INTRODUCTION

This report presents the findings of the Water Quality Study performed for the City of Rockville's water system, evaluating strategies and providing recommendations to the City for compliance with simultaneous Safe Drinking Water Act regulations applicable to distributed water quality, including the Surface Water Treatment Rule (SWTR), the Total Coliform Rule (TCR), Stage 2 Disinfectant / Disinfection Byproduct Rule (DBPR), and the Lead and Copper Rule (LCR). This report supersedes the April 2010 Interim Water Quality Report.

The scope of this study includes the following major tasks:

- Analyze the City's historical chlorine residual and DBP sampling data in order to better understand the water quality issues experienced.
- Evaluate water quality improvement strategies, and provide a set of feasible options along with steps to further evaluate the strategies for implementation in the City's system.
- Perform bench- and full-scale performance testing of alternative coagulants and distribution system operational enhancements (tank aeration and alternate chlorine dosing practices).
- Utilize the existing hydraulic model to analyze the effect of water age and to perform water age simulations of alternative improvements.
- Review the condition of the existing tanks, storage criteria and alternatives for meeting the storage requirements, while optimizing water quality and hydraulics.
- Collect and evaluate chlorine residual, DBP, and lead and copper data with the implementation of strategies at the full-scale, to evaluate simultaneous compliance with SWTR, Stage 2 DBPR, and LCR.
- Provide a recommended plan of action for the City of Rockville to follow for complying with the SWTR, Stage 2 DBPR, LCR, and other Safe Drinking Water Act (SDWA) regulations.

The work of this study was performed in conjunction with several other studies and improvement projects related to the Rockville WTP and distribution system (e.g. Distribution System Master Plan, the Water Treatment Plant Facility Plan, the Water Storage Tank Evaluation, and Twinbrook Rezoning Study). The scope of this study was modified to include further investigations into treatment alternatives and the combining of recommendations from this study with those of other related work. The ultimate goal of this combined effort was to provide the City with a comprehensive set of treatment and distribution system improvements and operational strategies to address water quality issues.

REGULATORY REQUIREMENTS

The key SDWA regulations that most affect the control of water quality in the City's water distribution system include the Surface Water Treatment Rule (SWTR), Total Coliform Rule (TCR), Stage 1 and Stage 2 Disinfectants / Disinfection By-Products Rule (DBPR), and the Lead and Copper Rule (LCR).

The SWTR requires the presence of an adequate disinfectant residual in the distribution system. The Maryland Department of the Environment (MDE) requires that a detectable disinfectant residual be present in 95 percent of the twice-monthly distribution system samples collected under the sampling provisions of the SWTR. The SWTR also requires a minimum disinfectant residual of 0.2 mg/L at the entrance to the distribution system.

The TCR establishes a Maximum Contaminant Limit (MCL), based upon the presence or absence of total coliforms. The rule also details the type and frequency of testing that water systems must do. Proposed revisions to the current TCR, focusing on frequency and location of monitoring, follow-up monitoring procedures after a total coliform positive is detected, conversion to a treatment technique for total coliform, and establishment of a maximum contaminant limit (MCL) for *e. Coli*, were published for comment in late summer 2010. The TCR revisions are scheduled for promulgation in November, 2012.

The Stage 1 DBPR established maximum contaminant levels (MCLs) of 80µg/L for TTHM and 60µg/L for HAA5. This is the DBPR which is currently in effect for the City. Compliance is based on a running annual average (RAA) of all quarterly samples taken at several sites within the system. In addition, the Stage 1 DBPR establishes a maximum disinfectant residual level (MDRL) of 4 mg/L for chlorine. Thus, the City is required to maintain its chlorine residuals in the distribution system between 0 and 4 mg/L.

Completed	• **October 1, 2007** – Submit IDSE Plan • **October 1, 2008** – Begin monitoring in accordance with approved IDSE Plan • **September 30, 2009** – Complete monitoring • **January 1, 2010** – Submit IDSE Report
Next Steps	• **October 1, 2013** – Complete Stage 2 DBPR Compliance Monitoring Plan and begin complying with the monitoring requirements of the Stage 2 DBPR (*states may allow up to 24 months additional time for compliance with MCLs for systems requiring capital improvements*) • **July 2014** – Begin compliance with rule requirements to determine compliance with the operational evaluation levels • **October 1, 2015** – Last date for compliance for systems requiring capital improvements

