DRAFT

TOWN OF AMHERST

Amherst County, Virginia

Water Quality Study and Hydraulic Modeling

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Project No. 100059-01-001

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I. EXECUTIVE SUMMARY

Disinfection Byproducts (DBP) sample results from the Stage 2 Rule have recently become of concern to the Town. The Town made application for and received a planning grant through the Virginia Department of Health (VDH) Drinking Water State Revolving Fund to perform a Study to resolve current and future water quality concerns. The Town commissioned Bowman Consulting Group to perform this study. This Study expands on the previous exceptional and substantial efforts and sample data performed by the Town and the VDH. Using this information, we further evaluated and identified ways in which modifications to the treatment processes and/or facilities, as well as distribution system operations, would minimize the production of disinfection byproducts. Simultaneous compliance with other drinking water regulations was considered. After substantial evaluation, which is documented in this report, the following actions are recommended:

1. Modify chlorine doses at current locations
2. Feed Powered Activated Carbon only during critical DBP formation periods (July through October)
3. Install mixing and exhaust fan equipment in the Waugh's Ferry and Union Hill storage tanks
4. Relocate the point of chlorine addition to the midpoint of the sedimentation basins
5. Install sludge removal equipment in the sedimentation basins

Also as a part of this study, the Town's existing hydraulic model was evaluated and updated. The analysis undertaken as part of the hydraulic modeling and including an overall understanding of the system's facilities and operation indicated that it would be highly unlikely that if the above recommendations are implemented, the Town would have any system limitations regarding flow, pressure, storage, current or future water quality standards, etc.

DBP data (TTHM and HAA5) has been collected at some sampling sites since 2007. The data includes sampling required during an initial Stage 1 of the DBP Rule and during Stage 2 (ongoing). The HAA5 concentrations are the most critical over time with the TTHM concentrations approaching or exceeding the limits occasionally. Typically, actions taken to resolve the HAA5 concerns will also address TTHMs.

II. INTRODUCTION

The Town of Amherst's water system consists of a raw water pump station, a 1.0 MG conventional water treatment plant, two 1.0 MG ground level storage tanks, a transfer pump station to the Sweetbriar College 0.5 MG storage tank, and a distribution system.

The source of raw water for the water plant is the Buffalo River. Raw water flows by gravity from the screened intake structure to the wet well of the raw water pumping station which houses two vertical turbine pumps that discharges to the water treatment plant.

The water treatment plant consists of one static mixer, two flocculation basins, two sedimentation basins, four rapid rate sand filters, and a clearwell. Three vertical turbine pumps deliver treated water to the distribution system.

Chemical addition at the water treatment plant consists of sodium hypochlorite, polyaluminum chloride, dry alum (backup coagulant), soda ash, lime, fluoride (fluorosilicic acid), and a corrosion inhibitor.

See Appendix A for the distribution system map. See Appendix B for the VDH Waterworks Description Sheet which further describes the treatment facility.

DBP sample results from the Stage 2 Rule have recently become of concern to the Town. See Appendix C for graphs depicting these concerns. The goal of this study is to proactively identify options on how to address bacteriological, disinfection byproduct contaminants and other identified issues so that the best quality of water can be delivered to the Town's users in the most cost efficient way.

Additionally, and as an integral part of this study, updating the Town's hydraulic water model, creating a new water quality model and producing a report on how the Town should address existing and anticipated water quality problems was performed. A detailed report and exhibits are located in Appendix K.

The Town made application for and received a planning grant through the VDH Drinking Water State Revolving Fund to perform a Study to resolve current and future water quality concerns. This Study took a holistic approach to the evaluation of the treatment, storage and distribution system for characteristics or operational procedures that might be contributing to the occurrence of elevated TTHM and HAA5 levels. Furthermore, this study evaluated the actions already taken by the Town to lower TTHM and HAA5 levels and to confirm that these actions were appropriate measures to be taken. See Appendix D for List of Actions Taken. The Study also evaluated factors that are known to contribute to elevated TTHM/HAA5 levels and addressed whether these are applicable for the Town.

The Study expanded on the previous exceptional and substantial efforts and sample data performed by the Town and the VDH. Please see Appendix G and H. As DBP issues are closely associated with system hydraulics, especially the Water Age component, as we updated the Town's hydraulic water model we included Water Age computations. We evaluated and identified ways in which modifications to treatment processes and/or facilities as well as distribution system operations would minimize the production of disinfection byproducts.

As the individual issues were evaluated, the impacts on Simultaneous Compliance (compliance with all Safe Drinking Water Act regulations) as well as water quality in general were considered. Please see Appendix L for a chart of Existing SDWA Regulations and a chart depicting how various alternatives can affect water quality. Please note that the best overall combination may include sub-optimal preferences for individual rule compliance.

The formation of DBPs can be a complicated process. A basic explanation is that DBPs are formed by the reaction between organic substances naturally occurring in water (precursors) and the chemical disinfectants that are added to water during treatment. The formation of DBPs is a function of many factors, including: precursor concentration, disinfectant dose, pH, temperature, contact time, etc.

The longer the contact time between disinfectant and precursors, the greater the amount of DBPs that can be formed. Generally, DBPs continue to form in drinking water as long as disinfectant residual and precursors are present. As a consequence, high concentrations of DBPs can accumulate in water that has been dormant or aged.

High DBP levels usually occur where the water age is the oldest. However, HAA5 are known to biodegrade over time when the disinfectant residual is low. The limited data for the Town indicates this may only occur during the warm summer periods as would be expected.

In studies of this nature with water quality data collected over a long period of time but with varying sample collection times under varying seasonal and water treatment conditions, it is more important to focus on data trends rather than individual sample results.

III. ISSUES EVALUATED AND DISCUSSION

The following issues were selected to evaluate based on discussions with Town staff, VDH, a review of available system information, EPA publications, and the firm's knowledge of pertinent DBP (TTHM/HAA5) factors. (Please see the Decision Tree in Appendix E). The issues evaluated included both operational issues and structural facility additions

A. Operations

1. Water Source Management – Source management refers to the various techniques that water systems can use to manipulate their water source or sources to comply with DBP's by utilizing source water with the lowest natural organic matter (NOM).

    a. Purchase ACSA Water – There is an existing interconnection between the Town and the Amherst County Service Authority (ACSA). The interconnection could be gravity fed by the ACSA's Faulconerville tank. A review of the DBP results for ACSA indicates very little benefit would be expected by utilizing this alternative source with the added cost for the Town of purchased water. **This alternative does not appear to be feasible at this time.**

b. Utilize ACSA Reservoir to Supplement Buffalo River – It is our understanding that an ACSA reservoir has been utilized to supplement the Buffalo River during periods of drought. No water quality data is available, but it is unlikely that a significant difference in DBP precursors would occur. **This alternative does not appear feasible at this time.**

c. General Management – The Town should continue its source water protection activities in order to reduce the introduction of contaminants, including sources of turbidity and DBP precursors into the source water. **Continued identification and assessment of potential contaminant threats reduces risk to public health and may reduce treatment issues. Continuing the activities under the 2012 MOU with the Robert E. Lee Soil and Water Conservation District seems prudent.**

2. Water Treatment (Precursor or DBP Removal)

   a. Treatment Evaluation. See Appendix F for report detailing 1-3 below

      1) Resume the addition of Alum – **not considered necessary**
      2) Change DelPAC (Polyaluminum Chloride) type or dose - **not considered necessary**
      3) pH/Alkalinity/Soda Ash – **no changes recommended**
      4) Enhanced Coagulation - One way to remove NOM is to practice enhanced coagulation. Enhanced coagulation has been shown to be an effective strategy for reduction of DBP precursors for many systems. Reduction of pH to between 5 and 6 and/or use of higher coagulant doses has been found effective in reducing TOC to required levels. Enhanced coagulation can include one or more of the following operational changes:

         - Increasing coagulant dose
         - Changing coagulant
         - Adjusting pH (using acid to lower the pH as low as 5.5)

- Improving mixing or applying moderate dosage of an oxidant
- Adding a polymer

As one part of the treatment process is modified, consideration should be given to the resulting impacts on subsequent processes and the distribution system.

Some advantages of enhanced coagulation include:

- May improve disinfection effectiveness
- Can reduce DBP formation
- Can reduce bromate formation
- Can enhance arsenic and radionuclide removal

Some disadvantages of enhanced coagulation include:

- Adverse impacts to filtration process
- Corrosion concerns
- Increased concentrations of inorganics in the finished water
- Reduction of pH between 5-6

The negative effect of reducing the pH on HAA5 formation would be expected to be extremely detrimental to DBP compliance. This option will not be considered further at this time.

b. Disinfection (Type) – The disinfectant type can be a significant factor in DBP formation. Where the use of free chlorine is considered to be a contributing factor to elevated DBP concentrations, systems might consider switching to other disinfectants for primary or secondary disinfection.

   There are a number of alternative disinfectants that could be used to reduce DBPs. These alternative disinfectants include:

- Chloramines - Chloramines are formed when free chlorine reacts with ammonia and may be present as monochloramine, dichloramine, and/or trichloramine. The chloramine compounds react more slowly than free chlorine and as a result, they form fewer DBPs and are more persistent in the distribution system. Some studies have shown that chloramine compounds can penetrate biofilms more effectively than free chlorine. Monochloramine is generally considered the preferred species for disinfection purposes because of its biocidal properties, relative stability, and infrequent taste and odor problems (Kirmeyer et al. 2004a). Because monochloramine is a weaker disinfectant than free chlorine, it is more frequently used as a residual disinfectant in the distribution system. If not properly controlled, the use of chloramines can lead to nitrification episodes in the distribution system and may cause taste and odor issues, loss of disinfectant residual, and other problems.

The use of chloramination to comply with the Stage 2 DBPR presents numerous benefits in terms of implementation and operation. Advantages include:

- Lower DBP formation
- More persistent than free chlorine residuals
- Biofilm control in the distribution system
- May reduce occurrence of *Legionella*

Potential disadvantages associated with the use of chloramines include:

- Nitrification
- Increased corrosion and metal release
- Taste and odor issues
- Weaker disinfectant
- Blending issues - chloraminated and chlorinated waters
- Safety concerns
- Issues with ozonation and GAC filtration

- Issues for dialysis patients, fish owners, and industrial customers

Due to the significant Water quality issues for chloramines such as the formation of other currently unregulated DBPs, nitrification, corrosion, taste and odor issues and the cost, handling, and safety issues related to chloramines, this option will not be considered any further at this time.

- Ozone - Ozone is a powerful chemical disinfectant and an alternative to free chlorine. It is an unstable gas that is generated on-site, using either air or liquid oxygen. It is very effective at disinfecting many microbes and as a pre-oxidant. It can, however, convert bromide to bromate, a DBP regulated by the Stage 1 D/DBPR. It also oxidizes organic matter into smaller molecules, which can provide a more easily degradable food source for microorganisms in the distribution system. Because of its instability in water, ozone cannot be used to provide a disinfectant residual in the distribution system. Furthermore, ozone can produce odor compounds such as aldehydes and ketones.

  The main advantages of ozone are:
  - Effective against pathogens
  - Does not form chlorinated DBPs
  - Effective pre-oxidant
  - Can oxidize taste and odor compounds
  - Can raise UV transmittance of water and UV disinfection effectiveness
  - Independent of pH
  - Can aid coagulation

  The main operational and simultaneous compliance issues associated with ozone are:
  - May form bromate
  - Forms smaller organic compounds

  - Does not provide a residual in the distribution system
  - May increase dissolved oxygen in the water
  - Can form taste and odor compounds
  - Can increase corrosion
  - Ozone bubbles can hinder filter performance
  - Switching to ozone with biological filtration may cause manganese release from filters
  - Requires additional training

  Due to the significant water quality, operational and cost issues, this option will not be considered any further at this time.

- Ultraviolet light (UV) - Recent research indicating that UV light can inactivate *Cryptosporidium* at relatively low lamp intensities has spurred interest in its use for drinking water disinfection. UV light works by damaging the genetic material of microorganisms, interfering with the ability of pathogens to replicate and therefore with their ability to be infective. Similar to chemical disinfectants, the extent of UV inactivation depends on the intensity of the light and the time the microorganism is exposed to it. UV is an effective way to disinfect without producing regulated DBPs. UV does not provide a residual, however, so it is not effective in providing a distribution system residual. Extensive information on the mechanisms of UV disinfection and recommendations on UV system design, validation, and operation are provided in the UV Disinfection Guidance Manual (USEPA 2006b).

  UV light's advantages include:

  - It can inactivate chlorine-resistant pathogens such as *Cryptosporidium* oocysts and *Giardia* cysts at relatively low doses;
  - It does not produce regulated DBPs; and
  - Its effectiveness is not pH or temperature dependent.

Potential operational and simultaneous compliance issues associated with UV disinfection include:

- Substances in water can interfere with UV disinfection
- Hydraulic upsets can lower the delivered dose and possibly cause lamp breakage
- Much higher doses are needed for virus inactivation
- UV disinfection provides no distribution system residual
- Power quality problems can disrupt disinfection
- Requires additional training

Due to the significant water quality, operational and cost issues, this option will not be considered any further at this time.

- Chlorine dioxide - Chlorine dioxide is an alternative chemical disinfectant that can be used to lower DBP production while maintaining adequate levels of inactivation. Because it is unstable, it is generated onsite using chlorine dioxide generators. Chlorine dioxide has gained popularity because it produces relatively few THMs and HAAs. It is also very effective against bacteria, viruses, and *Giardia* cysts, and can provide some inactivation of *Cryptosporidium* oocysts at higher temperatures. The main drawback of chlorine dioxide is that the chlorine dioxide MRDL of 0.8 mg/L combined with an MCL of 1.0 mg/L for chlorite, the main byproduct of chlorine dioxide, limit the dose that can be applied. In addition, low water temperatures can make it more difficult to use chlorine dioxide.

  Chlorine dioxide's advantages include:

  - Effectively inactivates bacteria, virus, and *Giardia* cysts; can achieve some *Cryptosporidium* oocyst inactivation;
  - Less TTHM and HAA5 formation than chlorine;
  - Effective oxidant for the control of iron, manganese, hydrogen sulfide, and phenolic compounds;

- May treat high-bromide, high-TOC waters better than chlorine or ozone; and
- Not significantly affected by pH values between 6 and 9.

Potential disadvantages with using chlorine dioxide include the following:

- Forms chlorite, a regulated DBP
- Reduced effectiveness at low temperature
- Chlorine dioxide MRDL of 0.8 mg/L
- Can form brominated DBPs
- Degrades when exposed to UV light
- Residual dissipates quickly
- Potential odor problems
- Requires additional training and safety concerns

Due to the significant water quality, operational, cost, and safety issues, this option will not be considered any further at this time.

- Sodium Hypochlorite – **It is recommended that this disinfectant continue to be the chemical of choice. It is further recommended that the doses to the raw and finished water be modified.** Steps should be taken to reduce the dose in the raw water and if necessary to increase the post filtration dose. Please see Appendix F for details.

For a summary of potential benefits and adverse effects associated with different combinations of primary and residual disinfectants and the simultaneous compliance issues with other regulations, please see Appendix M.

c. Powdered Activated Carbon (PAC) - PAC is commonly used to adsorb natural organic compounds, taste and odor compounds, and synthetic organic chemicals in drinking water treatment. Adsorption is both a physical and a chemical process of accumulating a substance at the interface between liquid and solids phases. Activated carbon is an effective adsorbent because it is a highly porous material and provides a large surface area to which contaminants may adsorb or attach. PAC is made from organic materials with high carbon content such as wood, coconut, lignite and coal. PAC is commonly used by water treatment plants on either a full time basis or on an as needed basis for taste and odor control or removal of organic chemicals. The Town currently has the necessary equipment to add PAC.

It appears prudent to ensure that the existing equipment remains operational and to add PAC only during critical DBP formation periods. If other recommended solutions results in compliance the periodic PAC addition may not be necessary in the future.

3. Water Age Management - Water age is a significant factor in DBP formation. As water travels through the distribution system, chlorine continues to react with NOM to form DBPs. The longer the travel time or water age, the more likely it is that water quality will degrade and exhibit higher TTHM and HAA5 concentrations, reduced levels of residual chlorine, reduced effectiveness of chlorine residual through formation of organochlorine compounds, increased microbial activity, nitrification, and/or taste and odor problems. The following measures are often taken to minimize water age in a distribution system.

    a. Pipe Looping - The highest DBP concentrations in a distribution system are most often observed at dead-ends (although this may not be true for HAAs because of biodegradation). Water at dead-ends is often stagnant and therefore provides long contact times for DBP formation. Excessive hydraulic residence time at dead ends can be reduced with pipe looping, which involves constructing new pipe sections to make appropriate hydraulic connections among existing pipes. Pipe looping may not always eliminate water age problems. **The Town's distribution system is reasonably well looped with little**

expected benefit to DBP removal from additional looping and the associated cost.

b. Managing Valves - Intentional or unintentional closed valves in a distribution system may create stagnant water leading to high DBP levels in those locations. A comprehensive valve inventory and maintenance program can help systems locate valves, determine their status, and find improperly positioned and broken valves. **The Town has an excellent system for managing and exercising valves at their treatment facility and on their distribution system.**

c. Bypassing oversized pipes - In portions of a distribution system where pipes are oversized, the water velocity is lower and therefore hydraulic residence times are longer than necessary, causing high DBP levels. Areas of a distribution system that have been abandoned or have experienced negative demand growth over many years may contain oversized pipes, causing excessive hydraulic residence time. Where appropriate, the pipe sizes in these areas can be reduced or sections of pipes can be valved off if they are no longer needed to reduce the residence time of water. However, the effect of bypassing or valving oversized pipes on downstream areas should be evaluated to make sure that such modifications will not cause hydraulic constrictions for the downstream areas. **There are no areas within the Town that have been abandoned or that have experienced enough negative demand growth for this to be practical.**

d. Installing dedicated transmission main - When water travels through low demand areas and finished water storage facilities in a distribution system before reaching a consecutive system, the water at the entry point to the consecutive system may have high DBP levels due to high water age. In such cases, the installation of a dedicated transmission main to supply water to the consecutive system may be considered to reduce water age but its effects on water age in the wholesale system should be estimated. **Installing a dedicated transmission line to critical areas like Sweet Briar College is not practical.**

e. Improving tank mixing/aeration and turnover - Excessive hydraulic residence time in distribution storage tanks results in high water age, which can cause high DBP levels in tanks and at downstream locations in the distribution system.

Typically, the average hydraulic residence time for a storage tank should not exceed 5 days (Kirmeyer et al., 1999). However, some systems may need much lower hydraulic residence times due to site-specific water quality constraints.

Improving storage tank mixing characteristics can reduce average water age and minimize stagnant zones in the tank. The stagnant zones often have higher water age and thus tend to have higher DBP concentrations.

Poor mixing conditions can cause thermal stratification in a tank. Thermal stratification in turn can exacerbate the poor mixing condition. Depending on the location and orientation of the inlet pipe and tank geometry, the water entering a tank from buried pipes may be cooler than the bulk water in the tank during the summer or warmer than the bulk water in the tank during the winter. In a tank with poor mixing characteristics, colder, denser water remains in the lower portion of the tank, whereas the warmer, less dense water has a tendency to rise to the top of the tank. Water temperature profiles can be used to determine the existence of thermal stratification inside a tank. The temperature profiles can be obtained from the collection of continuous water temperature measurements at various locations in the tank over the course of several days. Temperature differences as low as 1°C between the top and bottom of a tank may indicate a thermally stratified tank with poor mixing.

Also, disinfectant residual measurements, collected either as grab samples or from continuous online monitoring at various elevations in the tank, can be used to evaluate mixing and identify water quality stratification. Acceptable differences in disinfectant residuals within a tank is location-specific and depends on the system water quality. However, the minimum residual should be sufficient to minimize microbial growth and water quality degradation.

Tank stratification was investigated by performing chlorine residual and temperature profiling in both Town tanks by Utility Services Company on

December 16, 2016. The profiling indicated stratification in both tanks. Please see Appendix I for a detailed report.

It is recommended that mixing equipment and exhaust fans be installed at both tanks

f. Eliminating excess storage and tanks in series - Historically, distribution system storage tanks have generally been built to provide adequate pressures, fire flows, and to meet peak demands. Tanks are also often designed to accommodate future growth and long-term water system needs. Therefore, some distribution system storage tanks may be oversized. Regardless of the sizes of the Town's storage tanks, adequate mixing would eliminate this concern.

   Tanks in series can also lead to high DBP levels in areas downstream of the tanks if there is inadequate mixing and volume turnover in the tanks. There are no tanks in series owned by the Town. However, the tank owned by Sweet Briar College could be considered in series with the Town's Waugh's Ferry Tank. The Town is taking action to ensure that the water being delivered to Sweet Briar College meets current Water Quality standards.

   No further action is recommended this time.

4. Flushing - Flushing can be an effective tool to control TTHM and HAA5 peaks by removing pipe sediments and biofilms, thereby reducing disinfectant demand as well as avoiding low disinfectant residuals, high heterotrophic plate counts (HPCs), coliform-positive samples, or nuisance bacteria that are often associated with high water age locations.

   a. Revise Current Program – The Town is currently routinely flushing to address the chlorine dissipation and THM formation problem. Locations are at the end of the 6" pipe that terminates on U.S. Rt. 60 just east of the railroad tracks (former Rutledge Inn site), E. Monitor Road at the end of the 12” main (parallels Rt. 60 West) and the very end of the main on Kenmore Road (far west).

It appears that no significant changes need to be made to the Town’s flushing program at this time.

b. Directional Flushing - Directional flushing involves the flushing of water in one direction through systematic operation of distribution system valves.

