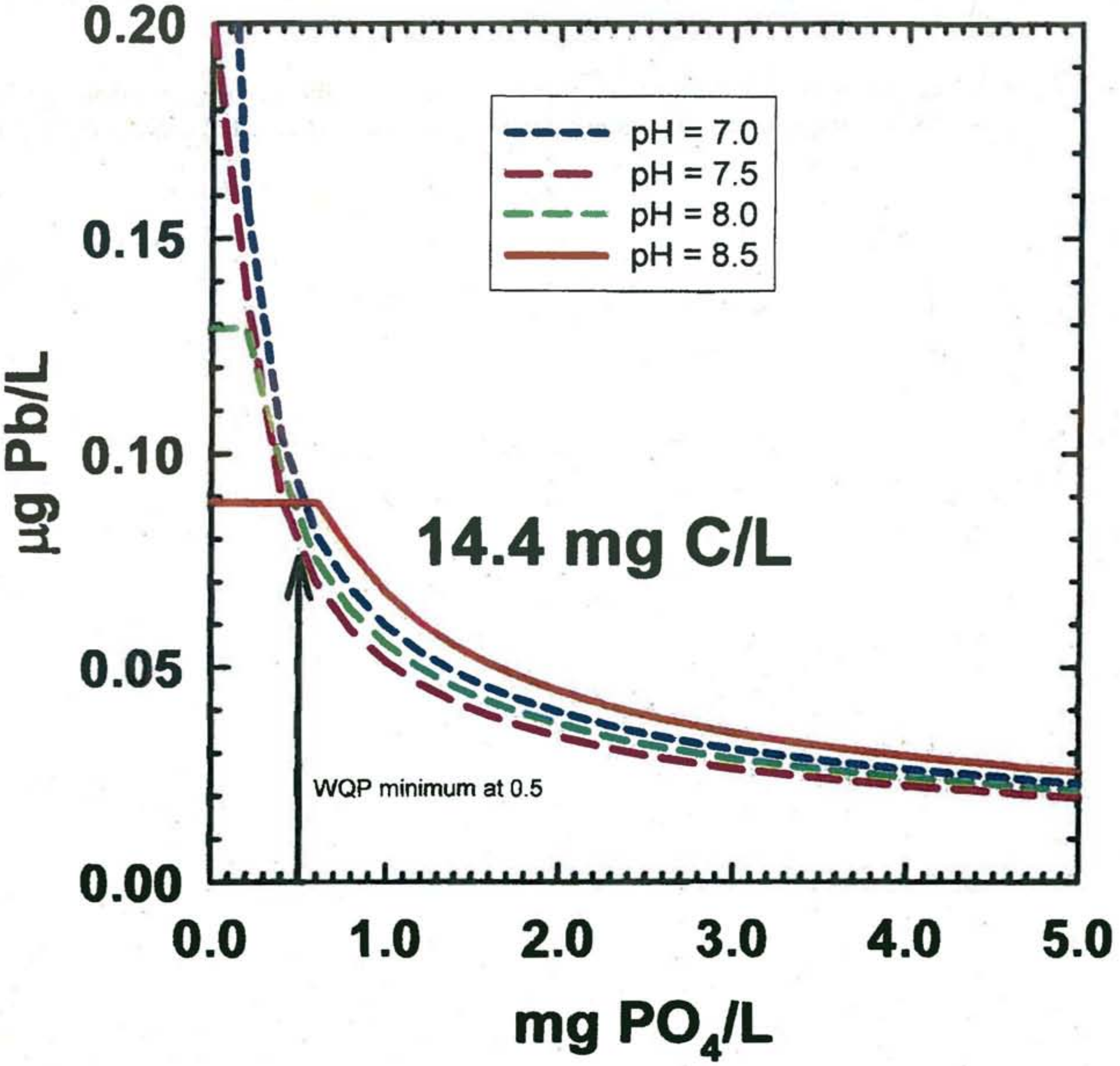

Figure 2. Approximate solubility diagram for Pb(II) orthophosphate for a DIC similar to the DC plants.

Citations

Cardew, P. T. Measuring the benefit of orthophosphate treatment on lead in drinking water, *Journal of Water and Health*, *7* (1), 2009:123–131

Hayes, C. R., Incledion, S. and Balch, M. Experience in Wales (UK) of the optimization of ortho-phosphat dosing for controlling lead in drinking water, *Journal of Water and Health*, *6* (2), 2008:177-185.

Attachment 12: EPA TSC review of disinfection profile and benchmark data

MEMORANDUM

TO: William Arguto, Jennie Saxe

FROM: Derek Losh

DATE: July 31, 2009

SUBJECT: Review of Washington Aqueduct Disinfection Profile and Benchmark Calculations

I have completed my review of the spreadsheet calculations of the disinfection profiles and benchmarks for the Washington Aqueduct (hereafter, Aqueduct). These calculations encompass both the current disinfection protocol and the proposed disinfection protocol, which consists of using liquid sodium hypochlorite in lieu of gaseous chlorine. The profile and benchmark analyses are based on monitoring data collected throughout 2008, and meet the requirements for data quantity of a minimum of twelve consecutive months. The calculations in the spreadsheets follow the procedure described in EPA's 1999 *Disinfection Profiling and Benchmarking Guidance Manual* (hereafter, Guidance Manual). Based on the 2008 data provided and the assumptions listed below, I concur that the Dalecarlia and McMillan plants will be capable of achieving the required 3-log and 4-log inactivation of *Giardia* and viruses, respectively, under the proposed disinfection protocol.