Figure ES-1: – Stage 2 DBPR Compliance Dates for Schedule 3 Systems

The Stage 2 DBPR established MCLs of 80 µg/L for TTHM and 60 µg/L for HAA5 as a locational running annual average (LRAA) for each quarterly sampling site selected through the Initial Distribution System Evaluation (IDSE) process, including worst-case TTHM and HAA5 sites. Also, quarterly monitoring under the Stage 2 DBPR must include the month of highest TTHM and HAA5 formation and must be done at 90-day intervals, eliminating some of the flexibility in terms of the timing of sample collection

which exists under the Stage 1 DBPR. MDE recognizes the City of Rockville as a Schedule 3 system (population served is 10,000–49,999). Key compliance deadlines for Schedule 3 systems are shown in Figure ES-1. In addition to the LRAA requirements of the Stage 2 DBPR, the rule also contains a requirement for systems to calculate Operational Evaluation Levels (OEL) at each monitoring site. If the OEL calculated exceeds the MCLs at any monitoring location, the system must conduct an operational evaluation of treatment and distribution practices and submit a report to MDE documenting the results within 90 days of submitting the analytical result that triggered the evaluation.

The LCR governs concentrations of lead and copper in water distribution systems and at customer taps. Promulgated by the EPA in June 1991, the rule has four major components, including establishing action levels for lead (15ppb) and copper (1.3ppm), increased monitoring programs based on the population served by the system, targeted samples are collected from locations where consumers are most likely to be exposed to increased copper or lead levels. Treatment technique requirements are triggered if greater than 10% of measurements exceed the action levels. In the event the lead action level is exceeded, the water system must undertake a number of additional actions to control corrosion, inform the public of protective steps that will safeguard their health, and potentially be required to replace existing lead service line(s). Revisions to the LCR were finalized in October 2007 and include changes to the monitoring requirements, requirements to obtain prior approval from the primacy agency before implementing treatment process changes that may increase lead corrosion, and changes in public notification procedures, among other revisions. The City has historically and is currently in compliance with LCR, and has qualified for reduced monitoring. However, if the City implements any major treatment process changes, MDE approval will be required and the City will be required to increase LCR monitoring.

HISTORICAL DATA ANALYSIS

Historical data analysis was performed to assess the City's compliance position relative to the SWTR, Stage 1 DBPR, Stage 2 DBPR, and the LCR. The analysis indicated that the City has a number of competing issues which will make simultaneous compliance with the SWTR and Stage 2 DBPR challenging under current operations. The City experienced several instances of low chlorine residuals during the summer and early fall of 2008.

A review of historical chlorine residual data from 2005 through 2008 indicated that several sites have had issues maintaining residuals prior to these events. High water ages, combined with high water temperatures and tuberculated cast-iron pipes, were identified as the primary contributors to the low chlorine residuals.

Due to high TTHM measurements in the distribution system, the City received a Stage 1 DBPR Notice of Violation (NOV) for exceeding the Running Annual Average (RAA) for TTHM in November 2008. TOC, chlorine dose, water age, and water temperature were all recognized as contributing factors to the elevated DBP formation in the system leading up to the NOV, and

action has been taken to reduce several of these variables in the system. Subsequent sampling after the 2008 NOV revealed levels below Stage 1 DBPR MCLs and so no further action was required by MDE to ensure compliance.

To identify the monitoring sites for the Stage 2 DBPR, the City completed the required year of quarterly DBP monitoring at the existing Stage 1 and planned Stage 2 monitoring sites in August 2009, in accordance with the Initial Distribution System Evaluation (IDSE) requirements of the Stage 2 DBPR. Details of the IDSE can be found in the Final IDSE Report, submitted to and approved by the Maryland Department of the Environment (MDE) and the United States Environmental Protection Agency (EPA) in December, 2009. From this analysis, four Stage 2 DBPR compliance monitoring sites were chosen:

- 5807 Halpine Road
- 1355 Piccard Drive
- 612 Oak Knoll Terrace
- 213 Luckett Street

The TTHM LRAA values reported at these four locations after the year of monitoring (11/2008 – 10/2009) were 71.6µg/L, 77.0µg/L, 84.4µg/L, and 106.8µg/L, respectively. The HAA5 LRAA values calculated at these four sites were 36.0µg/L, 48.5µg/L, 66.1µg/L, and 53.0µg/L. These levels indicate that TTHM and HAA5 were elevated to levels above the MCL at locations in the system. Several circumstances during the monitoring period contributed to these elevated levels, including high TOC levels in the raw water, high applied chlorine doses being utilized in response to low residual levels in the system, and changes in tank operating practices. In preparation for Stage 2 DBPR compliance, these and other issues are being addressed and evaluated during this study.