   A properly designed and implemented directional flushing program can achieve water velocities higher than 5 feet/second to scour the pipe. In addition to increasing water flow in the selected main, directional flushing can reduce the impact of other factors contributing to the formation of high DBP concentrations including the accumulation of sediments and the build-up of corrosion byproducts. (Joseph and Pimblett, 2000)

   While directional flushing is generally considered the most effective flushing technique, there are issues regarding personnel requirements and volume of water used. **It doesn’t appear necessary for the Town to adopt this flushing method at this time.**

c. Blowoffs - “Blow-offs” can be used to eliminate dead-ends and stagnant water zones that have high water age and therefore contribute to high DBP levels. Blow-offs can operate in an automatic intermittent mode or continuous mode to remove old water from dead-end or stagnant zones and pull fresher water into these locations from other areas. Typically, velocities are much lower (< 2.5 feet/second) as seen with conventional flushing or directional flushing. Blow-offs can be used on a seasonal basis when DBP peaks are more likely to occur, such as during high water temperature periods. The Town has and operates “blow offs” throughout the system. **The Town may want to consider automatic intermittent flushing valves in specific locations.**

5. Rechlorination – Rechlorination is often utilized on large distribution systems that have difficulty maintain a residual at extreme ends of the system. Currently the Town is able to maintain adequate residuals with minimal infrequent flushing. Additionally, rechlorination is often utilized with a planned reduction in chlorine residual in the treatment plant's finished water to assist in the reduction of DBPs. **This option will not be pursued further as it is felt that the Town is maintaining optimal residuals and rechlorination would require additional chlorine feed equipment, housing, operator time, etc.**

6. Miscellaneous
   a. Throttling flows to Union Hill Tank – The Town is currently throttling flow to the Union Hill Tank on Mondays to promote turnover in the Waugh's Ferry Tank. **This practice should be continued but may not be in needed in the future.**
   b. Water Plant Hours of Operation – Current hours of operation for the plant are approximately 14 hours for Monday, Tuesday, Thursday and Friday and 10 hours on Wednesday (66 hours per week). The plant does not typically operate on Saturday or Sunday. Consistent daily hours of operation is a generally recognized practice to reduce Water Age and DBP production in distribution systems and in maintaining adequate chlorine residuals throughout the system. In addition, if instituted, the practice of throttling flow to the Union Hill Tanks could be suspended. However, a major issue with daily operation is the impact on operations staff. To operate seven days a week would require current operators to man the plant approximately 9.5 hours per day. Another operation option is to operate on a day on/day off mode. This would require adjusting operating hours to match system demands as well as require weekend operation. Additionally, the intangible negative impacts to staff schedules and job satisfaction of these schedule changes should not be overlooked especially in a time of limited qualified operation staff availability. **Consideration should be given to operating on a more consistent basis or day on day off during critical DBP formation potential time periods <u>if</u> the DBP compliance issues are not resolved by the other recommendations.**

c. Relocating Point of Chlorination – Moving the point of chlorination downstream in the treatment process can:

- Reduce DBP concentrations in the finished water
- Reduce amount of disinfectant used

However, moving the point of chlorination downstream in the treatment process can:

- Raise issues with meeting CT requirements
- Affect pH of water being treated, possibly requiring adjustment of water treatment chemistry

It appears that moving the point of chlorination to the midpoint of the sedimentation basin in conjunction with sludge removal (see B.1.a.1) below) is a prudent step to take in resolving DBP issues. The VDH has indicated that there is adequate CT available with this option. However, improved chlorine piping, etc. to ensure adequate mixing of the chlorine downstream of the injection point must be provided. It has been determined in conjunction with VDH that the following may be required: multiple injection pipes, injection nozzles and flow baffles.

d. Revise Stage 2 DBD Sample Site

By request, during this study, VDH has revised the sample site plan by moving the Sweet Briar College sample site to a similar site on the Town's distribution system.

e. DBP Sample Collection Schedule – the sampling dates were reviewed and samples are generally collected on Tuesdays through Fridays. These are the preferable collection days. **No change in sample collection is recommended.**

B. Structural Facility Addition

1. Water Treatment

a. Precursor or DBP Removal

1) Sedimentation Basin Sludge Removal (Precursor Removal) – Please see Appendix F and N for discussion and recommendations.

2) Unit Addition (Precursor or DBP Removal)

- GAC - The main benefit of granular activated carbon (GAC) is that it is effective in adsorbing and removing organic compounds from water. Removing organic matter lowers DBPs, taste and odor complaints, and microbial activity in the distribution system. The main drawbacks to using GAC are the possibility of release of bacteria or carbon fines into the system and its reaction with disinfectants. GAC can be used as an additional layer on top of an existing filter (GAC cap), or it can be placed in a separate contactor. Design will vary depending on whether it is used as a separate adsorber or if it is added as a filter cap. Its efficiency is determined by the contact time and the relative absorption strength of the compounds that are to be removed.

  It is not recommend to pursue this option at this time as the other recommendations are expected to resolve the DBP compliance issue.
- Microfiltration/Ultra filtration - Microfiltration/Ultrafiltration (MF/UF) is a low pressure membrane technology. The membranes remove particulate matter larger than the membrane pore size. MF membranes generally operate at slightly lower pressure and have larger pore sizes than UF membranes. In some cases, MF/UF membranes will be used together, with the MF membranes acting as a pre-filter for the UF membranes. MF/UF units are often supplied on skid mounted assemblies that can easily be installed and have high degrees of automation.

  Advantages of MF/UF include:
  - Removes bacteria and protozoa
  - Can lower DBPs by allowing lower disinfectant doses
  - Can remove particulate arsenic

  Potential issues associated with MF/UF use include:
  - Can be fouled by organics and minerals

- Increased loss of process water
- Additional training required

It is not recommend to pursue this option at this time as the other recommendations are expected to resolve the DBP compliance issue.

- Nanofiltration - Nanofiltration is a membrane process that physically removes contaminants from water that are larger than the pore size of the membranes. Nanofiltration uses pore sizes and operating pressures that fall between those of UF and reverse osmosis. Nanofiltration's main advantage over MF/UF is that it can remove virtually all particulate matter as well as larger dissolved compounds, including dissolved organic matter. In addition to meeting all removal requirements for pathogens, it leads to lower DBPs by removing DBP precursors. Its main disadvantages are that it can be fouled by organics or precipitated minerals, it can increase corrosiveness of the water, it has a large reject stream, and it requires additional training.

  Some advantages of nanofiltration include:
  - Significant removal of bacteria, protozoa, and viruses
  - Can remove organics that act as DBP precursors
  - Removes arsenic

  Potential issues associated with nanofiltration include:
  - Can be fouled by organics and precipitated minerals
  - Can increase corrosiveness of water
  - Issues with reject stream
  - Additional training required

  It is not recommend to pursue this option at this time as the other recommendations are expected to resolve the DBP compliance issue.

b. Miscellaneous

New Chlorine Contact Tank – There does not appear to be a need for this capital expense since the option of moving the point of chlorination (with improvements to chlorine dispersal) will maintain the required CT. If a GAC contactor became a necessity, then a new chlorine contact tank would be necessary.

It is not recommend to pursue this option at this time as the other recommendations are expected to resolve the DBP compliance issue.

2. Distribution System
   a. Pipe looping - See A.3.a above.
   b. Tank Mixers/Aeration - See A.3.e above.
   c. Installing Dedicated Transmission Main – See A.3.d above

IV. CONCLUSIONS/RECOMMENDATIONS

- Modify chlorine doses at current locations
- Feed Powered Activated Carbon only during critical DBP formation periods (July-October).
- Install mixing and exhaust fan equipment in the Waugh’s Ferry and Union Hill storage tanks. Please see Appendix N for details and an estimated installed cost.
- Relocate the point of chlorine addition to the midpoint of the sedimentation basins. Please see Appendix N for details and an estimated installed cost.
- Install sludge removal equipment in the sedimentation basins. Please see Appendix N for details and an estimated installed cost.

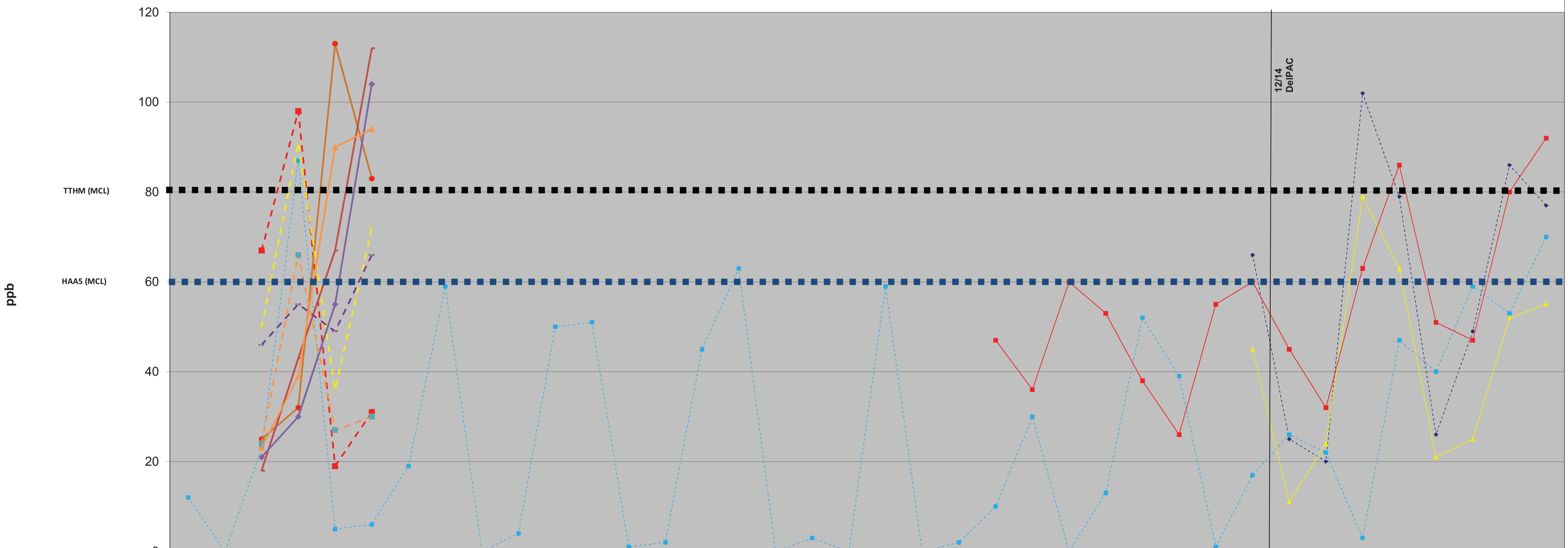
It is further recommended (since no capital cost necessary) that consideration be given, moving forward, to modifying chlorine doses and adding PAC for a period before the next required DBP sample date(s) as a pilot test of sorts to determine the effectiveness. This could be accomplished while the DWSRF application for funding is in process.

Appendix A: Distribution System Schematic

Appendix B: VDH Engineering Description Sheet

Appendix C: DBP and TOC Graphs

Amherst - TTHM and HAA5

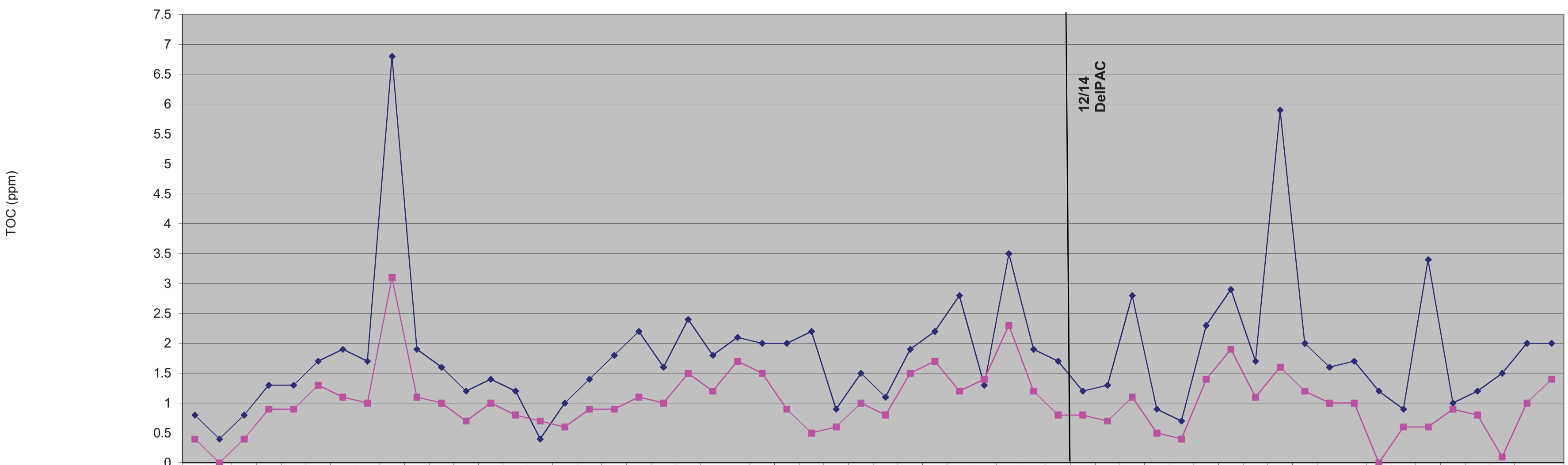


	3-07	4-07	1-08	2-08	3-08	4-08	1-09	2-09	3-09	4-09	1-10	2-10	3-10	4-10	1-11	2-11	3-11	4-11	1-12
Fairmont Crossing HAA5																			
SBC Riding Center/Physical Plant HAA5	12	0	23	87	5	6	19	59	0	4	50	51	1	2	45	63	0	3	0
Fairmont Crossing TTHM																			
SBC Riding Center/Physical Plant TTHM																			
SBC IDSE HAA5			67	98	19	31													
SBC IDSE TTHM			25	32	113	83													
Fairmont Crossing IDSE HAA5			50	91	36	72													
Fairmont Crossing IDSE TTHM			18	43	67	112													
Quik-E IDSE HAA5			46	55	49	66													
Quik-E IDSE TTHM			21	30	55	104													
Wilkins IDSE HAA5			24	66	27	30													
Wilkins IDSE TTHM			23	39	90	94													

	2-12	3-12	4-12	1-13	2-13	3-13	4-13	1-14	2-14	3-14	4-14	1-15	2-15	3-15	4-15	1-16	2-16	3-16	4-16
Fairmont Crossing HAA5											66	25	20	102	79	26	49	86	77
SBC Riding Center/Physical Plant HAA5	59	0	2	10	30	0	13	52	39	1	17	26	22	3	47	40	59	53	70
Fairmont Crossing TTHM											45	11	24	79	63	21	25	52	55
SBC Riding Center/Physical Plant TTHM				47	36	60	53	38	26	55	60	45	32	63	86	51	47	80	92
SBC IDSE HAA5																			
SBC IDSE TTHM																			
Fairmont Crossing IDSE HAA5																			
Fairmont Crossing IDSE TTHM																			
Quik-E IDSE HAA5																			
Quik-E IDSE TTHM																			
Wilkins IDSE HAA5																			
Wilkins IDSE TTHM																			

Quarter/Year

Amherst - Total Total Organic Carbon (TOC)
Raw Water vs. Finshed Water



	1/12	2/12	3/12	4/12	5/12	6/12	7/12	8/12	9/12	10/12	11/12	12/12	1/13	2/13	3/13	4/13	5/13	6/13	7/13	8/13	9/13	10/13	11/13	12/13	1/14	2/14	3/14	4/14
Raw Water	0.8	0.4	0.8	1.3	1.3	1.7	1.9	1.7	6.8	1.9	1.6	1.2	1.4	1.2	0.4	1	1.4	1.8	2.2	1.6	2.4	1.8	2.1	2	2	2.2	0.9	1.5
Finished Water	0.4	0	0.4	0.9	0.9	1.3	1.1	1	3.1	1.1	1	0.7	1	0.8	0.7	0.6	0.9	0.9	1.1	1	1.5	1.2	1.7	1.5	0.9	0.5	0.6	1

	5/14	6/14	7/14	8/14	9/14	10/14	11/10	12/14	1/15	2/15	3/15	4/15	5/15	6/15	7/15	8/15	8/15	9/15	10/15	11/15	12/15	1/16	2/16	3/16	4/16	5/16	6/16	7/16
Raw Water	1.1	1.9	2.2	2.8	1.3	3.5	1.9	1.7	1.2	1.3	2.8	0.9	0.7	2.3	2.9	1.7	5.9	2	1.6	1.7	1.2	0.9	3.4	1	1.2	1.5	2	2
Finished Water	0.8	1.5	1.7	1.2	1.4	2.3	1.2	0.8	0.8	0.7	1.1	0.5	0.4	1.4	1.9	1.1	1.6	1.2	1	1	0	0.6	0.6	0.9	0.8	0.1	1	1.4

Quarter/Year

Appendix D: List of Actions Taken

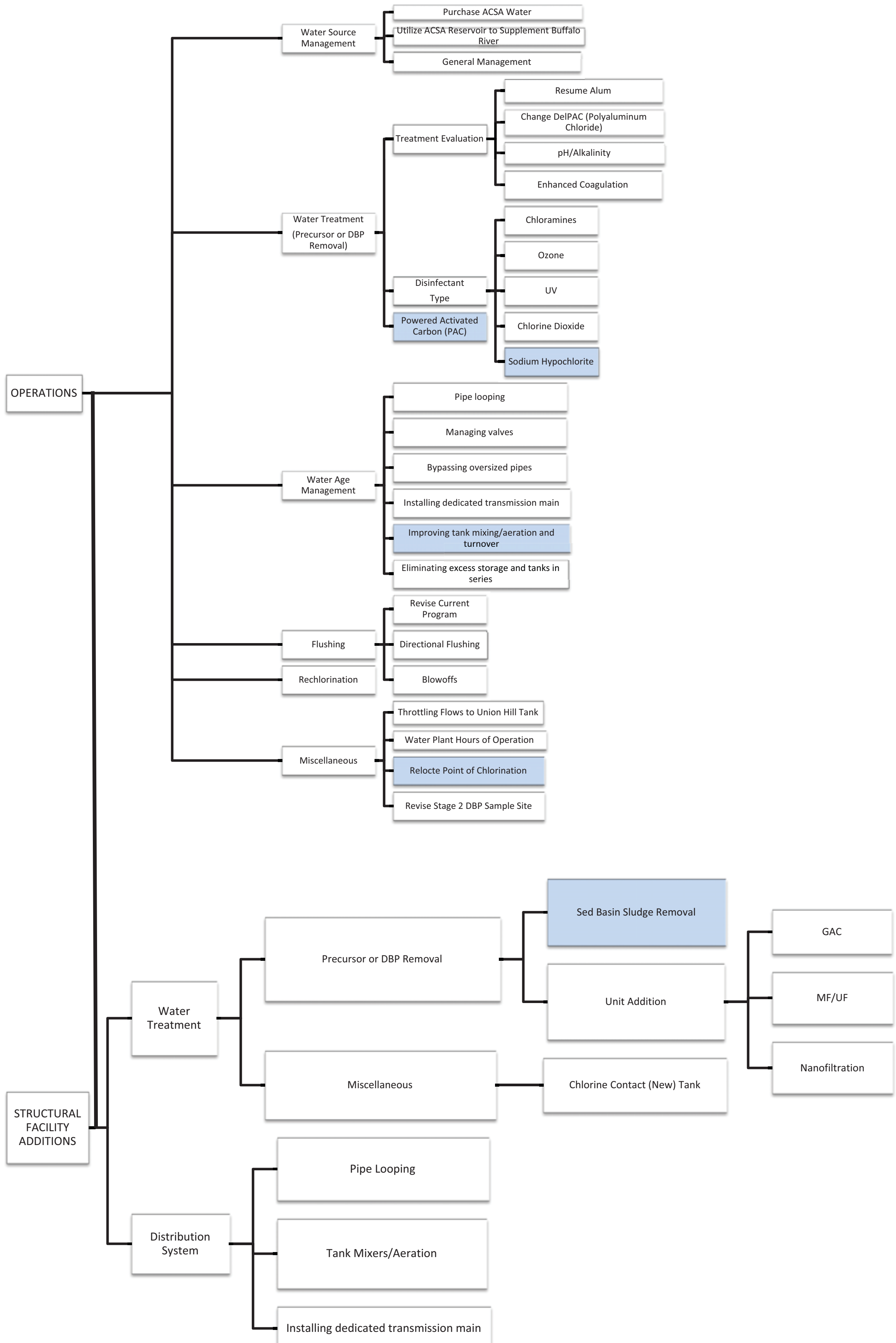
List of Actions Taken

The Town has greatly improved its water system's infrastructure over the past two decades. Featured accomplishments include:

- A watershed protection program that has maintained and improved the Town's water source,
- Refurbishing and expansion of the Town's water treatment plant which has doubled the rated production capacity and associated pumping rate,
- Interconnection with a neighboring water system for redundancy,
- Adding a 1.0 MG water tank and refurbishing the one old 1.0 MG water tank,
- Taking on Sweet Briar College as a wholesale water customer when that organization decided to suspend its water production operations,
- Installation of many miles of 8, 10 and 12" water mains to replace old pipes, some of which were smaller than 2",
- Identification and removal of many system leaks,
- An end of pipe flushing program, and
- Collected numerous water quality samples during a chlorine/fluoride decay study.

Appendix E: Decision Tree

Decision Tree
DPBs



Appendix F: Plant Operation Impact on DBPs

Amherst WTP

Treatment Conditions

The surface water enters the treatment plant through a rapid mix chamber where the first chemical additions take place. Hypochlorite is injected to achieve disinfectant Contact Time (CT), soda ash to add alkalinity, an aluminum based coagulant to aid in the removal of organic material, and fluoride as desired by the Town. The WTP has the capability to add both a dry form and a liquid form of aluminum based coagulant. The WTP also has the capability to add a dry form of Powdered Activated Carbon (PAC) adsorbent to aid in the removal of organic material. However, as of the date of this study, it is not being used

Between the sedimentation basins and the sand filters, the WTP has the capability to inject disinfectant to ensure an adequate concentration continues through to the clearwell.

Finished water is dosed with hypochlorite to maintain an effective level within the distribution system, polyphosphate to achieve protection for, and from, the distribution system pipelines and tanks, and hydrated lime to maintain an optimum pH for the polyphosphate.

Data graphed in Appendix C, shows that from Jan 2008 through the transition to DelPAC 2020 in Nov 2014 the DBP (HAA5) concentrations peak in only one quarter of each year – the winter quarter. Following the DelPAC 2020 change, DBP (HAA5 and TTHM) levels peaked in the warmer quarters (which is typical of DBP formation).

Plant personnel report the coagulant switch was motivated by a desire to optimize WTP operations. WTP personnel report that the resulting DelPAC 2020 floc settles immediately upon reaching the sedimentation basin with a subsequent noticeable reduction in floc at the top of the sand filters. This reportedly happens regardless of the temperature or season. Evidence of rapid settling was observed at the beginning of the sedimentations basins during the site visit conducted on 22 Nov 2016.