ASSUMPTIONS

I reviewed a total of four spreadsheets, consisting of a *Giardia* inactivation spreadsheet and a separate virus inactivation spreadsheet for each the Dalecarlia and McMillan water treatment plant. In reviewing each of these spreadsheets I have made the following assumptions:

- **Monitoring Data**—I have assumed that the data on water temperature, pH, chlorine residual, and flow are accurate and representative.
- **Disinfection Segments**—I have assumed that the disinfection segments (three for each plant) have been accurately established and that the clearwell detention times are accurate. In addition, I have assumed that the baffling factors used for each disinfection segment are representative.
- **Filters**—I have assumed that the filter parameters (surface area, filter depth, media depth, and porosity) are accurate. I have also assumed that the data describing filter operation (number of filters in service and distribution of flow across the filters) are accurate.

- **Change in pH**—As indicated in the spreadsheet, I have assumed that the switch to sodium hypochlorite will increase the pH of the water in the first two disinfection segments by 0.3 units, at most, but the pH in the final disinfection segment will remain at its current target of 7.7.

FINDINGS

The following is a list of specific items reviewed and a discussion of my findings:

- **Filters**—I reviewed the filter volume calculations and the formulas used to compute filter detention time. I verified that the formulas used to calculate the total volume of the filters in service and the filter detention times are accurate. However, I believe there is an error in the individual filter volume calculations, involving media porosity. Porosity (*e*) is generally defined as the ratio between the volume of voids in a fixed media bed and the total volume of the bed. Using this definition, the volume of the media, itself, would be the product of 1-*e* and the total volume of the media bed. However, the spreadsheet calculates media volume as the product of *e* and the total volume of the media bed. If this is the case, the spreadsheet over-estimates the individual filter volumes and, therefore, over-estimates the filter detention times.
- **CT Achieved**—I verified that the formulas used to compute *CT achieved* are accurate.
- **CT Required**—The Guidance Manual allows some flexibility in using equations to calculate *CT required* based on the CT tables provided in Appendix C. I reviewed the accuracy of the equations used in the Aqueduct spreadsheet for *CT required* by comparing them with the results of alternative equations for *CT required*. For inactivation of *Giardia* by free chlorine, I used the equations provided in Appendix E of the Guidance Manual. For inactivation of *Giardia* by chloramines, and for inactivation of viruses by free chlorine and by chloramines, I used equations derived by linear regression on the tabular values for *CT required* that are provided in the Guidance Manual. For inactivation of *Giardia* by free chlorine, the equation in the Aqueduct spreadsheets generally computes a lower *CT required* than the equations provided in the Guidance Manual (and lower than the CT tables provided in Appendix C). The difference is most pronounced at low temperatures (e.g., below 5°C) and high chlorine residuals (e.g., above 3 mg/l). The average difference in the second disinfection segment is about 15%. For *Giardia* inactivation by chloramines, the deviation is quite low between the results of Aqueduct spreadsheets and the regression equations that I used for comparison. The Aqueduct spreadsheets do not compute *CT required* for virus inactivation, but instead directly compute virus inactivation achieved using the value for *CT achieved*.

- **Log-Inactivation Achieved (*Giardia*)** — I verified that the formulas used to compute total log-inactivation and monthly average log-inactivation of *Giardia* are accurate. In addition, I estimated monthly average log-inactivation of *Giardia* using filter volume values and *CT required* values that were revised as discussed earlier. Though the inactivation values in the Aqueduct spreadsheet were generally higher than those that I estimated, the differences were not great.
- **Log-Inactivation Achieved (Viruses)** — I did not investigate the formula used in the Aqueduct spreadsheets to compute virus inactivation, but I did compare the results of the Aqueduct spreadsheet with those that I generated using the values I computed for *CT required*. Though the inactivation values in the Aqueduct spreadsheet were generally higher than those that I estimated, the differences were not great. This result suggests that the formula used by the Aqueduct spreadsheet to compute log-inactivation is reasonable.
- **Benchmarks** — I reviewed the benchmarks on the Aqueduct spreadsheets to determine whether they were correctly identified. I found one error in identifying the benchmarks but the consequences are negligible (i.e., per the Aqueduct spreadsheet calculations, the Dalecarlia benchmark for the proposed disinfection protocol — when the disinfection residual is limited to 3.0 mg/l — occurs in February and is 4.8 rather than 4.9 log-removal). I also estimated benchmarks for comparison (see the table at the end of this memorandum). For *Giardia* inactivation, my estimated benchmarks are 7 to 15 percent lower than those calculated by the Aqueduct spreadsheets, but they easily exceed the requirement of 3-log inactivation. For virus inactivation, my estimated benchmarks are nearly the same as those calculated by the Aqueduct spreadsheets, and all easily exceed the requirement of 4-log inactivation.

Please contact me if you have any questions about this memorandum or my review of the Washington Aqueduct disinfection profile and benchmarks.

DL

Dalecarlia and McMillan Benchmarks for Current and Proposed Disinfection Protocol

	Dalecarlia		**McMillan**	
	Aqueduct Spreadsheet	Review Estimate	Aqueduct Spreadsheet	Review Estimate
Log Inactivation of *Giardia lamblia*				
Current Disinfection Protocol (actual disinfectant residual)	6.7	5.9	7.0	6.0
Current Disinfection Protocol (disinfectant residual ≤ 3.0 mg/L)	5.7	5.3	5.9	5.3
Proposed Disinfection Protocol (actual disinfectant residual)	6.0	5.4	6.4	5.4
Proposed Disinfection Protocol (disinfectant residual ≤ 3.0 mg/L)	4.8	4.8	5.3	4.8
Log Inactivation of Viruses				
Current & Proposed (actual disinfectant residual)	187	180	240	233
Current & Proposed (disinfectant residual ≤ 3.0 mg/L)	156	150	195	193