ALTERNATIVES ANALYSIS

The Water Quality Study focused on evaluating strategies and alternatives which could provide simultaneous compliance with the SWTR and Stage 2 DBPR. Table ES-2 provides a summary of the alternatives examined within this study. The alternatives have been categorized according to whether they are water treatment plant (WTP) or distribution system based strategies. Also included in the table are the results of an initial feasibility assessment provided in this report, and a summary of what action was performed to further evaluate alternatives initially deemed feasible for potential implementation.

Table ES-2: Summary of Alternative SWTR and Stage 2 DBPR Compliance Options

Alternative	Carried forward for further analysis? (Y/N)	Steps undertaken to further analyze or justification for eliminating alternative
Optimize Current WTP Operations		
1. Chlorine Dosage	Yes	Use semimonthly chlorine residual sampling and possible additional DBP sampling to monitor effectiveness.
2. Use TOC/UV_{254} correlation to optimize current WTP operations	Yes	Use sampling data to develop a correlation between raw water TOC concentrations and raw water UV-254 measurements that can be used in day-to-day chemical dose optimization.
3. Coagulation optimization / Alternative coagulant	Yes	Conduct bench-scale jar testing program, to include the following elements: • Determine the coagulant type and dose to optimize TOC, DBP precursor, turbidity and particle removal. Test alternate coagulants, including polyaluminum chloride (PACl), aluminum sulfate, ferric chloride and ferric sulfate. • Evaluate the type and required dosage of coagulant aid polymers. • Evaluate the need for and the required dosage of an acid feed for coagulant performance to enhance TOC and precursor removal. • Evaluate the effects of potassium permanganate as a pre-oxidant on DBP formation. Perform Full Scale testing program to evaluate effectiveness of implementing optimization of current coagulation strategy as well as to investigate advantages and disadvantages of changing coagulant based upon promising results from the bench scale evaluation
4. Powdered Activated Carbon	Yes	Perform bench scale jar test to evaluate PAC addition.
Implement Large Scale Treatment Modifications		
5. Primary or residual disinfection	No No	Change in primary disinfection to ozone or UV will not provide necessary DBP benefits to the City. Change in residual disinfection to chloramines is not recommended due to incompatibility with the free chlorine used in the interconnected WSSC system.
6. Magnetic Ion Exchange (MIEX®)	Yes	Perform bench scale jar tests to evaluate magnetic ion exchange resin (MIEX®).
7. Post-Filter Granular Activated Carbon (GAC)	Yes	Perform bench-scale rapid small-scale column testing (RSSCT) and/or pilot-scale 3-inch diameter column testing
8. Membranes	No	Nanofiltration membranes required to achieve significant DBP precursor removal. This would require a MF/UF pre-treatment membrane upstream of the nanofiltration membranes and would be very expensive (more so than MIEX or post-filter contactors).

Alternative	Carried forward for further analysis? (Y/N)	Steps undertaken to further analyze or justification for eliminating alternative
Implement Distribution System Operation Strategies for Reducing Water Age		
9. Flushing (Distribution System Pipes and Tanks)	Yes	Implement, along with localized flushing and use of autoflushing stations where needed. Develop a UDF program, focusing first on low chlorine residual areas. Use semimonthly chlorine residual sampling and additional spot checks of residuals to monitor effectiveness.
10. Assess Impact of Pipe Replacement	No	Results show no need for large-scale reprioritization. Small-scale reprioritization has occurred as dictated by UDF flushing results and to consider low chlorine residual locations. Replacement program has limited impact on water age, but replacing aging cast iron pipes will help better maintain chlorine residuals.
11. Strategies for Low Residual Sites	Yes	Develop strategies such as adding or moving up in priority in replacement program, autoflushing, or directing bulk water haulers to draw water at these locations to address these areas.
12. Examine Disconnected Loops / Dead Ends	No	No further analysis is needed. DPW is investigating dead-ends and implementing looping mains where feasible.
13. A. Permanently Take Tanks Offline B. Periodically Take Tanks Offline	Yes	Evaluate water quality and hydraulic impacts associated with taking Talbott Tank permanently offline (Part of Twinbrook Rezoning Study) and potential benefits of periodivcally taking tanks offline (operational strategy).
14. Optimize Tank Operation	Yes	Evaluate effects of increasing tank turnover and moderate reduction in storage volumes.
Implement Distribution System Treatment		
15. Mixing / Aeration Systems for Existing Storage Tanks	Yes	Test at full scale at Carr Tank. Coordinate testing program with MDE. Implement and evaluate a mixing and aeration system at Hunting Hill. Continue to evaluate and monitor the installed system at Carr Tank.
16. Booster Chlorination	Yes	Consider bench-scale analysis of booster chlorination. Coordinate testing program with MDE.
Storage Tank Replacement	Yes	For long-term tank planning, consider replacing Main Zone tanks with 4-6 MG of elevated storage in the vicinity of the existing Carr Avenue SP.