The new DelPAC 2020 coagulant is a proprietary liquid chemical mixture of poly aluminum chloro hydroxy sulfate with 10% aluminum oxide and sodium carbonate to increase basicity.

$$Al_2(OH)_xCl_y(SO_4)_{6-(x+y)/2} + Al_2O_3 + Na_2CO_3$$

A literature review of this coagulant shows a reduced need for pH adjustment to 7.0 or higher and a reduced need for additional alkalinity. As discussed below in the Alkalinity section, soda ash addition was discontinued when the DelPAC was first introduced but later reinstituted at a reduced dose.

Analysis of Historical Data

Historical data from January 2013 through October 2016 was made available for analysis. This period provided two years of data on either side of the coagulant change that occurred in Nov 2014.

- **Finished Water Production**

The quantity of Finished Water available for distribution is shown in Figure 1.

The monthly production trend has held steady over the last 4 years. The maximum monthly production has remained at approximately 10.5 MG/month. Predictable seasonal fluctuations were observed with production peaks occurring in the warmer months. An unexpected peak in production occurred during April 2013 and January 2015.

- **Disinfectant Dose**

The hypochlorite disinfectant dosed into the raw water and the finished water is shown in Figures 2 and 3.

Overall trends observed in both raw water and the finished water include predictable seasonal fluctuations showing higher dose rates occurred in the warmer months in both streams.

Another overall trend was the higher dose rate injected into the raw water than the finished water. ***This is of significant interest due to the greater TOC available for DBP formation at this location.***

Raw water dose rates saw a 4-year peak during the warmer months of both 2015 and 2016. ***This trend is especially significant when coupled with the DBP results that show regulatory levels were exceeded during the same time period.***

Finished water dose rates saw a 4-year peak during the warmer months of 2016. **This trend is especially significant when coupled with the DBP results that show regulatory levels were exceeded during the same time period.**

- **Residual Disinfectant**

The hypochlorite disinfectant residual measured at the top of the filters and in the finished water is shown in Figures 2 and 4.

The residual in the water applied at the top of the filters held steady, within the range of 1.6 to 1.7 mg/L, until July 2015. Figures 2 and 4 show the corresponding raw water dose fluctuated from 2.24 to 3.47 mg/L to maintain this narrow residual range. A new residual range of 1.9 to 2.0 mg/L was achieved and maintained beginning in Aug 2015. Figures 2 and 4 show the raw water dose fluctuated around new highs above 3.5 mg/L to maintain this higher residual range.

The finished water residual held a steady range of 1.4 to 1.6 mg/L until July 2014. Figures 2 and 4 show the finished water dose rate fluctuated from 0.96 to 2.77 mg/L to maintain this narrow residual range. A decrease in both finished water dose and the corresponding residual began in Sep 2014 that resulted in a 4-year residual low of 1.1 mg/L. The residual concentration gradually increased to 1.4 by Jan 2015 but gradually dropped again to 1.1 mg/L by Jun 2015. Figure 2 shows a corresponding drop in the finished water dose rate to a 4-year low of 0.45 mg/L. A rapid increase to the finished water dose rate occurred in Jul 2015 that resulted in a new residual level of 1.7 mg/L by Aug 2015. A residual range of 1.6 to 2.0 mg/L has been maintained in the finished water through Oct 2016.

- **Coagulant**

The coagulant dose rate and total pounds used is shown in Figures 5 through 7.

The DelPAC application rate was initially delivered at the same rate as the previous alum coagulant but was drastically increased in Mar 2015. The DelPAC 2020 dose rate during that month exceeded the previous alum peak by approximately 24%. The DelPAC dose rate continued to trend upward and reached as high as 44% above the previous alum peak during multiple months in 2016. ***This does not align with a literature review citing a reduction in dose rate to be the norm.***

- **Alkalinity and Soda Ash**

The soda ash dose rate and the alkalinity in both the raw water and the water applied to the top of the filters is shown in Figures 8 and 9.

Raw water alkalinity dropped from 40 mg/L in 2013 to 30 mg/L in 2014 to 20 mg/L in 2015 and 2016. The reason for this steady drop is unknown.

The data appears to show that the soda ash dose was adjusted to maintain the alkalinity of the raw water until Nov 2014 when the new coagulant was introduced. Dosing was then discontinued and the alkalinity at the top of the filter was allowed to drop below the alkalinity of the raw water. In Dec 2014, soda ash was re-introduced until the alkalinity at the top of the filter once again matched the alkalinity of the raw water. The dose required to achieve this for the DelPAC 2020 is significantly lower than the soda ash dose required for the alum coagulant. As the above is important for treatment optimization, but has minimal if any impact on DBPs, no recommendations are offered.

- **pH**

The pH of the raw water, the water applied to the top of the filters, and the finished water is shown in Figures 10 and 11.

The pH of the raw water held a steady monthly average of 7.1 within a range of 6.8 to 7.3 over the entire 4-year span. The only apparent trend is a slight peak occurring in the fall of each year.

The pH of the water applied at the top of the filters is affected by the chemical addition of disinfectant, coagulant, soda ash, and the settling out of coagulated organic material. The pH of the applied water held a steady monthly average between 6.6 and 6.7 until Aug 2014. Sep 2014 saw the beginning of an upward trend when soda ash injection was discontinued and the DelPAC 2020 coagulant was introduced. The upward trend stopped at a pH of 6.9 and held steady through Jul 2015. Another rise occurred in Aug 2015 and has held at a steady 7.0 to 7.1 to date.

The finished water pH is affected by the chemical addition of disinfectant, orthophosphate and hydrated lime. A steady monthly average between 6.7 and 6.9 was held through Apr 2014. A slight rise to a new monthly average of 7.0 was held through Aug 2015. A significant increase to a new monthly average between 7.6 and 7.7 has been held to date. It is important to note that the orthophosphate dosed into the Amherst distribution system is effective in a pH range of 7.2 to 7.8. As the above is important for treatment optimization, but has minimal if any impact on DBPs, no recommendations are offered.

RECOMMENDATIONS

1. Disinfectant Dose: Decrease the dose injected into both the rapid mix and the topic of the fitters.

For six straight years, from 2007 to 2013, a peak in DBP (HAA5) was consistently recorded during the 2nd quarter as shown in the graph in Appendix C. In 2014, the DBP (HAA5) peak occurred in the 1st quarter. Only one of those peaks exceeded the MCL. In both years following the Nov 2014 coagulant change to DelPAC, DBP (HAA5) formation peaked in the 3rd and 4th quarters. This also corresponds with an increase in the hypochlorite residual maintained in both the water at the top of the filters and in the finished water. The increase in hypochlorite residual at the top of the filters location is especially significant as the higher TOC concentrations present at this location present a greater potential for DBP formation. Considering that distribution system disinfectant can be injected after TOC reduction by settling and filtration, it is recommended that the pre-filter hypochlorite dose be decreased to the lowest level allowed to achieve CT.

WTP CT calculations show a minimum residual concentration at the top of the sand filter of 0.9 mg/L in worst conditions. (temperature of 5˚C, pH of 7.5, no baffles T10/T of 0.1). The current residual concentration maintained at the top of the filters may then be reduced by a significant 50% from the current residual levels shown in Figures 2 and 4.

CT calculation

detention time		VDH Engineering Description Sheet 20 Feb 2015
Floc basins	=	49 min
Sed basins	=	4.8 hr
T10/T	=	0.1 (Table L-8)
T10	=	0.1 X (49 min + (4.8 hr X 60 min/hr)) = 33.7 min

Target Residual Disinfectant at top of filters:

C	=	0.9 mg/L
CTcalc	=	0.9 mg/L X 33.7 min = 30.3 mg - min/L

Required inactivation is 0.5 logs for this conventional treatment plant.

Worst case conditions for this plant will be 5˚C and pH of 7.5:

From Table L-3, 5˚C:

At pH 7.5 and 0.9 mg/L:

0.5 logs requires:

CT	=	29.5 mg - min/L
CTcalc > CT		30.3 > 29.5

2. **PAC Dose: Initiate the addition of PAC during warmer months.**

   Powdered Activated Carbon (PAC) has not yet been utilized by the WTP.

   a. Literature supports adding PAC prior to rapid mix for best TOC removal.

   b. Initiate jar testing by the PAC supplier:

      i. determine the most effective type of PAC (wood, bituminous, etc.).

      ii. determine the best dose rate and subsequent turbidity combination.

      iii. conduct with water from the warmer months to most effectively adsorb the organic type that is resulting in the DBP spikes.

3. **Disinfectant Injection: Move the hypochlorite dosing location from the rapid mix to the middle of the sedimentation basin.**

   Allow settling in the first half of the sedimentation basin to remove as much TOC as possible before hypochlorite addition to inherently reduce the potential for DBP formation.

   ODW agrees that hypochlorite dosing at mid basin can still provide adequate CT for the Amherst system.

   Effective mixing in a settling basin is an inherent challenge. Settling will naturally be disrupted by introducing the usual mixing techniques.

   A reportedly abandoned disinfectant dispersion pipeline was observed in one of the basins during the site visit. This single pipeline traversing the width of the basin would not adequately mix the hypochlorite to achieve CT credit. As-Built drawings do show this pipeline was connected to the disinfectant dosing system. WTP personnel report it was not utilized due to a concern of inadequate mixing. Additionally, until the DBP Rule this was not considered necessary.

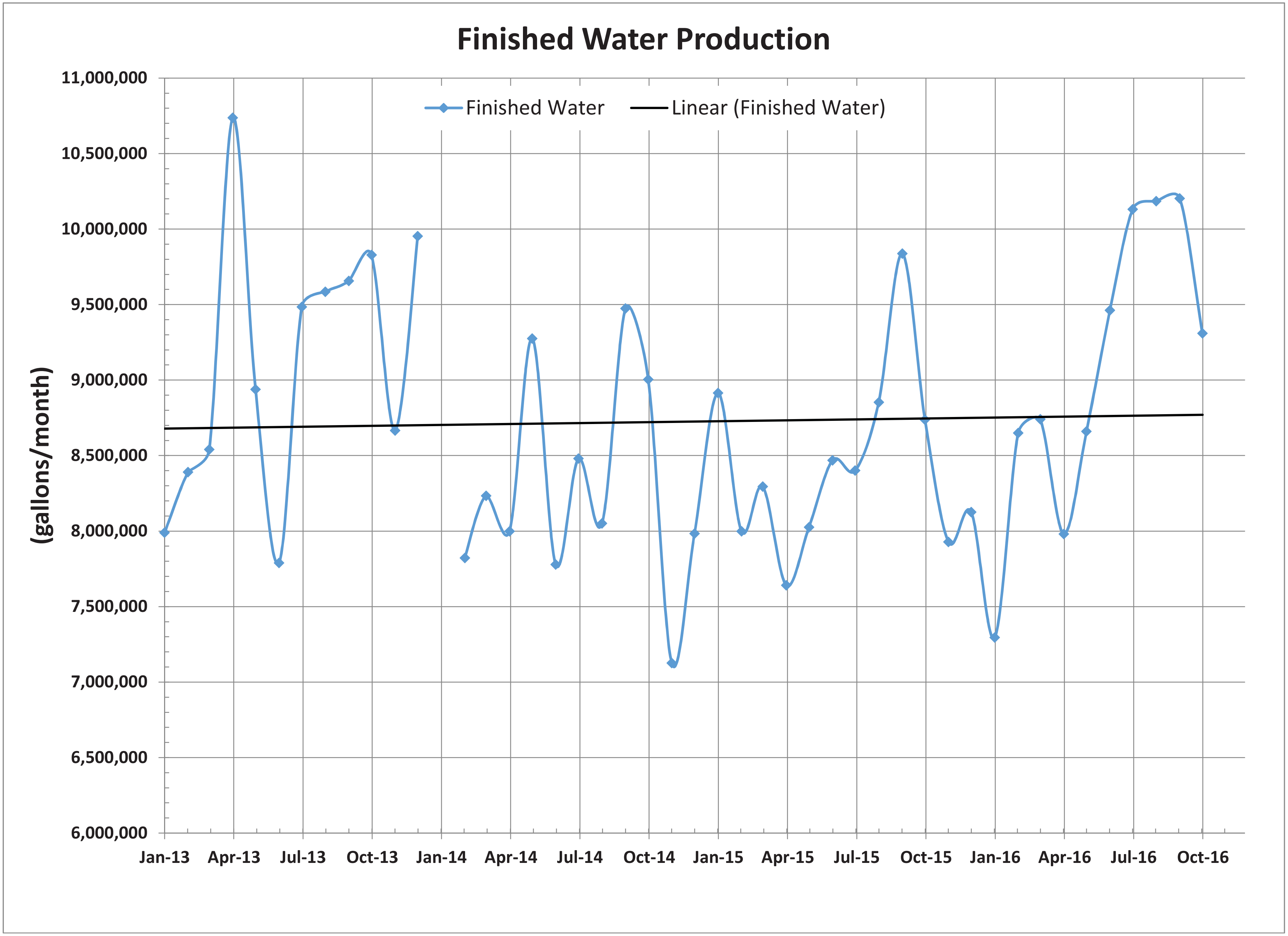
   With DelPAC 2020 causing settling to occur predominantly in the first half of the sedimentation basins, the second half may be re-dedicated, in effect, as a disinfectant contact tank. Baffles anchored to the walls and floor would direct the entire basin flow around disinfectant injection pipe(s) to achieve adequate contact. Three sets of baffles would provide a serpentine flow to preserve the current basin detention time to achieve the required CT. Settling will likely be disrupted by the increased flowrate and sedimentary sludge may not exist in this half of the basin.

Both the reduction in TOC achieved by mid basin and the reduction, if not total absence, of sedimentary sludge will lower the organic demand on the hypochlorite at mid basin. *Therefore, a reduction in the total quantity of hypochlorite is expected which will inherently reduce the potential for DBP formation.* Residual disinfectant testing at the top of the sand filters should continue to be employed to verify adequate CT.

Preliminary sketches for this approach are included in Appendix N. Applying this approach to both basins is estimated to cost $50,000 installed.

4. Sedimentation Basin Sludge: Install sludge collection equipment.

Not only is sedimentation basin sludge an inherent source of organics for DBP formation, the decaying organic material within the sludge creates an increased demand upon the hypochlorite concentration. This increased demand results in an increased dose of hypochlorite which, in turn, creates a greater potential for DBP formation. It is therefore recommended that sludge removal equipment be installed to ultimately diminish the amount of hypochlorite injected into the raw water. Sludge collection equipment for both sedimentation basins is estimated to cost $150,000 installed.


Finished Water Production
Finished Water
Linear (Finished Water)
(gallons/month)
11,000,000
10,500,000
10,000,000
9,500,000
9,000,000
8,500,000
8,000,000
7,500,000
7,000,000
6,500,000
6,000,000
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
Apr-14
Jul-14
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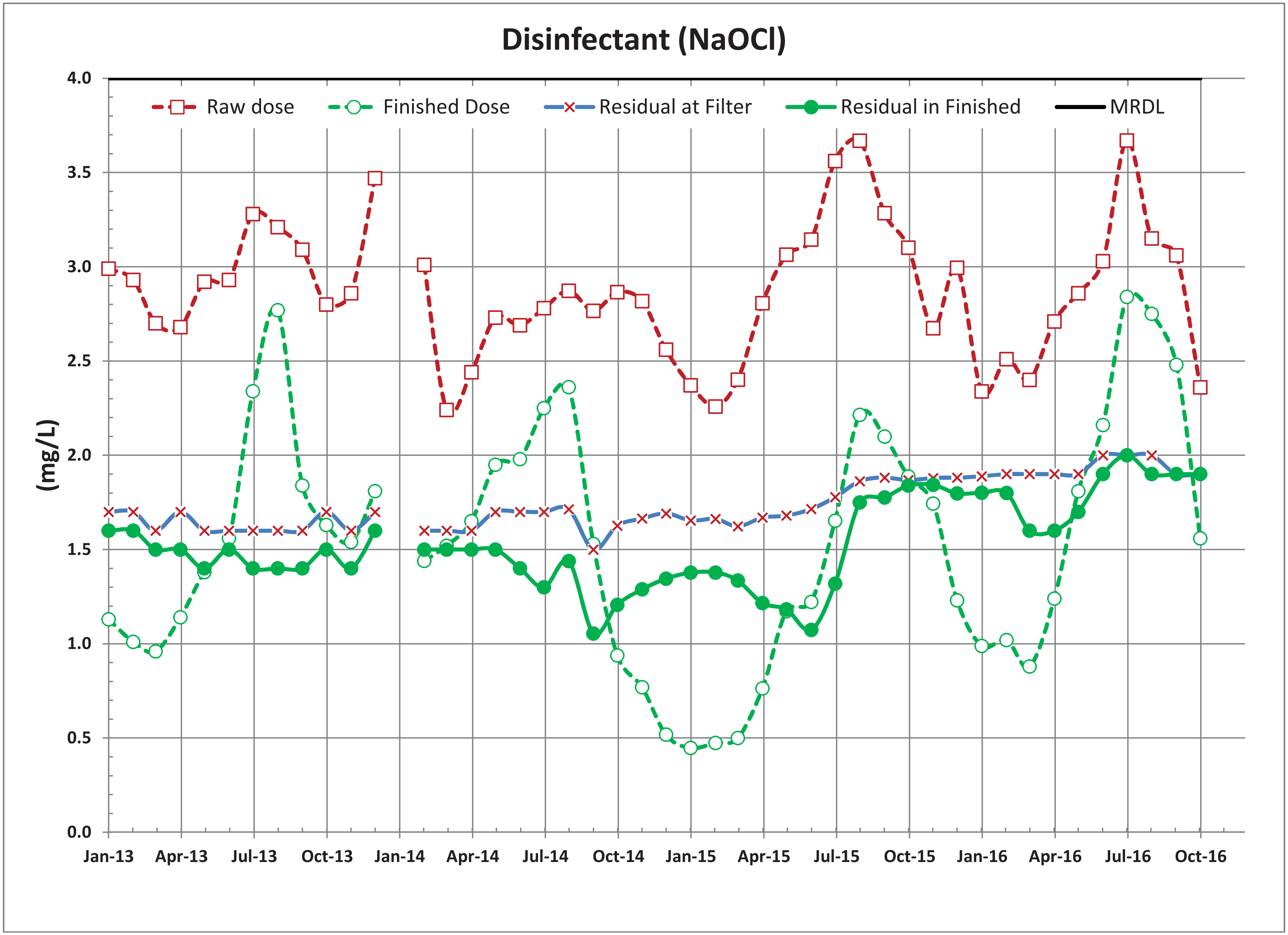
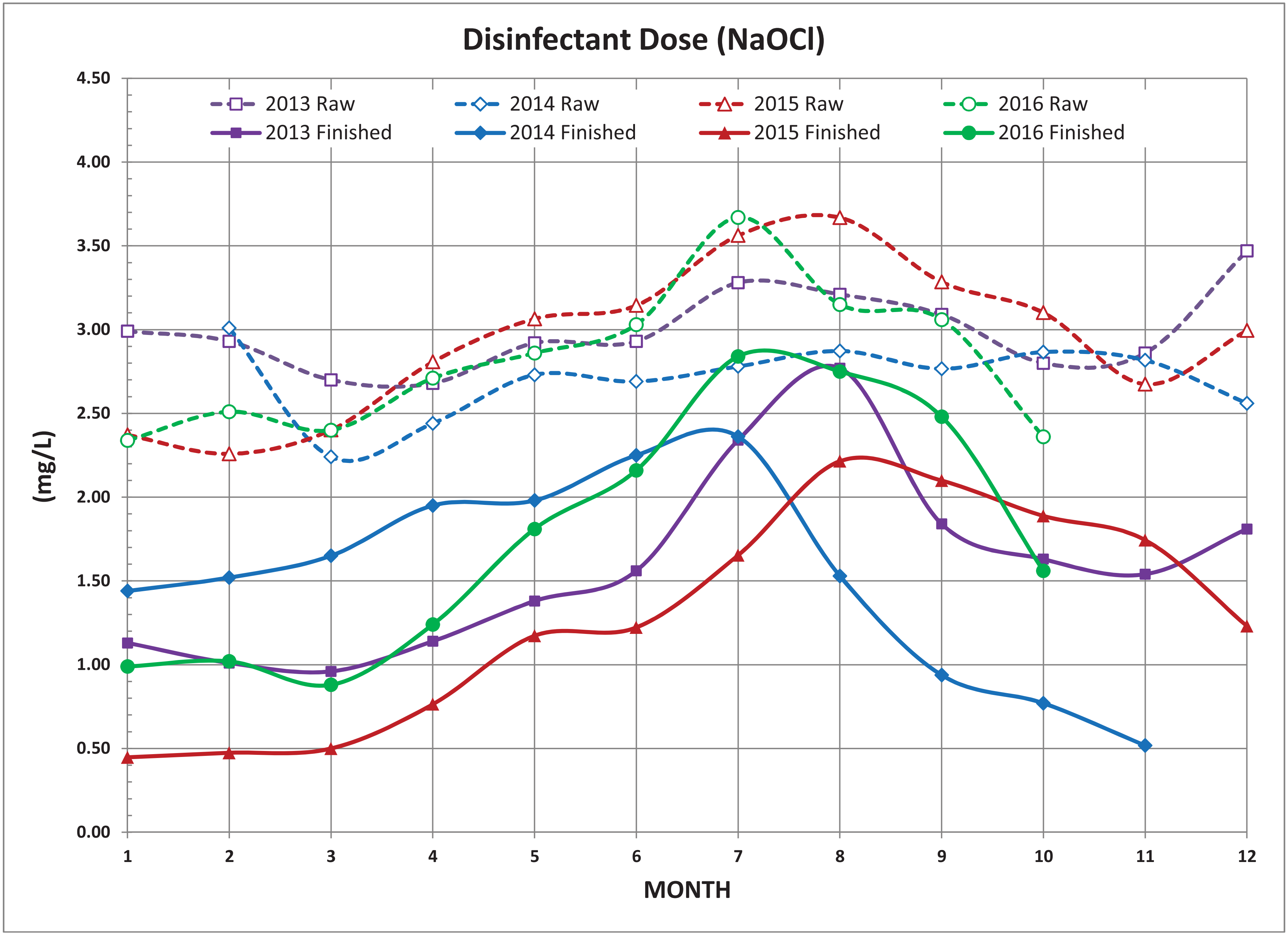
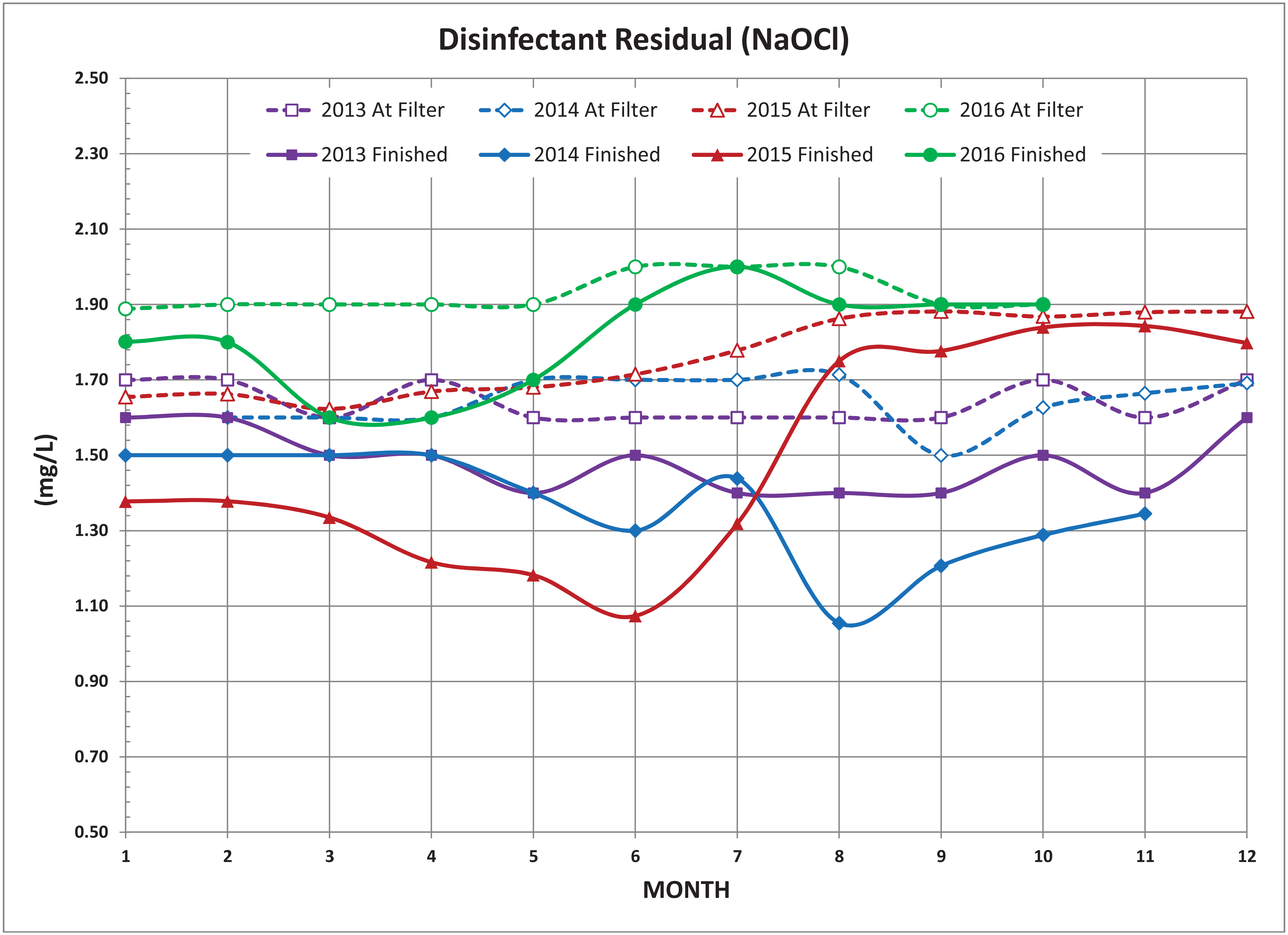
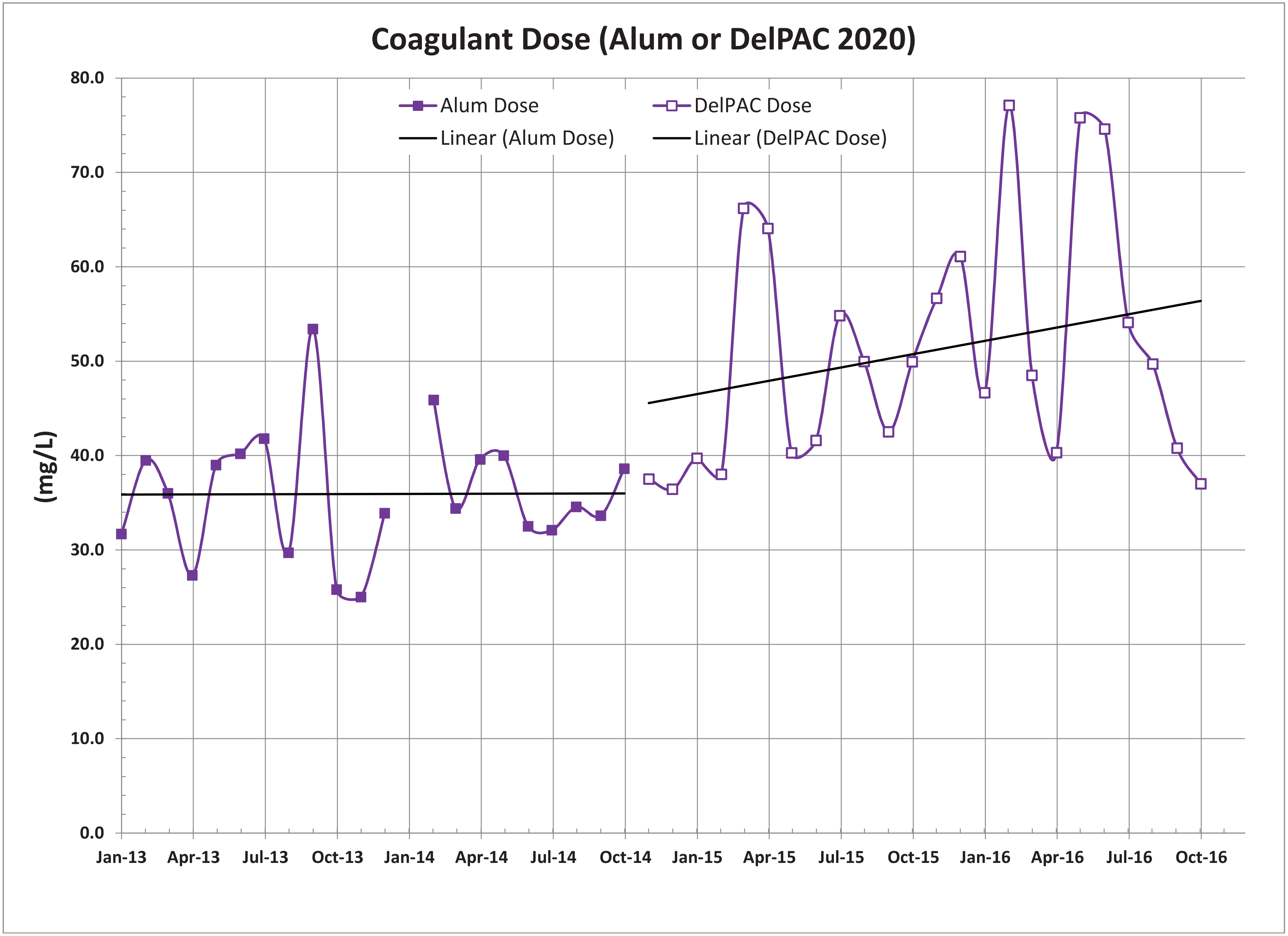
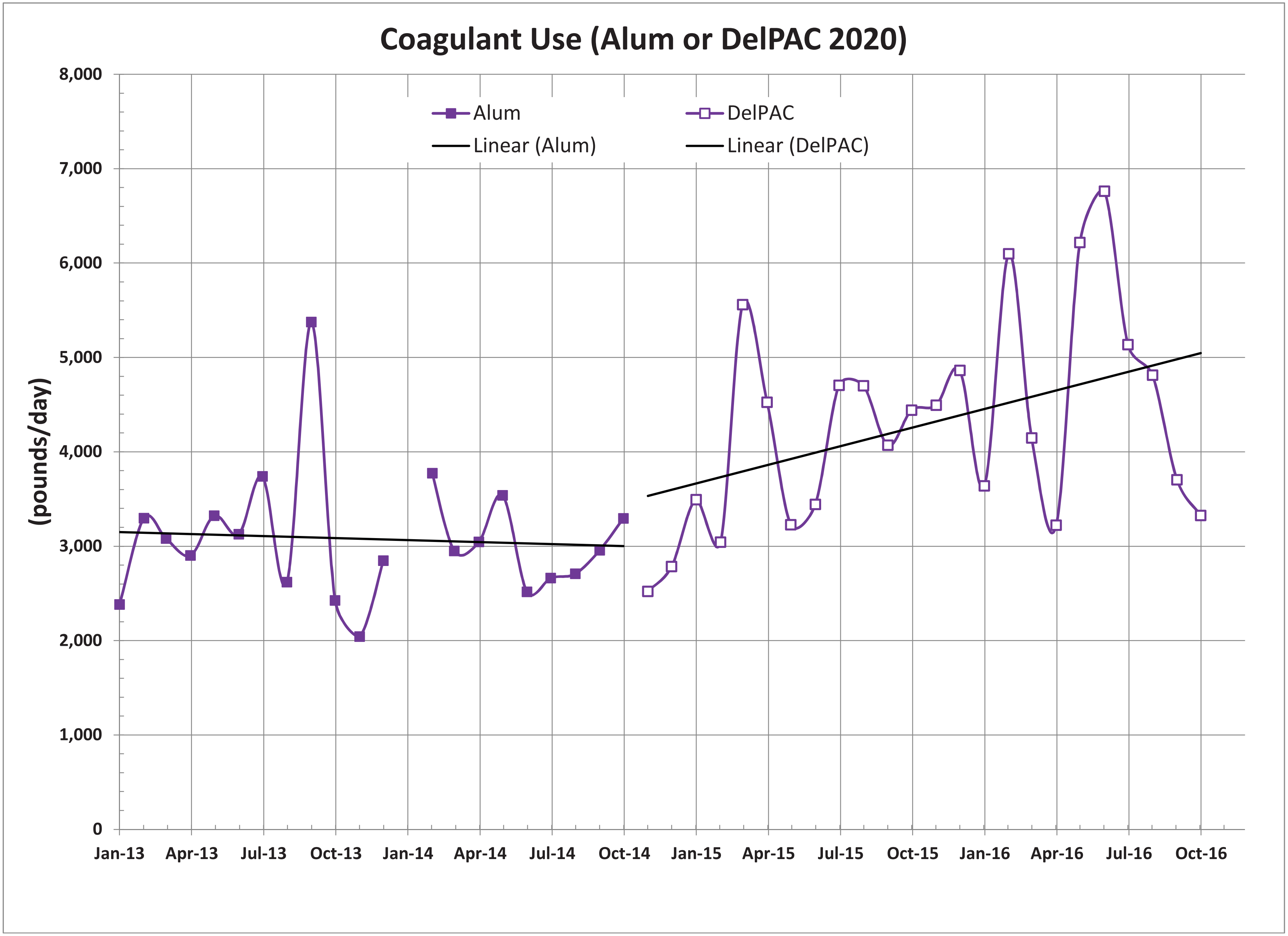
Jan-16
Apr-16
Jul-16
Oct-16

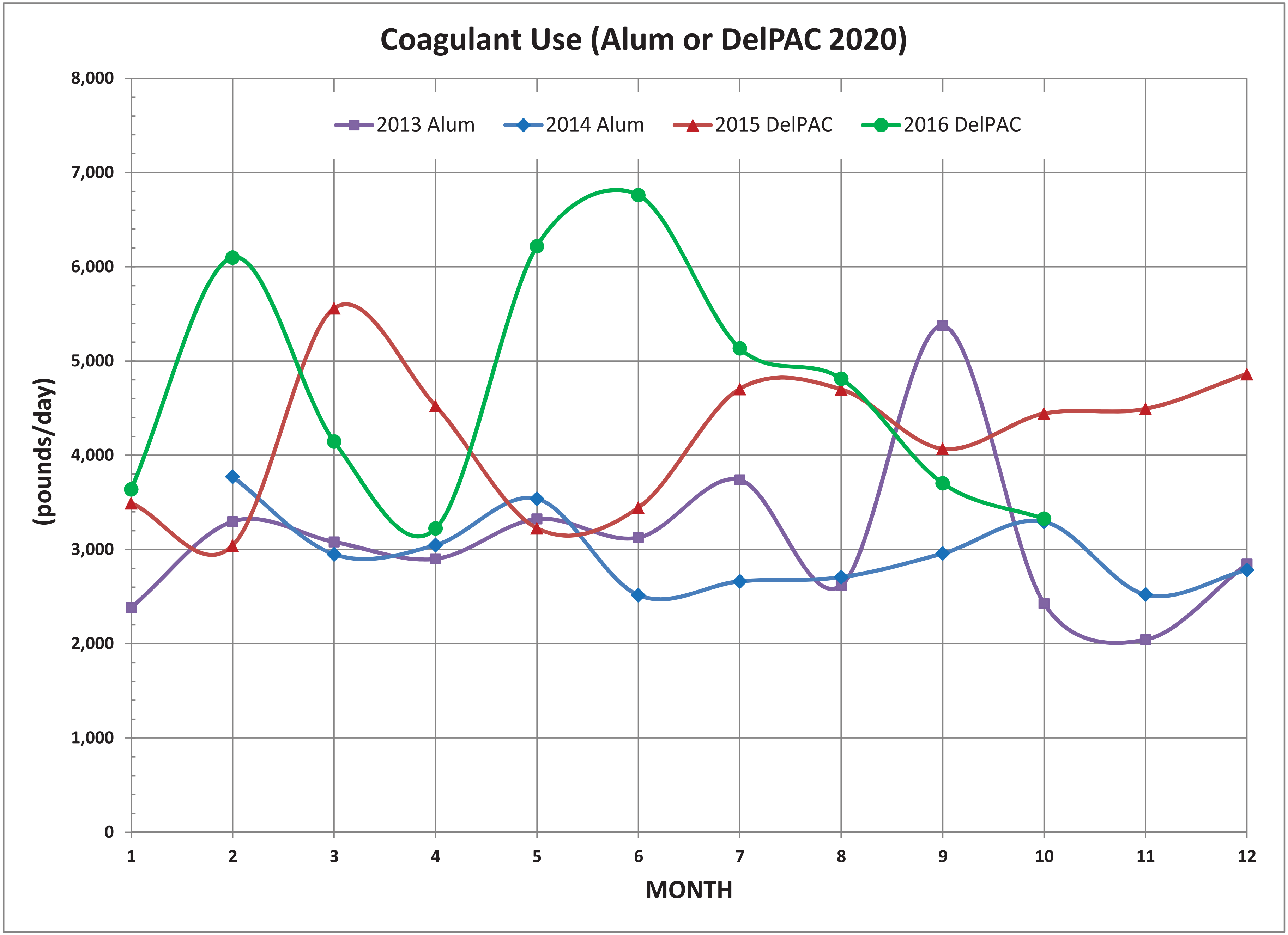

Disinfectant (NaOCl)
(mg/L)
Raw dose
Finished Dose
Residual at Filter
Residual in Finished
MRDL
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
Apr-14
Jul-14
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16

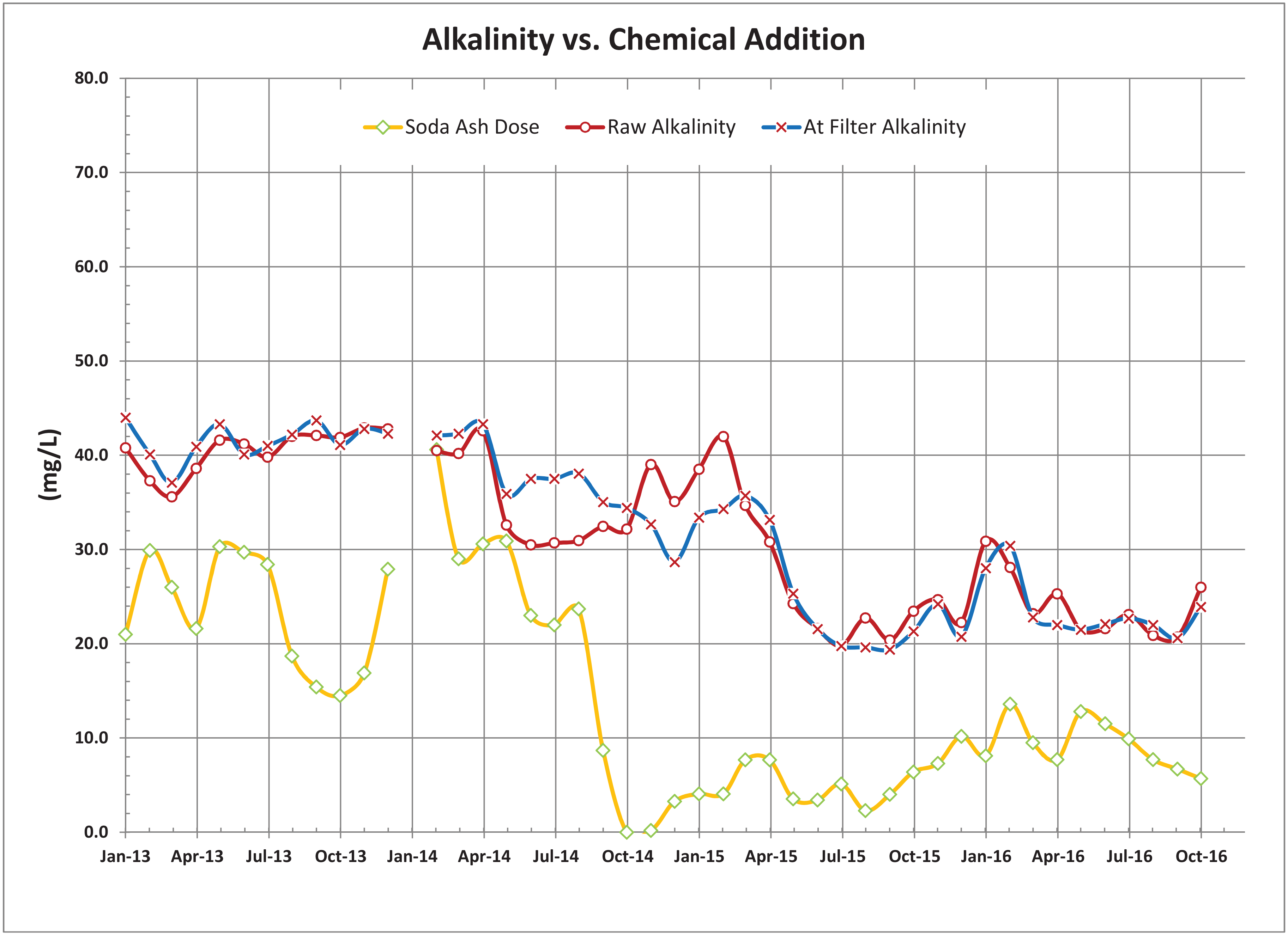

Disinfectant Dose (NaOCl)
(mg/L)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2013 Raw
2014 Raw
2015 Raw
2016 Raw
2013 Finished
2014 Finished
2015 Finished
2016 Finished
1
2
3
4
5
6
7
8
9
10
11
12
MONTH

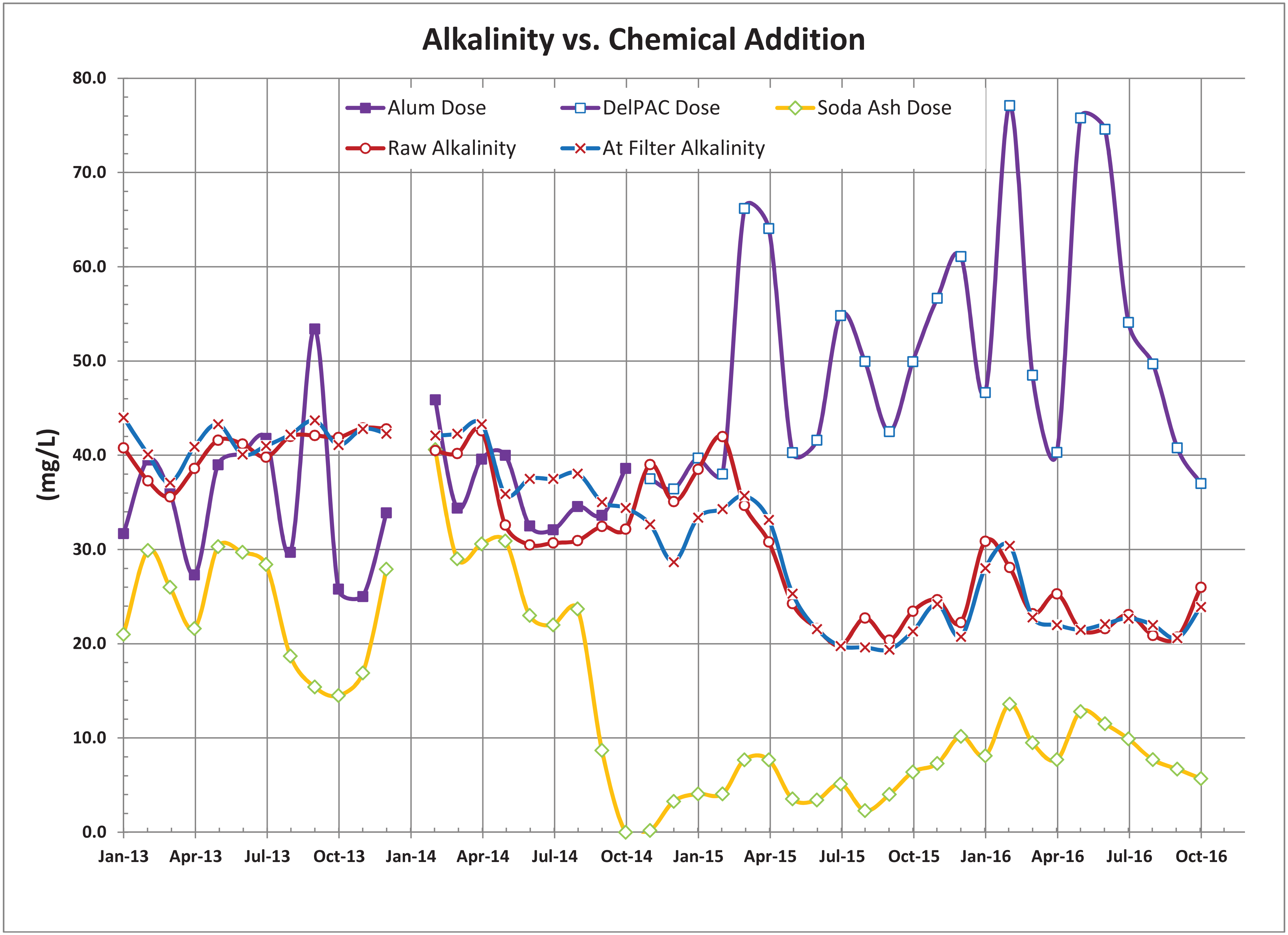

Disinfectant Residual (NaOCl)
2013 At Filter
2014 At Filter
2015 At Filter
2016 At Filter
2013 Finished
2014 Finished
2015 Finished
2016 Finished
(mg/L)
2.50
2.30
2.10
1.90
1.70
1.50
1.30
1.10
0.90
0.70
0.50
1
2
3
4
5
6
7
8
9
10
11
12
MONTH