EVALUATION OF SURVIVING ALTERNATIVES

The feasibility analysis resulted in elimination of several alternatives. Summaries of data collection activities for evaluating the surviving options are presented in this report, including updated WTP and system water quality data, bench scale testing, full-scale coagulation testing, and evaluations of distribution system operations (including Carr Tank aeration). As the ultimate evaluation criteria for all parts of the water quality analysis are defined as maintaining system residual disinfectant and achieving DBP levels ensuring compliance with a margin of safety (defined as 80% of the MCL of 64µg/L and 48µg/L for TTHM and HAA5, respectively), data was collected from 2009 to 2011 in support of evaluations performed within this Water

Quality Report. An intensive sampling effort focusing on DBPs in the distribution system occurred between December 2010 and November 2011, with samples collected over the span of the evaluation from Stage 1 DBP locations, Stage 2 DBP locations, SWTR chlorine residual locations, "DBP study" locations, and at Carr Tank for aeration assessment. A summary of the evaluation results is presented below.

Optimize Current WTP Operations

Chlorine Dosages

Data evaluation indicates that total chlorine usage at the WTP has dropped significantly from 2009 to 2011, from an average daily value of 4.63 mg/L in 2009 to 3.66 mg/L in 2011. Peak daily chlorine dosages used in the summer and the duration of elevated chlorine usage has been reduced, and minimum daily chlorine concentrations used in the winter have been lowered while the duration of lower chlorine usage has lengthened. Used together, these strategies reduced the amount of DBPs formed in the system, as expected because chlorine is one of the key reactants for DBP formation. However, based on system monitoring performed during the study, the observed magnitude of improvement utilizing optimized chlorine dosing alone is not enough to reduce DBPs to below compliance with a factor of safety.

TOC/UV_{254} Correlation

The correlation developed between TOC and UV_{254} indicated that the two parameters are well correlated, and by measuring UV_{254} it is possible for the City to accurately estimate TOC levels in the raw water and in points within the WTP prior to addition of chlorine. The City has been measuring UV_{254} and using the parameter as a criterion for coagulant dosage since the end of 2010. Historical data evaluation indicate that the practice has been successful, reducing average finished water TOC values from 1.97 mg/L in 2010 to 1.54 mg/L in 2011, representing a 22% reduction in average finished TOC. However, while monitoring TOC by using UV_{254} as a surrogate is an important tool to be used in conjunction with other WTP treatment strategies, the practice alone is not enough to reduce DBPs to below compliance with a factor of safety.

Coagulation Optimization / Alternative Coagulant

Bench scale testing was performed to identify and compare promising coagulation alternatives, as well as to suggest improvements to current coagulation practices for maximizing TOC reduction and minimizing DBP formation. The bench scale evaluation indicated that elevated doses of PACl and the use of ferric chloride were promising coagulation strategies for lowering TOC, and displayed some potential benefit for limiting TTHM and HAA5 formation. Other adjustments to standard coagulation processes, including acid addition and addition of rapid mix, showed little benefit and resulted in operational issues, including lack of floc formation.

Based on the bench-scale testing results, full-scale testing of two strategies, optimizing PACl dose to target maximum UV_{254} reduction and the use of ferric chloride as an alternative coagulant, was performed. A full-scale trial was performed both in the winter (January/February) and summer (August) of 2011 to compare performance of optimized PACl and ferric chloride coagulation strategies for enhancing removal of UV_{254} and TOC, and

reducing distribution system DBPs. In addition, testing was designed to examine the potential for leaching of lead and copper from plumbing materials.

Full scale testing indicated that both coagulation strategies improved UV_{254}, TOC, and system DBPs when compared to the coagulation strategy traditionally implemented at the WTP. However, ferric chloride coagulation was shown to improve TTHMs measured at the Stage 2 DBPR compliance sites (and others), particularly during times of elevated water temperature. Implementing optimized ferric coagulation, combined with other improvements in chlorine dosing and distribution system operations, reduced calculated OELs and LRAAs at future Stage 2 DBPR compliance sites in 2011 to the level of compliance with a margin of safety.