Coagulant Dose (Alum or DelPAC 2020)
(mg/L)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Alum Dose
Linear (Alum Dose)
DelPAC Dose
Linear (DelPAC Dose)
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
Apr-14
Jul-14
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16

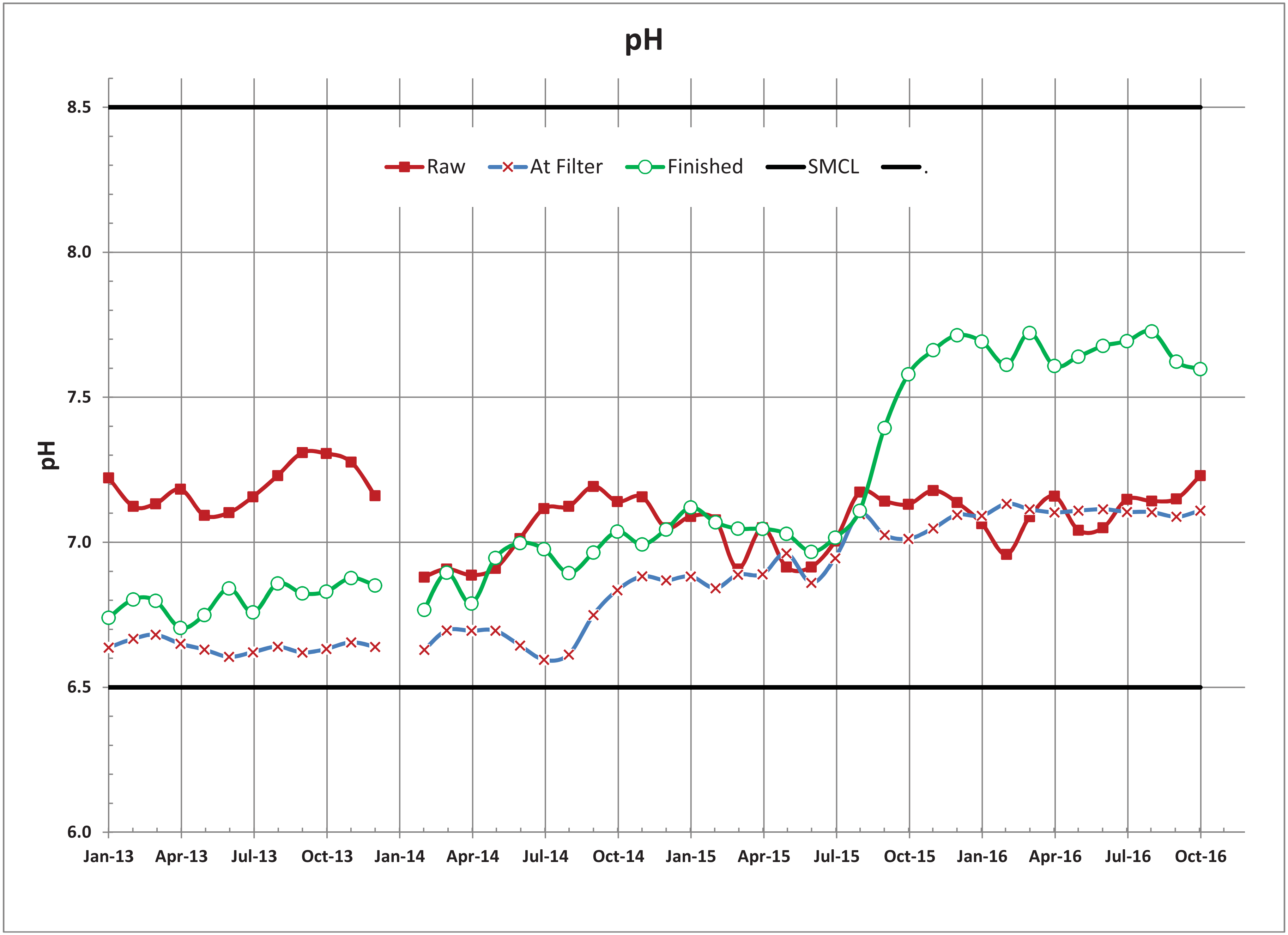

Coagulant Use (Alum or DelPAC 2020)
(pounds/day)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Alum
DelPAC
Linear (Alum)
Linear (DelPAC)
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
Apr-14
Jul-14
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16


Coagulant Use (Alum or DelPAC 2020)
2013 Alum
2014 Alum
2015 DelPAC
2016 DelPAC
(pounds/day)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1
2
3
4
5
6
7
8
9
10
11
12
MONTH


Alkalinity vs. Chemical Addition
Soda Ash Dose
Raw Alkalinity
At Filter Alkalinity
(mg/L)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
Apr-14
Jul-14
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16



Alkalinity vs. Chemical Addition
Alum Dose
DelPAC Dose
Soda Ash Dose
Raw Alkalinity
At Filter Alkalinity
(mg/L)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
Apr-14
Jul-14
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16


pH
Raw
At Filter
Finished
SMCL
.
pH
8.5
8.0
7.5
7.0
6.5
6.0
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
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Oct-14
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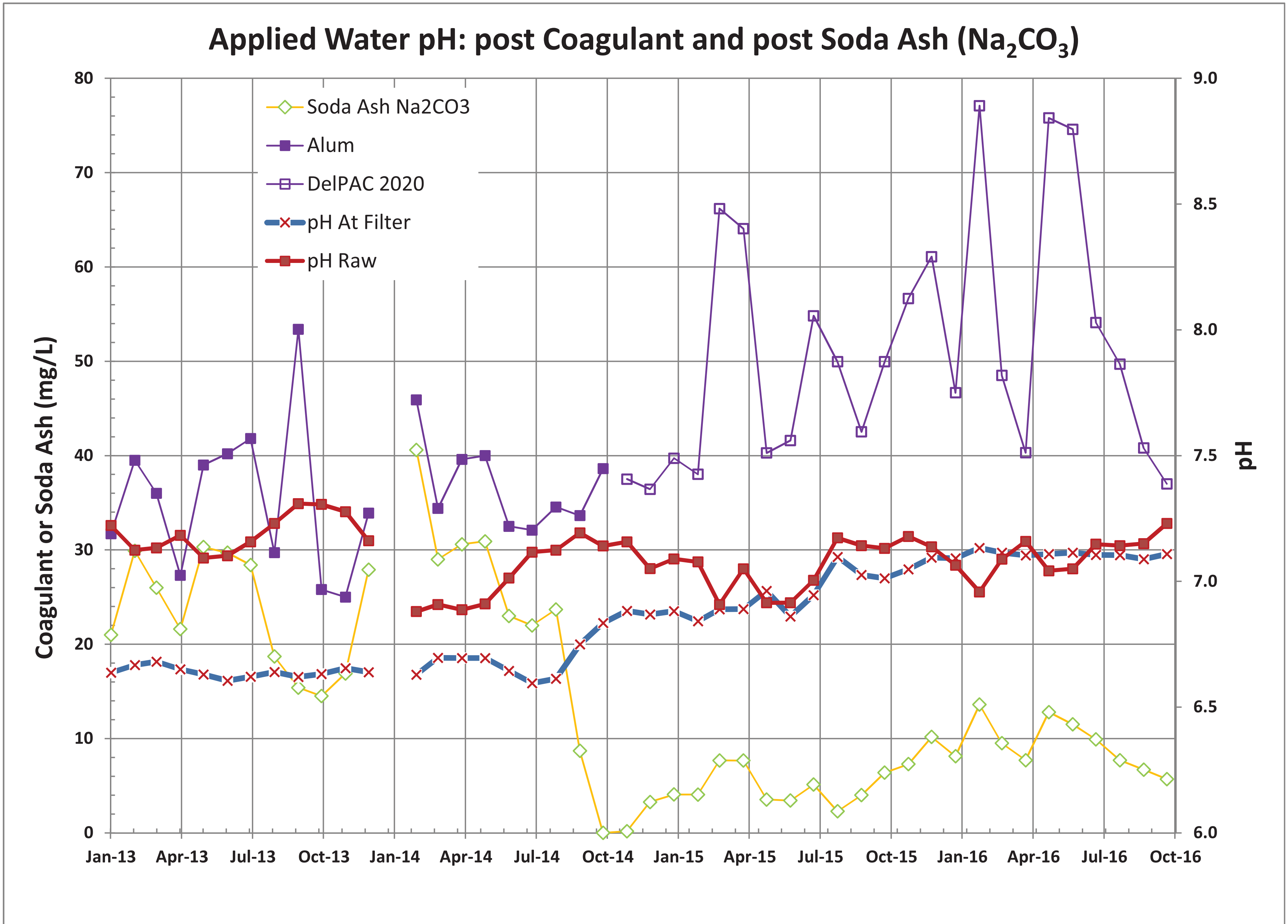
Jan-16
Apr-16
Jul-16
Oct-16



Applied Water pH: post Coagulant and post Soda Ash (Na_2CO_3)
Coagulant or Soda Ash (mg/L)
pH
Soda Ash Na2CO3
Alum
DelPAC 2020
pH At Filter
pH Raw
80
70
60
50
40
30
20
10
0
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
Apr-14
Jul-14
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16

Appendix G: VDH Fluoride Tracer Study

Appendix H: VDH DBP Investigation Study

Appendix I: Tank Profiling Report

TOWN OF AMHERST, VA - Water Quality Samples	**Sample Location**	**Result**	**Water Temp**
Waughs Ferry Tank 1MG-STP Steel Tank	Pump House	0.92	53 degrees
	Top of HWL	1.13	41 degrees
	10' Bleow HWL	0.96	
	30' Below HWL	0.96	
Note: Pump was on and fresh water was coming in.			
Union Hill Tank 1MG-GST Concrete	Hand Pump	0.72	38 degrees
	Top of HWL	1.07	37 degrees
	5' Below HWL	0.92	
	Bottom	0.88	

Data Results overview:

On December 19, 2016, Utility Service assisted with grab sampling in both the Union Hill and Waughs Ferry water tanks in Amherst, VA. These samples were taken to determine the level of stratification and temperature differeneces in each of the 1MG storage tanks the Town owns and operates. The data in th above spread sheet reveal several hydraulic and stratification issues that are present even in the cold weather months. The water quality is greatly effected in the summer months and historical data shows that the tanks are under greater attack of redsidual loss due to warmer water and thermal cline.

There was chemical stratification from the water entering the standpipe tank and what was leaving the outlet pipe. It was discussed that in the summer, these residualscould be as low as .1 in the pump house. The Union Hill tank did not have therma stratification, but did have a greater residual stratification from 1.03 down to .72 on the outlet line.

Mixing is recommended in both tanks to maintain more residual stability in the distrobution system.

Water Tank Inspection Report - Town of Amherst, VA

General Information -

Tank Picture

Tank Inspected: Waughs Ferry Tank

Capacity: 1,000,000 Style: Ground Storage Year Erected: 1961

Date of Last Inspection: N/A Last Inspection Performed: Visual

Inspection Date: Dec 19, 2016 Inspection Performed: Visual

Evaluation of Tank Conditions -

Exterior Inspection Observations:

Exterior Coating: Alkyd

Exterior Inspection Picture

Additional Inspection Pictures Attached

- ☐ EXCELLENT — Exterior protective coating is in excellent condition. The coating system has no cosmetic deficiencies or other signs of premature weathering and fading. The tank demonstrates good maintenance and components appear to be compliant. No visual or physical evidence of coating touch up or repair needed at this time.
- ☒ GOOD — The protective coating system has random cosmetic deficiences with signs of normal weathering and color fading. The structure does not need over-coating at this time, but some minor maintenance or repair may be needed in the near future.
- ☐ FAIR — The protective coating system shows clear signs of deterioration indicative of a system near the end of its useful life. Over 5% of the structures painted surfaces are currently showing signs of deterioration and random corrosion development. Proper cleaning and over-coating of the structure is recommened for the very near future.
- ☐ POOR — Greater than 10% of the coating system shows defective conditons of deterioration and spreading corrosion. Conditions indicate the coating system is beyond its protective lifecycle. A major renovation with possible repairs should be planned as soon as feasible.

Interior Inspection Observations:

Interior Inspection Picture

Additional Inspection Pictures Attached

Interior Coating: Epoxy

- ☐ EXCELLENT — Interior protective coating system is in excellent condition. The coating system has no cosmetic deficiencies or other signs of premature failure. No visual or physical evidence of coating deteriortaion or needed repair.
- ☒ GOOD — The interior coating has some minor cosmetic deficiencies. The protective coating has minor discoloring with random irregular shape deterioration. The interior does not need renovating, but some minor maintenance and repair may be needed in the near future.
- ☐ FAIR — The interior coating system shows clear signs of deterioration indicative of a coating system near its useful life. Over 20% of the interior painted surfaces are currently showing signs of deterioration and random corrosion development. A complete renovation is recommened for the very near future.
- ☐ POOR — Extent of coating failure and spreading corrosion affects more than 40% of the interior structure. Conditions indicates the coating system is beyond its useful lifecycle. A major renovation and possible repairs should be planned as soon as feasible.

The purpose of this report is to provide general information on the condition of the tanks protective coating systems and its compliance with the State and Federal regulator agencies. This report is not a structural evaluation, a guarantee of sanitary conditions or water quality. Thank you for the opportunity to provide this very important service. If you have any questions or would like to discuss the information contained in this document, please contact Brad Brown @ 434-249-8545

Water Tank Inspection Report - Town of Amherst, VA

Exterior Inspection Observations:

Common Coating Deterioration Observed -

- [x] MILDEW GROWTH - Superifical discoloration of the coating.
- [x] CHALK EROSION - Gradual thinning of finish coat to expose undercoat.
- [x] FLASH RUST - Rusting at pinholes or holidays in paint system.

Severe Forms of Coating Deterioration Observed -

- [ ] IRREGULAR SURFACE DETERIORATION - Breakdown at edges, corners, crevices, etc.
- [ ] PEELNG - Paint peeling or flaking between layers of paint.
- [ ] CHECKING - Narrow breaks in topcoat exposing undercoat.
- [ ] CRACKING - Deep cracks in paint.
- [ ] DELAMINATION - Paint peeling from undercoat or substrate.
- [ ] UNDERCUTTING - Blistering or peeling of paint where steel is rusting.

- [x] Exterior renovation is recommended as soon as feasible.
- [ ] Touch up of exterior coating recommended.
- [x] Repairs identified.

Future Exterior Renovation Window: 2017-18

Notes

The current coating is chalking heavily and random areas of delamination/ rust corrosion were noted during the inspection. It is recommended to renovate the exterior coating soon to avoid having to sandblast the tank. The adhesion of the current coating will allow for an exterior pressure wash and over coat.



Interior Inspection Observations:

Common Coating Deterioration Observed -

- [x] STAINING - Heavy staining of the sidewall from elements in the water.
- [x] FLASH RUST - Rusting at pinholes or holidays in paint system.
- [ ] PEELNG - Paint peeling or flaking between layers of paint.

Severe Forms of Coating Deterioration Observed -

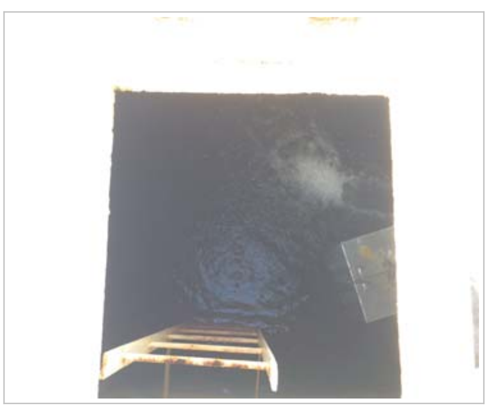
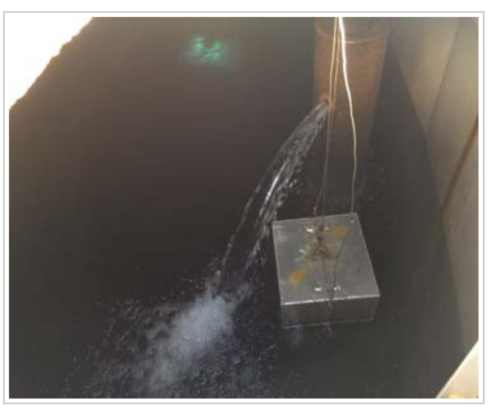
- [ ] IRREGULAR SURFACE DETERIORATION - Breakdown at edges, corners, crevices, etc.
- [x] BLISTERING - Water soluble material with trapped under or between coatings.
- [ ] DELAMINATION - Paint peeling from undercoat or substrate.
- [ ] UNDERCUTTING - Blistering or peeling of paint where steel is rusting.
- [ ] BARNACLES - Severe corrosion growth.

- [ ] Interior renovation is recommended as soon as feasible.
- [ ] Washout disinfection recommended to remove built up sediment.
- [x] Touch up of interior coating recommended.
- [ ] Repairs identified.

Future Interior Renovation Window: 3-5 Years

Notes

The interior coating is in very good condition for below the water level and up to the rafters. Flash rust is on the roof around the vent area. Blistering was found on the roof beams that should be repaired/touched up in the next 2 years. Some of the blisters have visible rust/corrosion in


Water Tank Inspection Report - Town of Amherst, VA

General Information -

Tank Picture

Tank Inspected: Union Hill Tank

Capacity: 1,000,000 Style: Ground Storage Year Erected: 2008

Date of Last Inspection: N/A Last Inspection Performed: Visual

Inspection Date: Dec 19, 2016 Inspection Performed: Visual

Evaluation of Tank Conditions -

Exterior Inspection Observations:

Exterior Coating: Sealant

- ☐ EXCELLENT — Exterior protective coating is in excellent condition. The coating system has no cosmetic deficiencies or other signs of premature weathering and fading. The tank demonstrates good maintenance and components appear to be compliant. No visual or physical evidence of coating touch up or repair needed at this time.
- ☒ GOOD — The protective coating system has random cosmetic deficiences with signs of normal weathering and color fading. The structure does not need over-coating at this time, but some minor maintenance or repair may be needed in the near future.
- ☐ FAIR — The protective coating system shows clear signs of deterioration indicative of a system near the end of its useful life. Over 5% of the structures painted surfaces are currently showing signs of deterioration and random corrosion development. Proper cleaning and over-coating of the structure is recommened for the very near future.
- ☐ POOR — Greater than 10% of the coating system shows defective conditons of deterioration and spreading corrosion. Conditions indicate the coating system is beyond its protective lifecycle. A major renovation with possible repairs should be planned as soon as feasible.

Exterior Inspection Picture

Additional Inspection Pictures Attached

Interior Inspection Observations:

Interior Inspection Picture

Additional Inspection Pictures Attached

Interior Coating: ________________

- ☐ EXCELLENT — Interior protective coating system is in excellent condition. The coating system has no cosmetic deficiencies or other signs of premature failure. No visual or physical evidence of coating deteriortaion or needed repair.
- ☒ GOOD — The interior coating has some minor cosmetic deficiencies. The protective coating has minor discoloring with random irregular shape deterioration. The interior does not need renovating, but some minor maintenance and repair may be needed in the near future.
- ☐ FAIR — The interior coating system shows clear signs of deterioration indicative of a coating system near its useful life. Over 20% of the interior painted surfaces are currently showing signs of deterioration and random corrosion development. A complete renovation is recommened for the very near future.
- ☐ POOR — Extent of coating failure and spreading corrosion affects more than 40% of the interior structure. Conditions indicates the coating system is beyond its useful lifecycle. A major renovation and possible repairs should be planned as soon as feasible.

The purpose of this report is to provide general information on the condition of the tanks protective coating systems and its compliance with the State and Federal regulator agencies. This report is not a structural evaluation, a guarantee of sanitary conditions or water quality. Thank you for the opportunity to provide this very important service. If you have any questions or would like to discuss the information contained in this document, please contact Brad Brown @ 434-249-8545

Water Tank Inspection Report - Town of Amherst, VA

Exterior Inspection Observations:

Common Coating Deterioration Observed -

- [ ] MILDEW GROWTH - Superifical discoloration of the coating.
- [ ] CHALK EROSION - Gradual thinning of finish coat to expose undercoat.
- [ ] FLASH RUST - Rusting at pinholes or holidays in paint system.

Severe Forms of Coating Deterioration Observed -

- [x] IRREGULAR SURFACE DETERIORATION - Breakdown at edges, corners, crevices, etc.
- [ ] PEELNG - Paint peeling or flaking between layers of paint.
- [ ] CHECKING - Narrow breaks in topcoat exposing undercoat.
- [x] CRACKING - Deep cracks in paint.
- [ ] DELAMINATION - Paint peeling from undercoat or substrate.
- [ ] UNDERCUTTING - Blistering or peeling of paint where steel is rusting.

- [x] Exterior renovation is recommended as soon as feasible.
- [ ] Touch up of exterior coating recommended.
- [ ] Repairs identified.

Future Exterior Renovation Window: 2017-18

Notes
The current exterior surface is showing signs of cracking and mildew growth. It is recommended to renovate the exterior surfaces to preserve the concrete integrity long-term.



Interior Inspection Observations:

Common Coating Deterioration Observed -

- [ ] STAINING - Heavy staining of the sidewall from elements in the water.
- [ ] FLASH RUST - Rusting at pinholes or holidays in paint system.
- [ ] PEELNG - Paint peeling or flaking between layers of paint.

Severe Forms of Coating Deterioration Observed -

- [ ] IRREGULAR SURFACE DETERIORATION - Breakdown at edges, corners, crevices, etc.
- [ ] BLISTERING - Water soluble material with trapped under or between coatings.
- [ ] DELAMINATION - Paint peeling from undercoat or substrate.
- [ ] UNDERCUTTING - Blistering or peeling of paint where steel is rusting.
- [ ] BARNACLES - Severe corrosion growth.

- [ ] Interior renovation is recommended as soon as feasible.
- [x] Washout disinfection recommended to remove built up sediment.
- [ ] Touch up of interior coating recommended.
- [ ] Repairs identified.

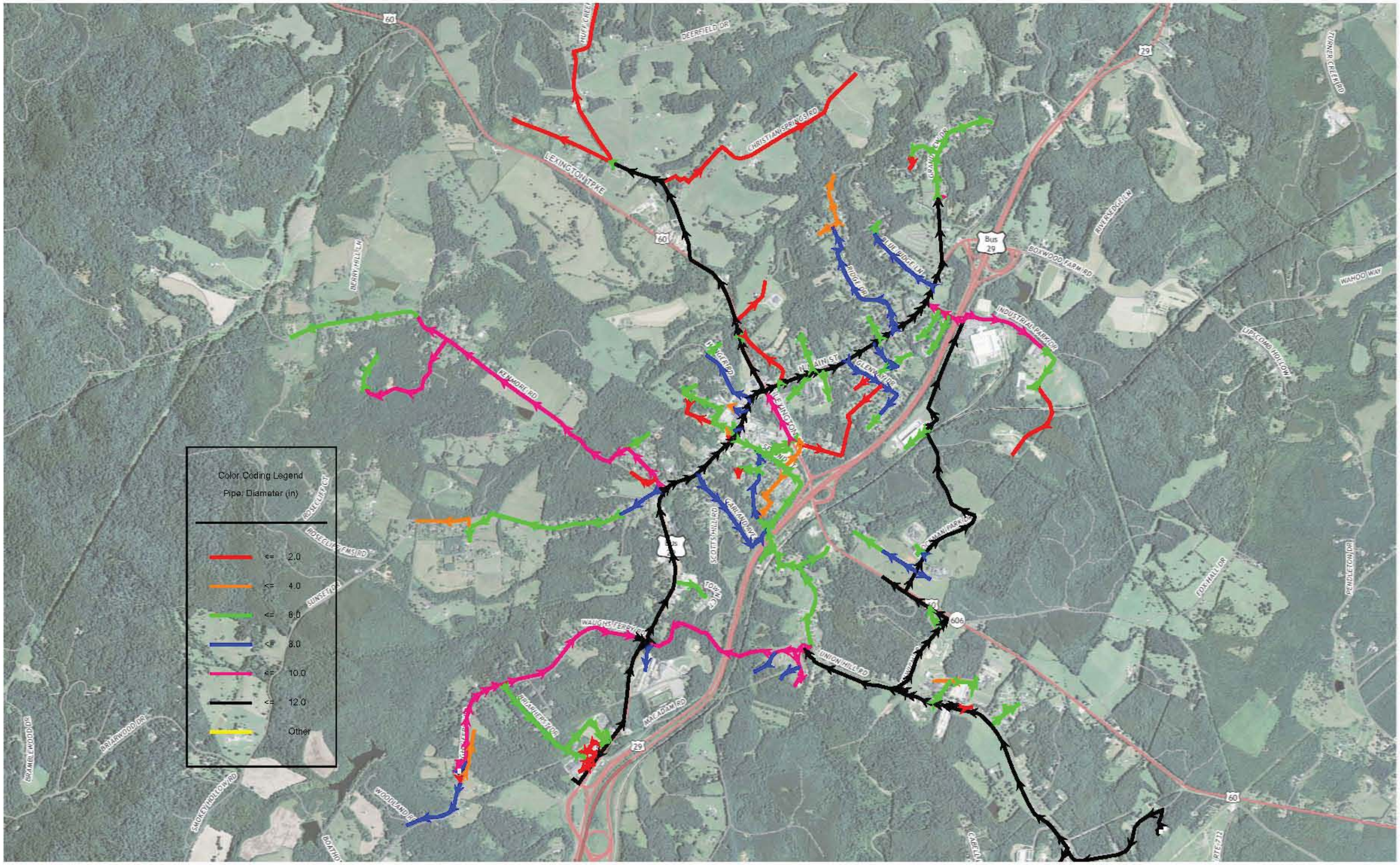
Future Interior Renovation Window: 5 Years

Notes
The interior is not coated and appears to be in good condition for the age of the storage tank. No failure and spauling was observed.

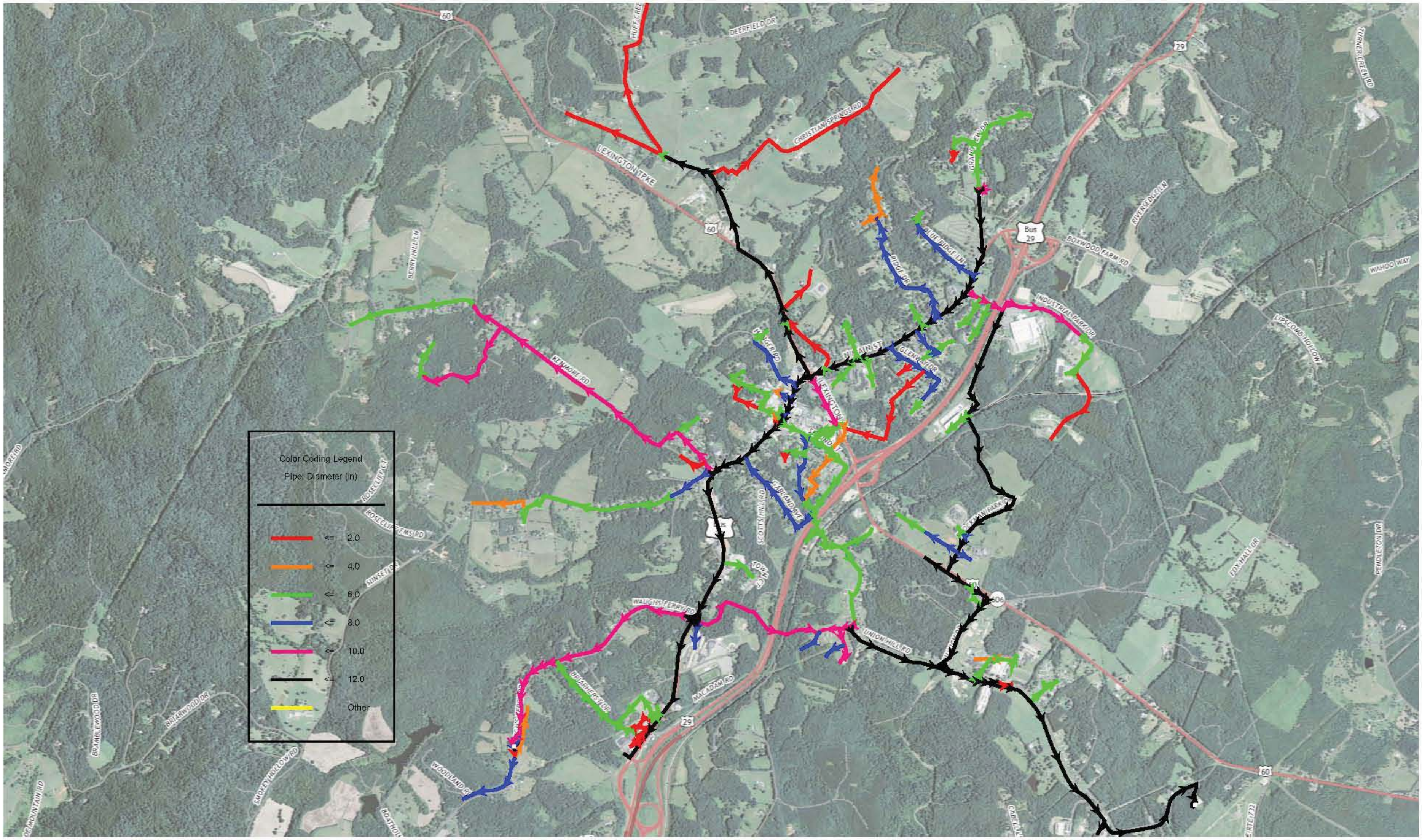


Appendix J: Water Flow Direction Diagrams

Scenario: 2016 Model Updates - Average Day Pressure - Tanks Only



Scenario: 2016 Model Updates - Average Day Pressure - WTP Pumps ON



Appendix K: Hydraulic Model and Water Age Analysis

I. Hydraulic Model Updates

A. Summary and Objectives

As part of this study, the Town's existing hydraulic model was updated and evaluated. The model was updated to include new water line sizes and alignments that have been installed since the last model update. Additionally, customer billing data was analyzed and the demands were updated in the model to reflect the average daily demands on the system.

The model was updated using Bentley WaterCAD V8i. It was assumed that the existing model was previously sufficiently calibrated and therefore, no new hydrant testing was performed as part of the model updates. Pipes in the model range in size from 2" to 12", with Hazen Williams friction coefficients ranging from 60 to 140. New 12" ductile iron piping was modeled using friction coefficients of 130.

The objectives for the hydraulic modeling updates were as follows:

- Update the water line sizes and alignments, update the customer demands
- Evaluate pressures and available flows throughout the system
- Perform an extended period water age analysis

B. Updated Customer Demands

There are approximately 977 residential connections. Metering and billing data from the past two years indicated that the average daily residential demand on the system is approximately 158,000 gpd, which translates to an average residential customer demand of 162 gpd. There are approximately 117 commercial customers with a total average daily demand of 110,400 gpd. There were approximately 30 commercial users with daily demands greater than 500 gpd. These demands were applied at a junction or hydrant closest to the facility in the model. The remainder of the commercial demands, as well as the residential demands were distributed evenly throughout the junctions and hydrants in model.

In addition to the commercial and residential demands, a demand of 48,000 gpd (33 gpm) was applied at the connection to Sweet Briar College.

The total average demand in the model is 235 gpm, which translates to an average daily demand of 338,400 gpd.

C. Pressure Analysis

Two pressure scenarios were evaluated. Both scenarios used a peaking factor of 2 to evaluate the pressures during peak day demands. The first scenario represents the system floating off the storage tanks. The second scenario represents the pressures throughout the system while one of the water treatment plant pumps are operating. It was assumed that the tanks were operating at their average water levels, which is at a hydraulic grade elevation of 885'.

The results of both scenarios indicate that pressures in the system meet the minimum requirement of 20 psi during peak day demands. Pressure within the system range from 20 psi to 132 psi, with the majority of the Town experiencing pressures between 45 psi and 100 psi.

D. Fire Flows

The fire flow scenario represents the available flows in the water main at the hydrant locations during average daily demands. This scenario assumes that the storage tanks are at their average operating levels (hydraulic grade elevation 885') and that the water treatment plant pumps are able to energize during a fire flow event. The fire flows were evaluated during average daily system demands.

Target fire flows were 500 gpm at residual pressures of 20 psi. The hydraulic model predicts that all of the hydrants except one are able to provide the target fire flows. The one hydrant that was not able to provide the 500 gpm fire flow is located at the end of the 6" water line along Sunset Drive.

E. Water Age Analysis

The water age analysis evaluated the water age at each point in the system over a 1,000 hour (42) day period. Throughout the evaluation, the pumps cycled on and off each day to meet the demand requirements and fill the storage tanks. For this analysis the average daily demands were used as base demands, which were peaked based on a diurnal curve. This water age model was used to supplement and support the research and findings of the water study.

F. Water Model Exhibits

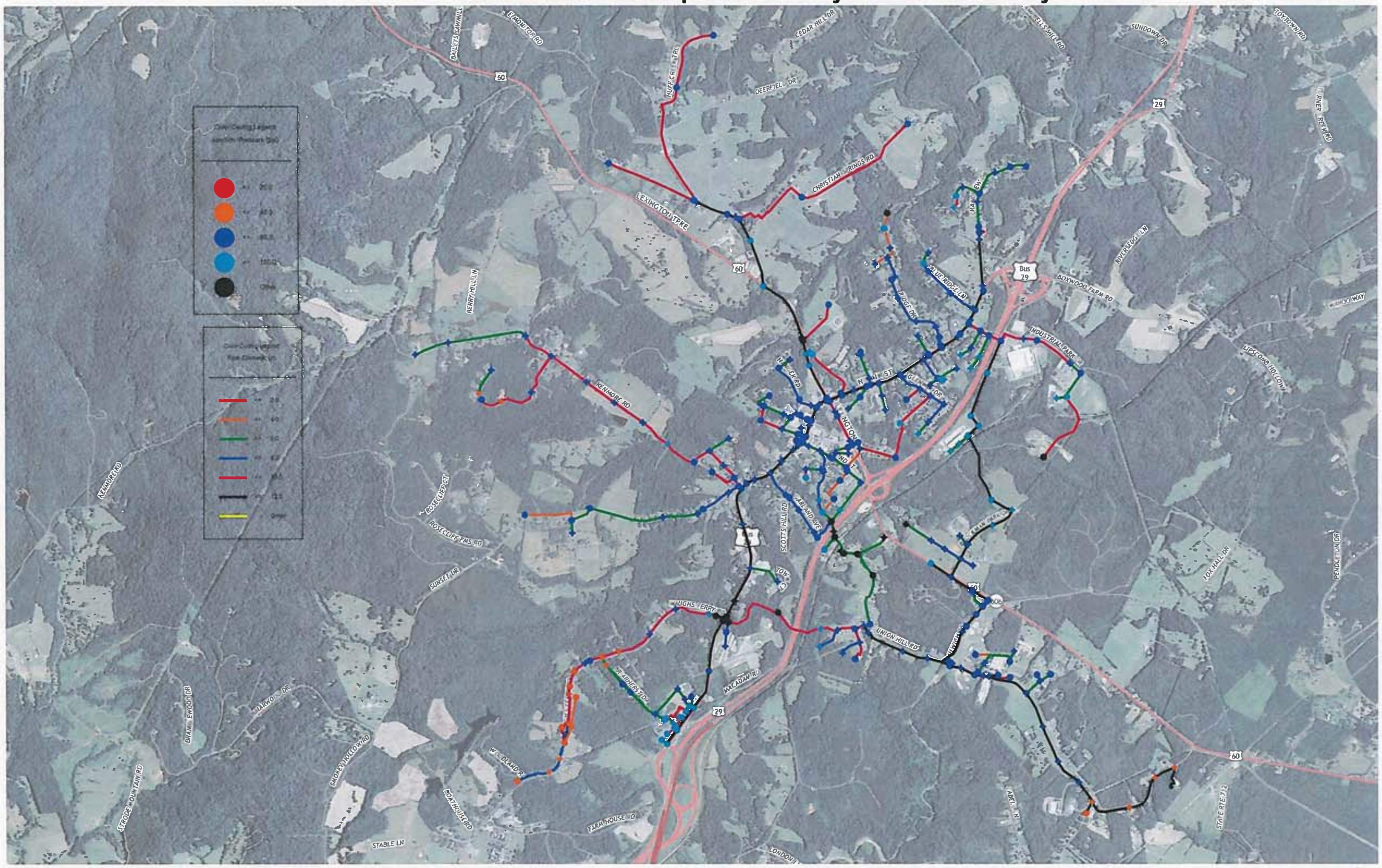
1. Peak Day Pressure – Tanks Only

2. Peak Day Pressure – WTP Pumps ON

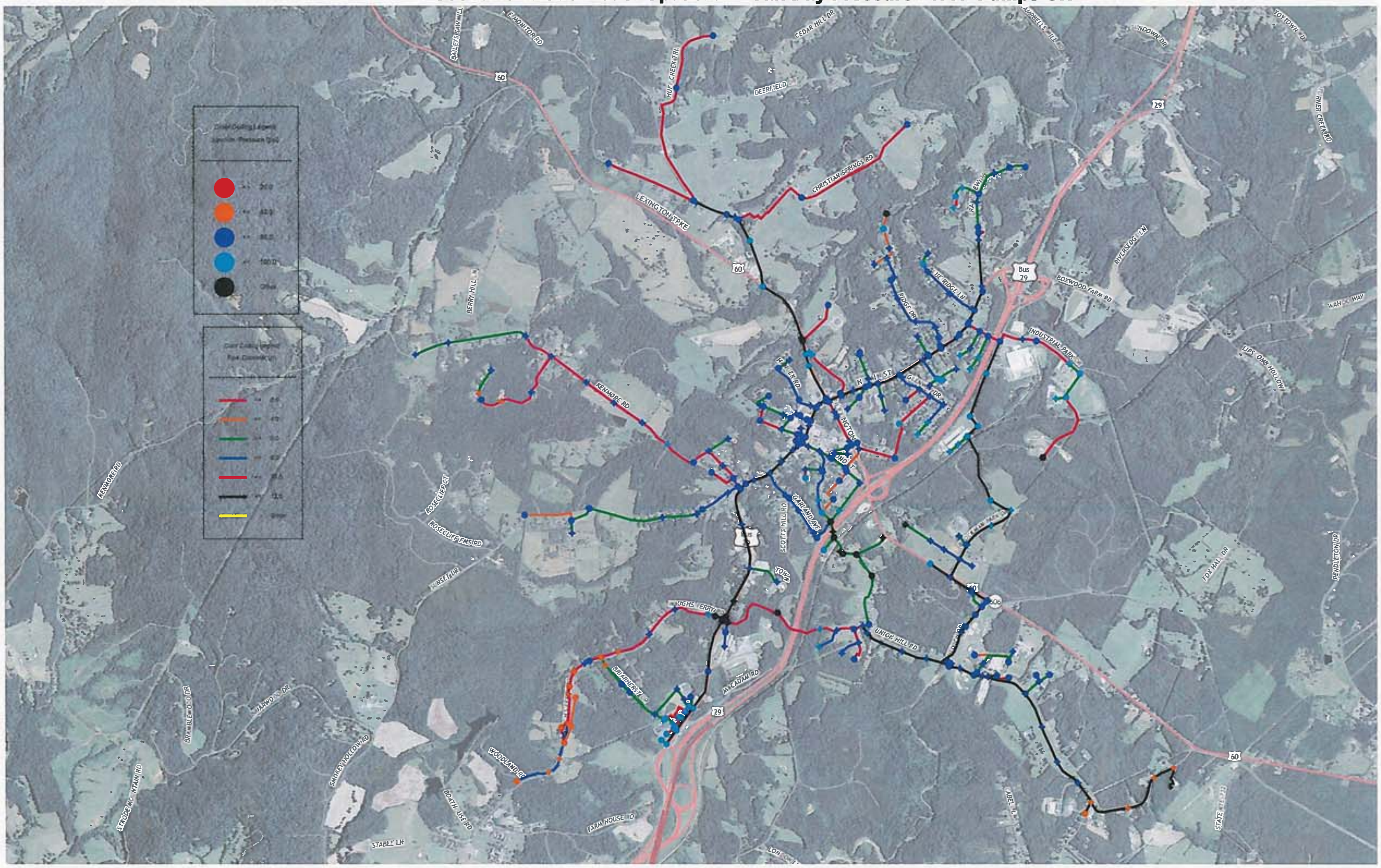
3. Average Day Fire Flows Available

4. Average Day Demand – Water Age

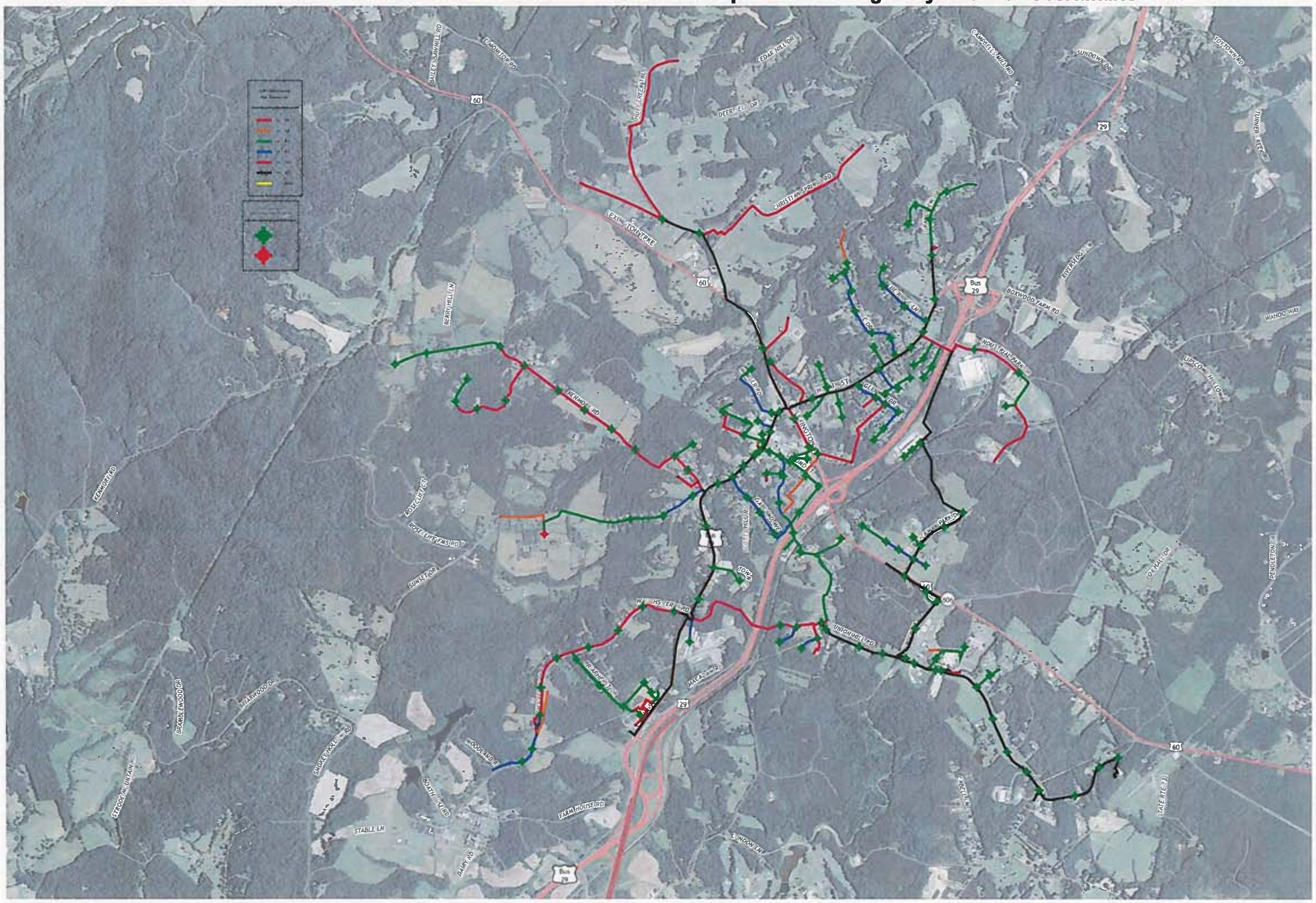
Scenario: 2016 Model Updates -Peak Day Pressure - Tanks Only