In addition, lead and copper testing at several locations in the system occurred during the winter ferric trial, to evaluate LCR compliance implications associated with a change in coagulant to ferric chloride. This testing indicated that the change to ferric chloride would minimally impact lead and copper levels, and violation of the LCR is not likely with a change to ferric chloride coagulation at the WTP. However, changing primary coagulants is considered a major change and requires MDE approval and will require increased lead and copper monitoring.

Powdered Activated Carbon

Powdered activated carbon (PAC) was evaluated through bench scale testing. The analysis indicated that PAC at 15 minutes of contact time was capable of reducing UV_{254} and TOC in the post-settled water. PAC addition to the existing clarifiers is a process modification that can be readily made and bench scale testing indicated it had the potential to provide a limited amount of additional organics removal. However, because of the contact time concerns and substantial solids associated with PAC, and the limited improvement in DBPs observed at the bench scale, the alternative was removed from the final compliance strategy.

Large Scale Treatment Modifications

Magnetic Ion Exchange (MIEX®)

MIEX® was evaluated through bench scale testing. The analysis indicated that 1 mL/L MIEX® was an appropriate dose for the Rockville WTP, and resulted in approximately 20% additional UV_{254} reduction. However, significant reductions in 9-Day SDS TTHM and HAA5 values were not observed when compared with other treatment strategies. Additionally, MIEX® treatment is a costly treatment strategy, and as of yet there are few current installations of the size required at the Rockville WTP. Because of these concerns, and the limited improvement in DBPs observed under the conditions tested at the bench scale, the alternative was removed from the recommended final compliance strategy.

Post-Filter GAC Contactors

Granular Activated Carbon (GAC) is commonly used in a post-filter contactor arrangement for additional TOC removal. As TOC is a precursor to DBPs, reduction by GAC leads to lower DBP levels throughout the distribution system. GAC is extremely effective for removing TOC, and also taste and odor (T&O) causing compounds, trace and synthetic organic compounds (SOCs), pesticides and herbicides, and emerging contaminants such as endocrine disrupting

compounds (EDCs) and pharmaceutical and personal care products (PPCPs). The ability of GAC to remove a wide variety of organic compounds makes it an attractive option as a final treatment step (after filtration). The operation of GAC contactors is similar to the operation of filters and does not require intense operator-training during startup.

However, the capital cost and annual O&M cost for GAC contactors can be high. Depending on the filtered water TOC (GAC influent TOC) and desired GAC effluent TOC, the GAC may be exhausted and need to be replaced annually or even more frequently. When exhausted, the GAC can be replaced with either new virgin GAC or with custom-regenerated GAC. Preliminary calculations for the Rockville system indicated that using GAC with PACl would likely require replacement or regeneration on the order of 12 months, while using GAC with Ferric Chloride coagulation may extend GAC exhaustion to approximately 18 months. However, piloting is required to determine important design parameters such as size of the system to achieve target TOC, and exhaustion and regeneration (or replacement) costs.

Due to the fact that post-filter GAC contactors are an effective TOC removal technology and can be implemented to ensure Stage 2 DBPR compliance, the strategy was included in the DBP compliance toolbox as an option for advanced TOC removal if necessary. Due to the potential decrease DBPs which may be observed with implementation of ferric chloride, GAC was not recommended for immediate implementation.

Distribution System Operations

Flushing

Distribution system pipe and tank flushing is a means of temporarily increasing demand in the system, thereby reducing water age and limiting DBP formation. The City is currently employing uni-directional flushing (UDF) as part of the distribution system operations and maintenance practice. The program initially focused on those areas of the system that have demonstrated low chlorine residuals in the past, and has been expanded to all portions of the distribution system.

Strategies for Low Residual Sites

Additional modeling was performed based on prior discussions of localized activities in areas of low chlorine residuals (e.g., Halpine). Modeling results indicate that auto-flushing devices will not be adequate to sufficiently reduce water age to the point where chlorine decay will no longer result in low residual levels. Auto-flushing was therefore removed from further consideration as a permanent strategy.

Installation of a temporary bypass line in the vicinity of Halpine was also evaluated through modeling. This strategy appeared to help reduce the magnitude of the low chlorine residual issue in that location, and the City is in the process of implementing a permanent bypass line in that location. Similar analyses should be performed on a case-by-case basis in other areas of the system with old water / low chlorine residuals.