Scenario: 2016 Model Updates - Peak Day Pressure - WTP Pumps ON



Scenario: 2016 Model Updates - Average Day Fire Flows Available



Scenario: 2016 Model Updates - Average Day Demand - Water Age

Color Coding Legend		
Junction: Age (Maximum) (days)		
●	<=	4.000
●	<=	8.000
●	<=	12.000
●	<=	16.000
●	<=	20.000
●	<=	24.000
●	<=	28.000
●		Other

● junction

✦ hydrant

Appendix L - Simultaneous Compliance Charts

Exhibit 1.1 Existing SDWA Regulations as of March, 2007

Rule/Memo	***Date of Promulgation***	***Contaminant of Concern***	***Rule Summary Information Available from EPA***
Ground Water Rule (GWR)	November 2006	Source Water Microbial Pathogens	Fact Sheet, included in Appendix A
Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)	January 2006	Source Water Microbial Pathogens	Fact Sheet, included in Appendix A
Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR)	January 2006	Disinfection Byproducts	Fact Sheet, included in Appendix A
Arsenic and Clarifications to Compliance and New Source Monitoring Rule	January 2001	Arsenic	Quick Reference Guide, included in Appendix A
Lead and Copper Rule (LCR)	June 1991	Lead and Copper	Quick Reference Guide, Included in Appendix A
LCR Clarification of Requirements for Collecting Samples and Calculating Compliance	November 2004	Lead and Copper	Fact Sheet, included in Appendix A
Total Coliform Rule (TCR)	June 1989	Distribution System Microbial Pathogens	Quick Reference Guide, included in Appendix A
Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 D/DBPR)	December 1998	Disinfectants and Disinfection Byproducts	Quick Reference Guide, included in Appendix A
Interim Enhanced Surface Water Treatment Rule (IESWTR)	December 1998	Source Water Microbial Pathogens	Quick Reference Guide, included in Appendix A
Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR)	January 2002	Source Water Microbial Pathogens	Quick Reference Guide, included in Appendix A
Filter Backwash Recycling Rule (FBRR)	June 2001	Filter Backwash (Microbial Pathogens)	Quick Reference Guide, included in Appendix A
Surface Water Treatment Rule (SWTR)	June 1989	Source Water Microbial Pathogens	Summary information on the web at http://www.epa.gov/safewater/therule.html#Surface

Exhibit 2.2 Technology Alternatives and How They Potentially Affect Water Quality

	Inactivation of microbial pathogens	pH	alkalinity	disinfectant residual[1]	iron or manganese	turbidity	NOM	DBPs	corrosivity	AOC	taste and odor
Source Management[2]	May decrease if colder water is used	may increase or decrease	may increase or decrease		may increase		may decrease	may decrease	may increase or decrease		may increase
Distribution System BMPs				may increase		may increase if flushing not done properly		TTHM may decrease; HAA5 may decrease or increase	may decrease		may increase
Moving the Point of Chlorination Downstream	May decrease			may increase or decrease	may increase			decrease			
Decreasing pH	Increase (for chlorine only)	decrease	may decrease					TTHM may decrease, HAA5 may increase	may increase		
Reducing Chlorine Dose Under Warmer Water Conditions	may decrease	may increase or decrease		may decrease				decrease			
Presedimentation					may decrease	may decrease	may decrease	may decrease			
Enhanced Coagulation	may increase	decrease	may decrease		manganese may increase	may increase or decrease	decrease	decrease	may increase		
Softening/ Enhanced Softening	may increase, may decrease due to high pH	increase	may increase		may decrease	may decrease	may decrease	HAA5 may decrease, TTHM may increase	concrete corrosion may increase		

	Inactivation of microbial pathogens	pH	alkalinity	disinfectant residual[1]	iron or manganese	turbidity	NOM	DBPs	corrosivity	AOC	taste and odor
GAC						may increase due to GAC fines	decrease	decrease		may decrease if GAC is biologically active	decrease
Microfiltration/ Ultrafiltration					may decrease	decrease		may decrease			
Nanofiltration		may decrease	may decrease		decrease	decrease	may decrease	decrease	increase	may decrease	
Bank Filtration					may increase						
Bag Filtration					may decrease	may decrease					
Cartridge Filtration					may decrease	may decrease					
Second Stage Filtration					may decrease	decrease	may decrease	may decrease		may decrease	
Slow Sand Filtration					may decrease	may decrease	may decrease	may decrease			
DE Filtration					may decrease	may decrease					
Improved Filter Performance					may decrease	decrease	may decrease	may decrease			
Chloramines[3]	decrease			may increase				TTHM and HAA5 will decrease	may increase or decrease		may increase or decrease
Ozone[3]	increase for protozoa							may decrease, but increase in bromate	may increase or decrease		may increase or decrease
UV Disinfection[3]	UV dose is low for protozoa, need higher dose for viruses							decrease			

	Inactivation of microbial pathogens	pH	alkalinity	disinfectant residual[1]	iron or manganese	turbidity	NOM	DBPs	corrosivity	AOC	taste and odor
Chlorine Dioxide[3]	increase for protozoa, decrease for viruses				may decrease if followed by filtration			TTHM and HAA5 decrease, chlorite will be formed			may increase or decrease

1 Refers to the disinfectant residual in distribution system water.

2 For the purpose of this guidance, *source management* refers to techniques water systems can use to manipulate their water sources to comply with Stage 2 DBPR or LT2ESWTR regulations. In this context, source management does not refer to source water protection or other long-term watershed efforts to improve water quality. The source management techniques discussed in this section are operational changes made by water systems to use the source with the least amount of natural organic matter (NOM), or selecting a blend of sources to try to achieve the most effective treatment for organics and turbidity removal. Source management strategies can affect raw water quality or they can affect finished water quality directly (e.g., blending or alternating sources).

3 Water quality changes for alternative disinfectants are compared to conditions when free chlorine is used.

Appendix A
Summary of Pertinent Drinking Water Regulations

This appendix contains fact sheets and quick reference guides for the major rules discussed in this guidance manual. The fact sheets and quick reference guides are brief summaries of the major requirements of the rules. More detailed information on rule requirements and guidance can be found on EPA's Web site at http://www.epa.gov/safewater. The following is a list of fact sheets and quick reference guides that are included in this appendix and the order in which they appear:

Rule	***Date of Promulgation***	***Contaminant of Concern***	***Rule Summary Information Available from EPA***
Ground Water Rule (GWR)	November 2006	Source Water Microbial Pathogens	Fact Sheet
Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)	January 2006	Source Water Microbial Pathogens	Fact Sheet
Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR)	January 2006	Disinfection Byproducts	Fact Sheet
Arsenic and Clarifications to Compliance and New Source Monitoring Rule	January 2001	Arsenic	Quick Reference Guide
Lead and Copper Rule (LCR)	June 1991	Lead and Copper	Quick Reference Guide
LCR Clarification of Requirements for Collecting Samples and Calculating Compliance	March 2004	Lead and Copper	Fact Sheet
Total Coliform Rule (TCR)	June 1989	Distribution System Microbial Pathogens	Quick Reference Guide
Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 D/DBPR)	December 1998	Disinfectants and Disinfection Byproducts	Quick Reference Guide
Interim Enhanced Surface Water Treatment Rule (IESWTR)	December 1998	Source Water Microbial Pathogens	Quick Reference Guide
Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR)	January 2002	Source Water Microbial Pathogens	Quick Reference Guide
Filter Backwash Recycling Rule (FBRR)	June 2001	Filter Backwash (Microbial Pathogens)	Quick Reference Guide

Appendix M – Summary of Potential Benefits and Adverse Effects Associated with Different Combinations of Primary and Residual Disinfectants

Summary of Potential Benefits and Adverse Effects Associated with Different Combinations of Primary and Residual Disinfectants

Disinfection Switch (primary/residual, from ºto)	**Potential Benefits**	**Potential Adverse Effects**	**Drinking Water Regulation(s) Impacted**
Chlorine/Chlorine º Chlorine/Chloramines	• improved ability to maintain a disinfectant residual • lower TTHM and HAA5 • possible improved biofilm control • improved taste and odor	• excess ammonia can cause nitrification • possible elevated nitrite/nitrate levels • possible corrosion concerns • concerns for dialysis patients, fish owners, and other industrial customers	• Stage 2 DBPR • SWTR • TCR • LCR • Stage 1 DBPR • IESWTR • LT1ESWTR
Chlorine/Chlorine º Ozone/Chlorine	• Lower TTHM and HAA5 • *Cryptosporidium* inactivation • better taste and odor control	• Bromate MCL concerns • additional bromate monitoring required • may increase brominated DBPs • increased AOC may enhance biofilm growth	• Stage 2 DBPR • Stage 1 D/DBPR • LT2ESWTR • TCR
Chlorine/Chlorine º Ozone/Chloramines	• Lower TTHM and HAA5 • *Cryptosporidium* inactivation • improved ability to maintain disinfectant residual • may improve taste and odor	• nitrification may increase • possible elevated nitrite/nitrate levels • possible corrosion concerns • bromate MCL concerns • additional bromate monitoring required • increased AOC may enhance biofilm growth • concerns for dialysis patients, fish owners, and other industrial customers	• Stage 2 DBPR • Stage 1 D/DBPR • SWTR • LT2ESWTR • TCR • LCR
Chlorine/Chloramines º Chlorine Dioxide/ Chloramines	• Lower TTHM and HAA5 • *Cryptosporidium* inactivation • *Giardia* and virus inactivation • can control iron and manganese • chlorite from chlorine dioxide may control nitrification	• additional chlorine dioxide and chlorite monitoring required • chlorite MCL concerns • chlorine dioxide MRDL concerns	• Stage 2 DBPR • Stage 1 DBPR • LT2ESWTR • LCR
Chlorine/Chloramines º Ozone/Chloramines	• Lower TTHM and HAA5 • *Cryptosporidium* inactivation • improved taste and odor control • *Giardia* and virus inactivation	• increased AOC can encourage nitrification and biofilm growth • additional bromate monitoring required • ozone taste and odor issues • may create brominated DBPs • bromate MCL concerns	• Stage 2 DBPR • Stage 1 D/DBPR • LT2ESWTR • TCR • LCR
	• Lower TTHM and HAA5 • improved ability to maintain a disinfectant residual • improved taste and odor control *Giardia* and virus inactivation	• AOC may encourage nitrification • concerns for dialysis patients, fish owners, and other industrial customers • possible corrosion concerns	• Stage 2 DBPR • SWTR • TCR • LCR
Chlorine/Chlorine or Chlorine/Chloramines º UV/Chlorine or UV/Chloramines	• Lower TTHM and HAA5 • *Cryptosporidium* inactivation • *Giardia* and virus inactivation •	• UV less effective than chlorine at inactivating viruses • UV is not a pre-oxidant • less taste and odor control	• Stage 2 DBPR • SWTR • LT2ESWTR
Ozone/ Chlorine º Ozone/ UV/Chlorine	• additional *Cryptosporidium* inactivation • good taste and odor control • *Giardia* and virus inactivation	• ozone can lower UV transmittance	• LT2ESWTR

Appendix N – Preliminary Engineering

This Water Quality Study has resulted in a need to make the following modifications to the water system.

1. Modify Chlorine doses at current locations

   There are no facility modifications required as the equipment is existing.

2. Feed Powered Activated Carbon only during critical DBP formation periods (July - October)

   There are no facility modifications required as the equipment is existing.

3. Install mixing and exhaust fan equipment in the Waugh's Ferry and Union Hill storage tanks

   There are a number of devices available for mixing in water storage tanks. We have past experience and knowledge of the alternatives. We are proposing the use of the PAX equipment. The installed cost (including exhaust fans) is estimated to be $58,000 per tank.

4. Relocate the point of chlorine addition to the midpoint of the sedimentation basins

   The existing piping located at mid-point of the sedimentation basins will be replaced with new piping, injection nozzles, flow baffles, etc. Please see attached diagram (Figure 1) for the preliminary design. The installed cost for both basins is estimated to be $50,000.

5. Install sludge removal equipment in the sedimentation basins

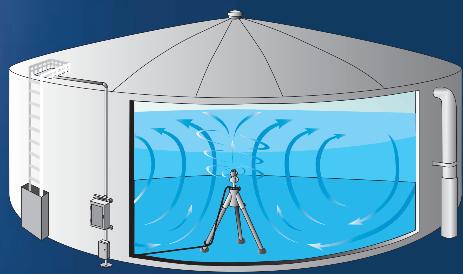
   There are a number of available equipment options to remove sludge from sedimentation basins. After review of the options, we propose the following: (Please see the attached diagram (Figure 2) for the preliminary design.) The installed cost for both basins is estimated to be $150,000.

ANY TANK. ANY SIZE.™

PAX Water Mixer (PWM400) Product Specifications

Using a PAX Water Mixer will...

- Lower DBP Production
- Reduce Nitrification Risk
- Prevent Ice Damage



PAX Water Mixer circulates residual throughout the entire tank.

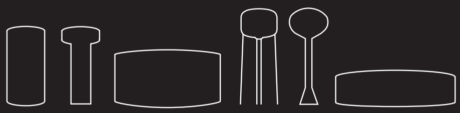
…and is more economical and reliable than Deep Cycling, Draft Tube Mixers and Passive Nozzles.

Smallest Footprint (Easy Installation)
Low Energy Requirements (Solar or Grid Powered)
SCADA Ready
Optional Chemical Injection System

Find out how a PAX Water Mixer can help you.
Call our Water Quality Specialists today at **1-866-729-6493**
or visit **www.paxwater.com**

PAX WATER TECHNOLOGIES™

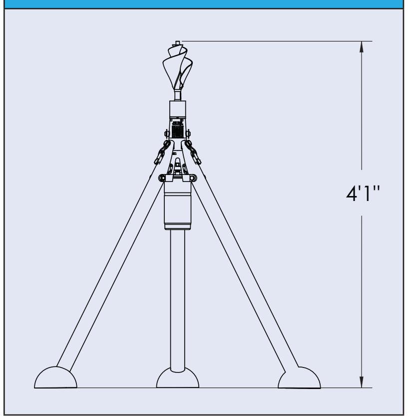
ANY TANK. ANY SIZE.™



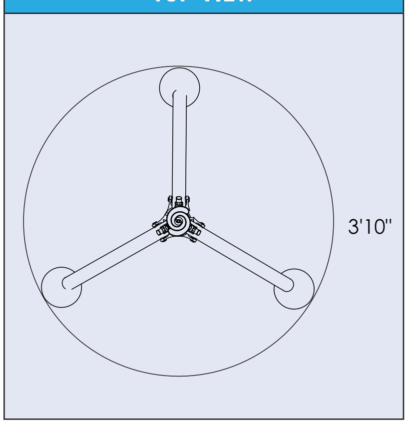
PAX Water Mixer (PWM400) Product Specifications

The PAX Water Mixer is an active, submersible mixing system for cost-effective management of drinking water quality in storage tanks and reservoirs. The mixer installs easily without service disruptions or tank modifications, and mixes on-demand to rapidly eliminate stratification, uniformly distribute disinfectants and prevent conditions favorable to nitrification. Efficient and effective mixing of large volumes is made possible by the patented impeller's characteristic axial jet which establishes a stable flow structure throughout the storage volume.

SIDE VIEW



TOP VIEW



MIXER SPECIFICATIONS	
Power Supply Requirement	120/240 VAC, 50/60 Hz, 15 amp circuit
Customer Supplied Power Switch	3R, fused, safety disconnect switch
Motor Type	115-230 VAC, water-filled, water-lubricated
RPM	1200
Nominal Power Draw	0.345 kVA (345 watts)
Impeller Specifications	316 stainless steel 8.3" (21.1 cm) tall x 4.5" (11.4 cm) diameter
Footprint Diameter	3' 10" (1.17 m)
Height	4' 1" (1.24 m)
Weight: Mixer Assembly	53 lbs (24 kg)
Weight: Control Center	29.5 lbs (13.4 kg)
Material: Control Center	Powder-coated carbon steel, 3R enclosure
Material: Stand	316 stainless steel
Material: Motor Seals	Chlorine/chloramine-resistant NBR rubber
Material: Feet	Chlorine/chloramine-resistant EPDM rubber
Wiring	NSF 61 & UL-listed submersible pump cable 14 AWG (2.1 mm^2) XLPE

NSF
Certified to NSF/ANSI 61-G

Find out how a PAX Water Mixer can help you.
Call our Water Quality Specialists today at **1-866-729-6493**
or visit **www.paxwater.com**

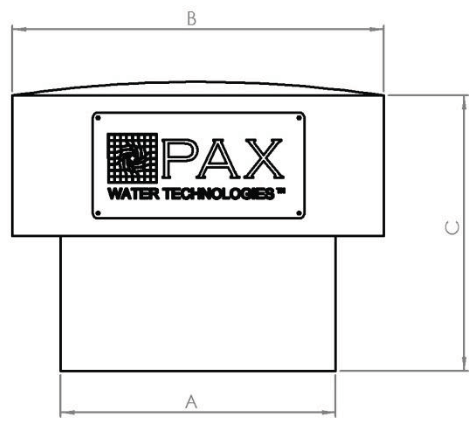
PAX WATER TECHNOLOGIES™

WATER TECHNOLOGIES™

Product Specifications: PAX PowerVent

Description

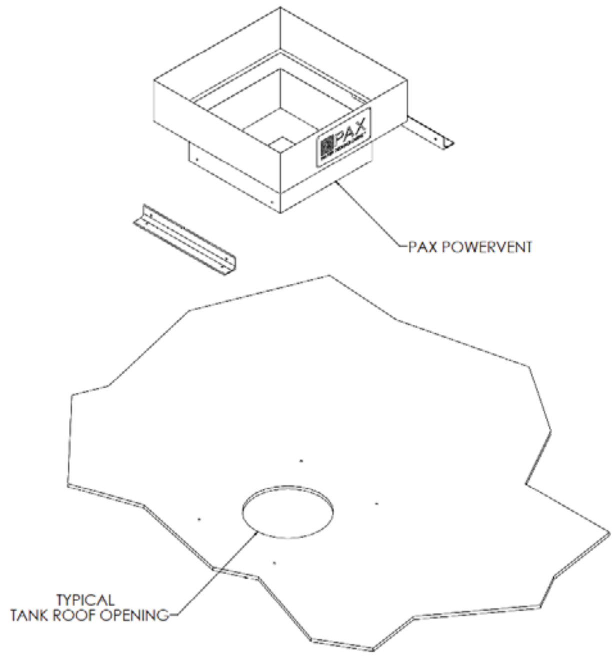
The PAX PowerVent is an active ventilation system for drinking water storage tank. The PowerVent is design to be installed at the roof of the storage tank. It is design to ensure efficient air circulation within the headspace of the tank and proper ventilation.



MODEL	A (inches)	B (inches)	C (inches)	Recommended roof opening (inches)	Weight (Lbs.)
PPV-200	**26**	**35**	**25 ¼**	**15 x 15**	**145**
PPV-400	**34**	**47+1/8**	**27 ¼**	**18 x 18**	**173**

Electrical Specifications

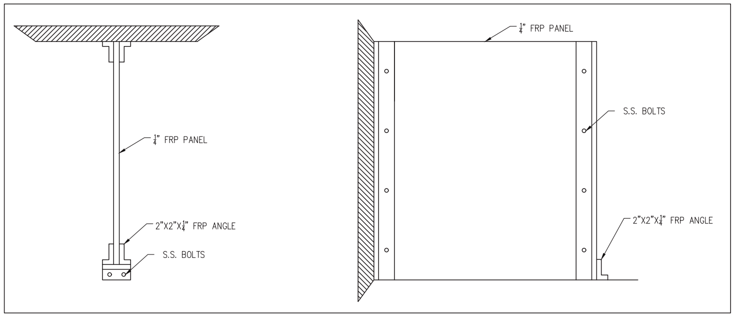
Standard 115V, 1-phase. Minimal 6.25 Amps. Nominal is 7.0 Amps.



PAX POWERVENT AS SHIPPED

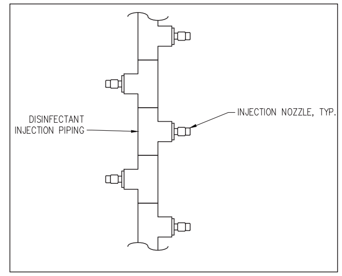
INSTALLED AC POWER WIRING

MOUNTING HARDWARE LOCATIONS



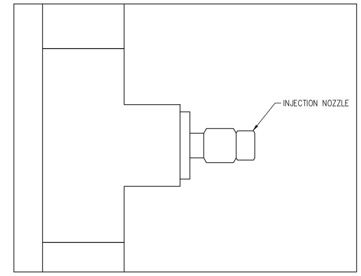
BAFFLE MOUNTING DETAIL

SCALE: NTS



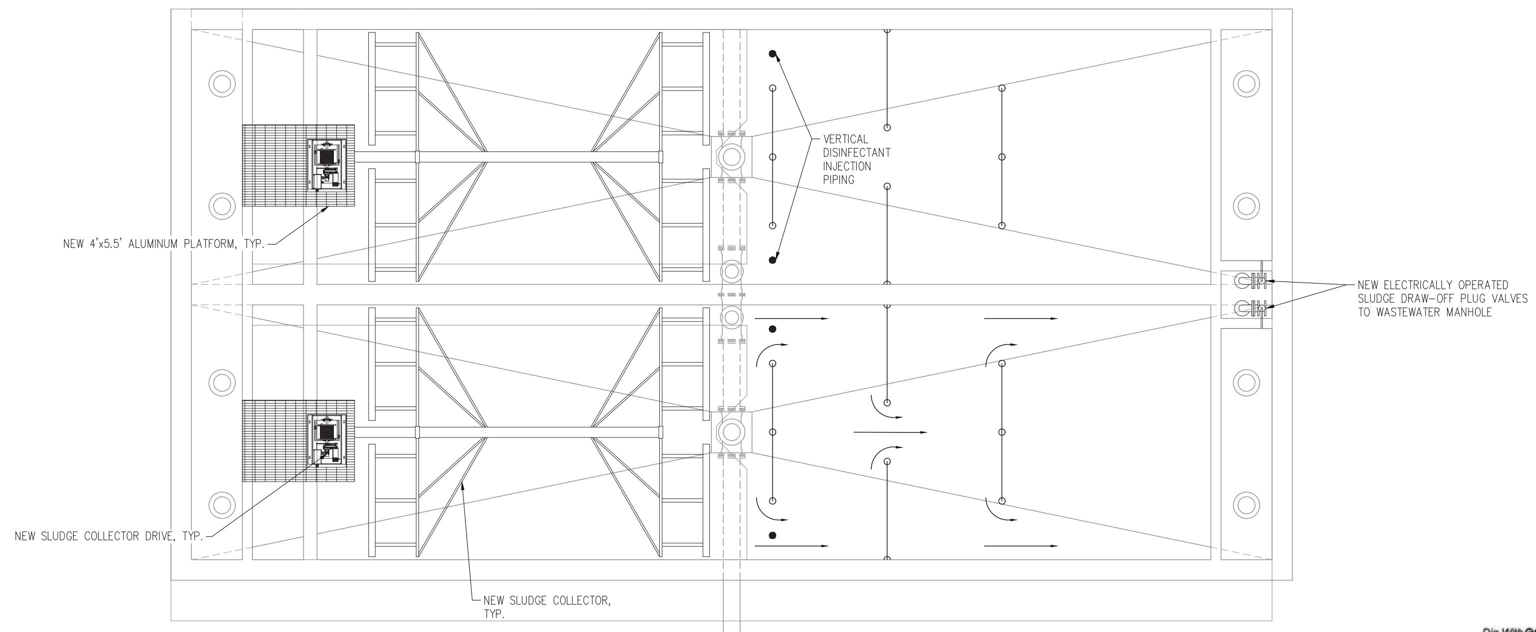
INJECTION PIPING DETAIL

SCALE: NTS



INJECTION NOZZLE DETAIL

SCALE: NTS



SEDIMENTATION BASINS PLAN

SCALE: NTS

PRELIMINARY

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DISINFECTANT INJECTION PLAN

TOWN OF AMHERST WATER TREATMENT PLANT IMPROVEMENTS

AMHERST COUNTY — VIRGINIA

COUNTY PROJECT NUMBER

PLAN STATUS

DATE	DESCRIPTION	
TJN	DWD/TCW	KMB
DESIGN	DRAWN	CHKD

SCALE H: N/A V: N/A

JOB No. 100059-01-001

DATE: DEC. 27, 2016

FILE No. 100059-01-001-XXX

SHEET 1 OF 2

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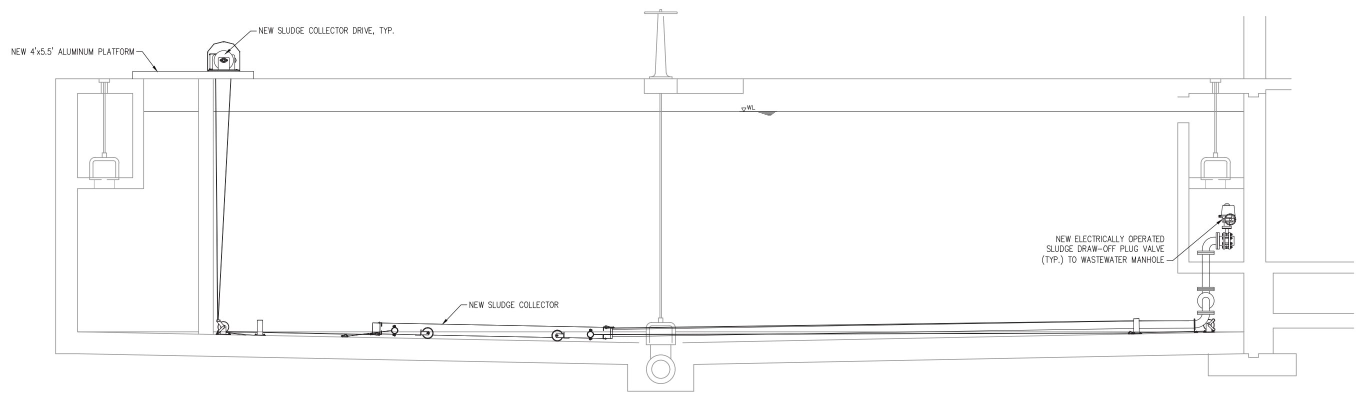
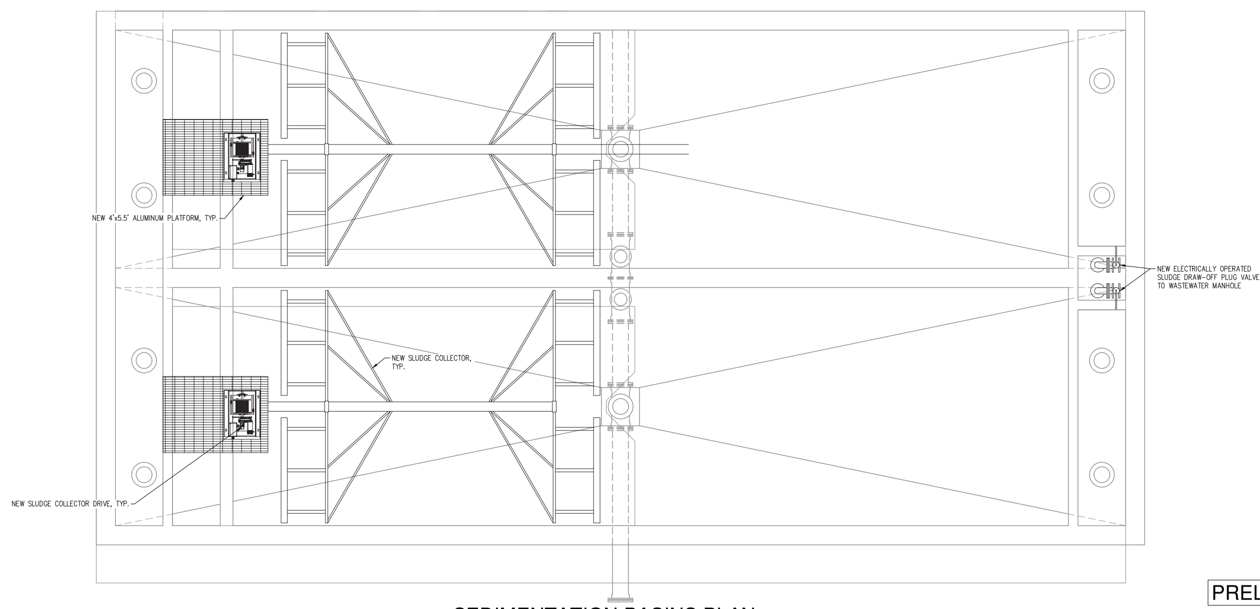


SEDIMENTATION BASINS SECTION

SCALE: NTS

NOTE:
SLUDGE COLLECTORS SHALL TRAVEL FULL LENGTH OF SEDIMENTATION BASIN.



SEDIMENTATION BASINS PLAN

SCALE: NTS

PRELIMINARY

NOTE: THESE PLANS AND SPECIFICATIONS INCLUDE PROPRIETARY INFORMATION. REPRODUCTION OF THESE PLANS AND SPECIFICATIONS IS NOT AUTHORIZED WITHOUT THE WRITTEN CONSENT OF BOWMAN CONSULTING GROUP, LTD.

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A Allow required time for marking.
R Respect the marks.
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SLUDGE COLLECTOR PLAN

TOWN OF AMHERST WATER TREATMENT PLANT IMPROVEMENTS

AMHERST COUNTY VIRGINIA

COUNTY PROJECT NUMBER

PLAN STATUS

DATE	DESCRIPTION	
TJN	DWD/TCW	KMB
DESIGN	DRAWN	CHKD

SCALE H: N/A V: N/A
JOB No. 100059-01-001
DATE: DEC. 27, 2016
FILE No. 100059-01-001-XXX
SHEET 2 OF 2

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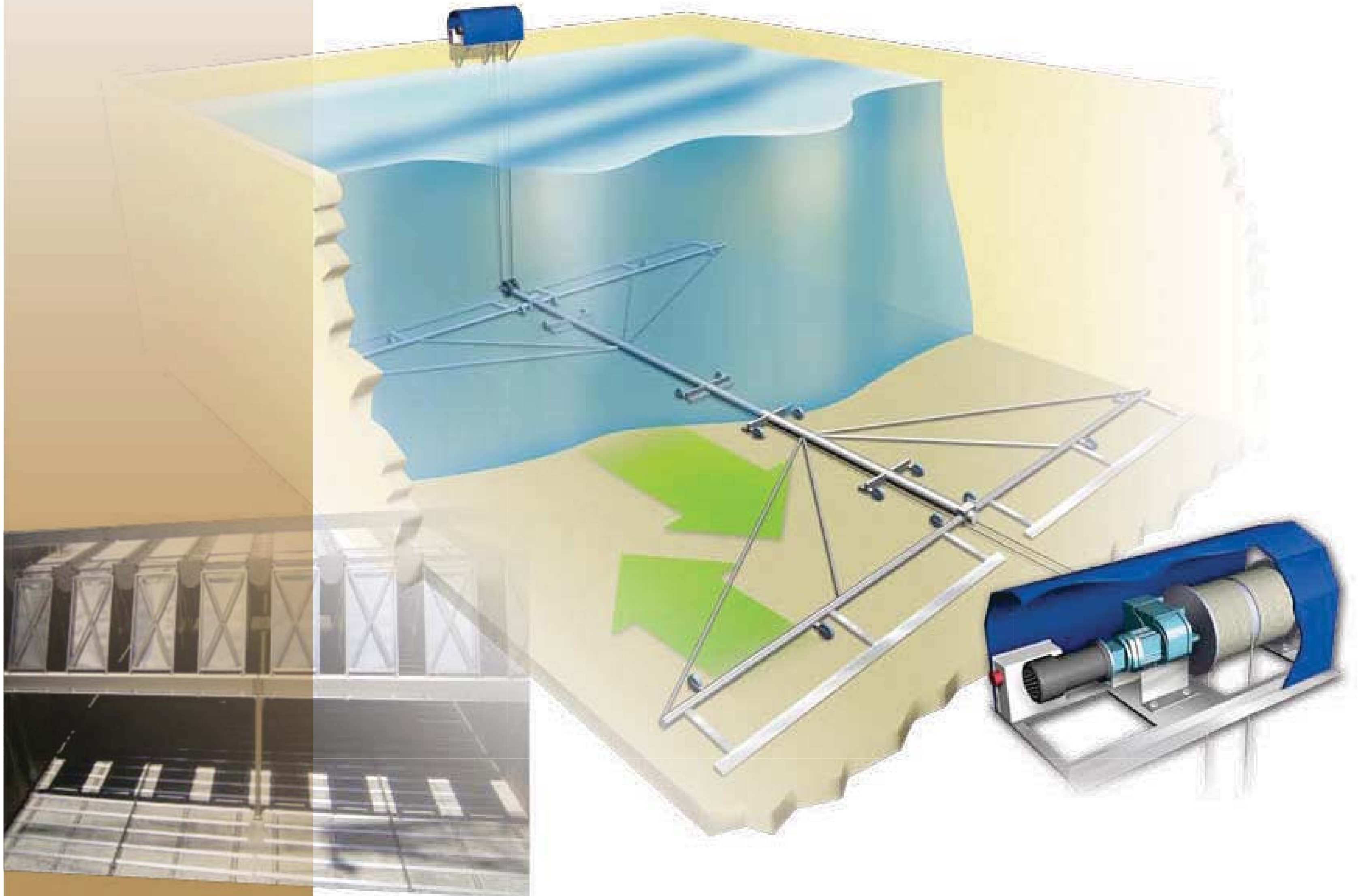
MRI SLUDGE COLLECTORS



The Optimal Choice for Sludge Collection:

MRI Hoseless Cable-Vac

MRI U/S Ultra-Scraper

MRI SLUDGE COLLECTORS

Sludge collection products built on ex

Meurer Research, Inc. began developing high-quality equipment in 1978 to provide water and wastewater treatment facilities with effective, reliable and economical methods of removing sludge from sedimentation basins. Over the years, MRI has built upon these standards by incorporating new ideas and technology into the design and manufacture of its products. The result is three fully engineered devices: one based on suction, the Hoseless Cable-Vac; one based on scraping, the U/S Ultra-Scraper; and one based on tradition, the Retro Cable-Vac.

THE EL SOBRANTE WATER TREATMENT PLANT IN OAKLAND, CA INSTALLED 22 MRI HOSELESS CABLE-VAC SYSTEMS.

MRI Hoseless Cable-Vac eliminates the hose.

Only the MRI Hoseless Cable-Vac™ sludge collector* delivers all the benefits of suction sludge removal without the need for hoses. Perfect for use in new or existing basins, the patented system has four key components:

- Tandem header pipes with tangential flow nozzles* optimize sludge removal
- Telescoping sludge conduit* eliminates the need for hoses and is self-priming
- Reel-to-Reel Drive* ensures reliable power without tensioning
- MRI's signature control system combines sophisticated operation with communications

MRI U/S Ultra-Scraper doubles performance.

Equipped with double-acting, reciprocating linear blades, the MRI U/S Ultra-Scraper is two times more effective than conventional scrapers. The high-capacity system has four key components:

- Two transport racks with scraper blades are assembled without field welding
- Reliable drive unit uses either hydraulic or electric power
- Cross collector optimizes sludge removal
- MRI's signature control system offers easy adaptability

perience.

At the facility in Brisbane, Australia, MRI U/S Ultra-Scrapers and Plate Settlers optimize tertiary wastewater treatment.

The water treatment plant in Piedmont, AL was completely refurbished with the MRI Retro Cable-Vac. (Top)

The Tobacco Road Water Treatment Plant in Augusta, GA utilizes the MRI Hoseless Cable-Vac under MRI stainless steel plate settlers. (Bottom)

MRI Retro Cable-Vac available as new system or retrofit.

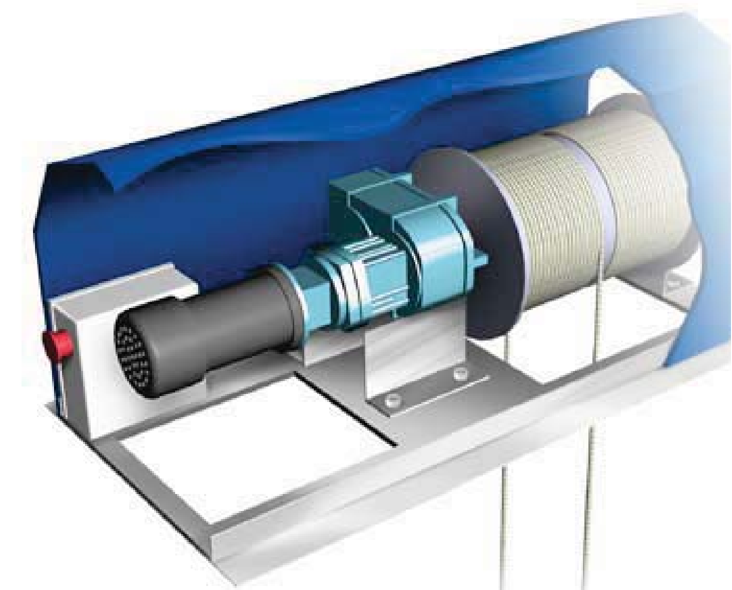
In addition to the Hoseless Cable-Vac and U/S Ultra-Scraper, MRI offers the Retro Cable-Vac with flexible hoses and guide rails. The Retro Cable-Vac is based on the original "Trac-Vac" system created by MRI in 1980. With well over 2,000 Trac-Vac systems sold, many have been refurbished to become like-new Cable-Vac sludge collectors. The Retro Cable-Vac is also available as a new system and consists of five main components:

- A single header pipe mounted on a traveling carriage
- A guide rail which extends the full tank length
- A sludge hose to transport the sludge from the header pipe out of the basin
- A Reel-to-Reel cable drive
- Control system

*Patented

Reel-to-Reel Drive ensures reliable pow

Built for simplicity, MRI's Reel-to-Reel Drive* makes the Hoseless Cable-Vac the ultimate in dependability. The above-water drive combines take-up and pay-out cables on one shared reel saving space and allowing a compact drum with the cable wrapped in a single layer without tensioning. Designed for continuous operation, the robust and energy efficient AC drive with variable frequency control can withstand a stall without sustaining damage.



EASY TO OPERATE, MRI'S MENU-DRIVEN, TOUCH SCREEN CONTROL SYSTEM IS DESIGNED TO MANAGE MULTIPLE HOSELESS CABLE-VAC UNITS. CONTROLS CAN BE PROGRAMMED TO FULLY MEET A TREATMENT PLANT'S SPECIFIC NEEDS.

Adaptable control system enables sophisticated operation.

The operator friendly control system automatically displays and manages all functions of the sludge collector. Through a programmable, menu-driven LCD touch screen, MRI control systems offer sophisticated SCADA and communications options and are powered by Rockwell International/Allen-Bradley. Variables include duration, speed, and frequency of operation which can be triggered by sludge depth, time, or signals from SCADA.

er.

Innovative tandem collectors maximize efficiency.

The key to the Hoseless Cable-Vac's ability to deliver increased solids removal is the innovative design of its tandem collectors.* Unlike conventional equipment, MRI's system has two collectors instead of one, with sludge collection orifices located on the side and facing forward, rather than pointing downward. This allows for enhanced, one-way directional sludge extraction as the assembly moves forward. On the reverse stroke, suction ceases. The orifices direct the sludge into the collection pipe tangentially (see illustration above), organizing the flow to remove more solids with less water and prevent clogging.

Unlike other systems, MRI's Hoseless Cable-Vac operates without guide rails on the basin floor enabling quick, simple installation. It can be used in new or existing basins with flat, sloping or slanted floors. Even in continuous operation, the collector is virtually maintenance free due to all stainless steel construction, long-life wheels and bearings, and a simple cable-winch drive.

Conventional Sludge Collector

In conventional sludge collectors (Figure A), the incoming flow enters at the bottom and continues upward, perpendicular to the internal flow, which is moving laterally toward the center outlet. This causes the two flows to collide at the orifices, disrupting the flow pattern and decreasing sludge removal.

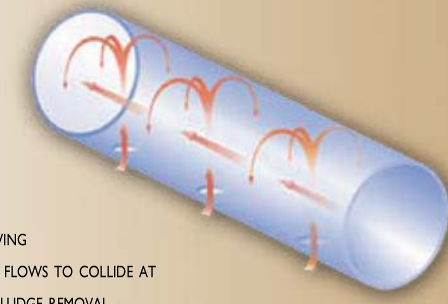


Figure A

MRI's Exclusive Tandem Collectors

With MRI's tandem collection design* (Figure B), the incoming flow enters tangentially to the bottom of each collector, causing the internal flow to travel in a spiral toward the center outlet. As the spiraling flow passes each orifice it is re-energized by the incoming flow. This creates a uniform, organized flow pattern that increases sludge removal and prevents clogging.

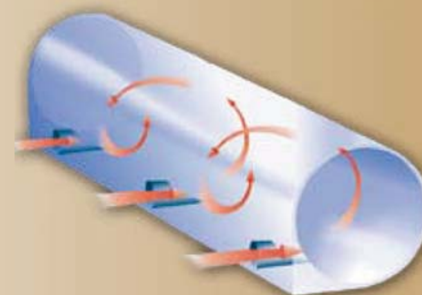
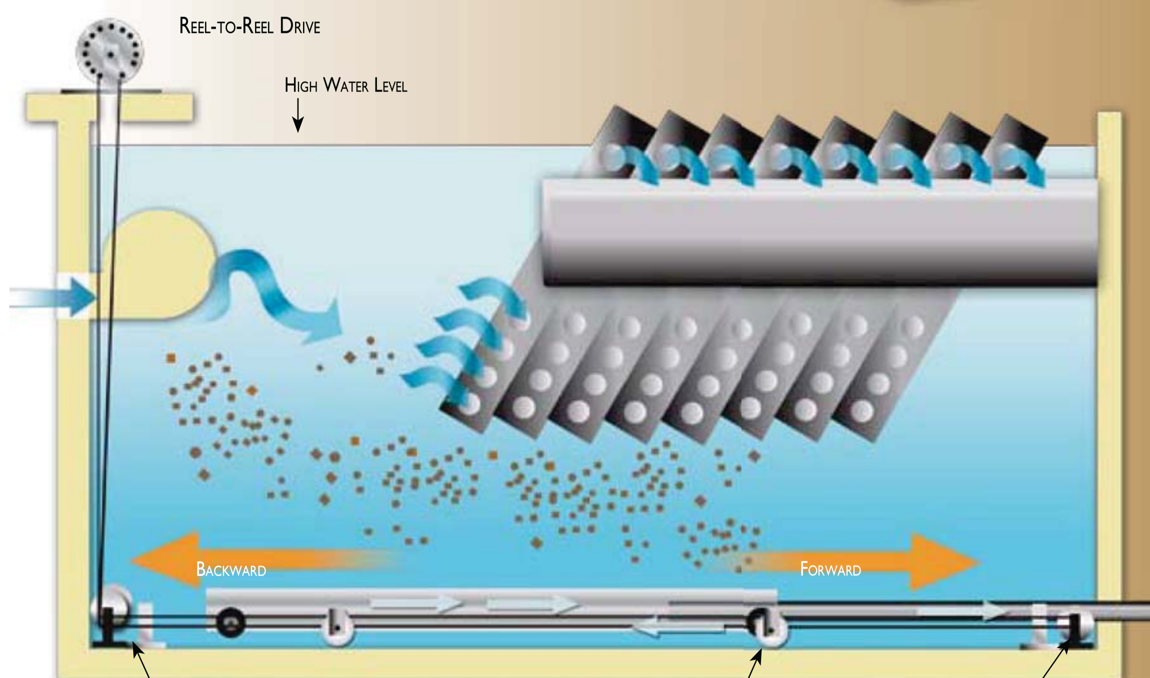


Figure B



Side view of MRI Hoseless Cable-Vac shows the simplicity of the single reel drive system. The low-profile design enables use under plate settlers, tube settlers or in open basins.

*Patented

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