Permanently and/or Periodically Taking Tanks Offline

Additional modeling was performed in order to assess the potential water quality benefits and resultant hydraulic impacts of taking the existing water tanks offline. Source trace analysis was also utilized to understand the "zone of influence" of the tanks under current and modified operational levels. Taking the Carr and/or Hunting Hill tanks off-line had limited impact on the water quality compliance locations due to their zone of influence being confined to the areas in the immediate vicinity of the tank. Any potential nominal water quality benefit is offset by the reduction in emergency storage volume, system reliability and reduced hydraulic performance of the system resulting from taking storage offline.

The Talbott tank and its operation in the City's Twinbrook low pressure zone were evaluated specifically to determine the water quality impact of this tank. The Talbott Tank has been determined through modeling to provide limited hydraulic benefit to the pressure zone as well as requires a significant investment for tank rehabilitation and maintenance. This is primarily due to its overflow elevation relative to the service elevations in the existing zone. The City is planning abandonment and removal of this tank coupled with a gradual or incremental rezoning of the Twinbrook zone in order to improve water quality by moving more water past the Halpine compliance point, as well as to improve system hydraulics (domestic and fire flow and pressure) and save cost.

Optimize Tank Operation

The City has already implemented a tank operations optimization program whereby the operating level in the storage tanks has been reduced to increase tank turnover and reduce the volume of water stored in the tanks (all to lower water age). Preliminary indications are that there have been no detrimental hydraulic impacts from this altered operating practice, and it is recommended that the City continue to optimize tank levels as a standard operating procedure.

Distribution System Treatment Strategies

Tank Mixing / Aeration

A significant reduction in TTHMs in Carr Tank and in the immediate zone of influence of Carr Tank was observed with implementation of a DPW custom designed tank mixing/aeration system, including at the Oak Knoll Stage 2 DBPR compliance site. Observed TTHM reductions did not indicate that chloroform (the most volatile of the TTHMs) was removed significantly in comparison with the other, less volatile TTHMs, indicated that the reductions observed at Carr Tank were likely due improved mixing within the tank, and not aeration. The results also indicated that the observed TTHM reductions were localized, and that this strategy implemented only at Carr Tank will not be an effective DBP reduction method across the entire system.

The City recently solicited assistance in design and installation of an aeration and mixing system in a larger storage tank in the system (Hunting Hill tank). The City should collect data evaluating the impacts of Hunting Hill tank aeration and utilize this information along with the Carr Tank data to determine the extent of TTHM reductions in which can be expected in the system, and at Stage 2 DBPR compliance sites. In general, the City should consider tank aeration/mixing as one of the "tools in the toolbox" for Stage 2 DBPR compliance but not the

sole means of achieving the LRAA MCLs. This strategy was included in the Final Water Quality Recommendations.

Booster Chlorination

As the revised chlorination practices at the Rockville WTP have shown benefit in controlling distribution system free chlorine residuals, along with the flushing and bypass piping arrangements noted previously, it is not recommended that booster chlorination facilities be constructed at remote sites in the distribution system. These can be difficult to operate and are potential sources of system vulnerability, and so should be avoided if possible. Booster chlorination was not included in the Final Water Quality recommendations; however this function may be necessary depending on the storage tank aeration and mixing systems.

Storage Tank Replacement or Modification

The final aspect of distribution system operations that was evaluated was whether or not to replace the existing ground level tanks with new elevated storage. The approach used to evaluate the potential benefit of a new elevated water storage tank program involved utilizing the City's water model to evaluate the impact on water age resulting from addition of elevated storage. A secondary consideration was improvement to system hydraulic performance, including the opportunity for raising the system overflow elevation that a new tank program represents.

Based on the analysis, the following conclusions were drawn regarding the proposed new tank program versus the existing tanks relative to water age:

- The new tank program (two new 2.0 mg elevated water tanks) results in a substantial decrease in water age in the tanks and in the system in general. This is a result of reducing the overall stored volume from 12.0 mg to 4.0 mg and the subsequent increase in usable volume as a percentage total stored volume.
- Water tank operation is critical to reducing water age, the proposed elevated water tanks would be cycled down to 1/4 to 1/3 tank volume, which results in overall reduced water age.
- Water ages for the Stage 2 DBPR compliance locations under the new tank program are well within the age range goals; however, not significantly less than the existing conditions.

Because it is recognized that tank replacement will reduce water age and provide water quality benefits throughout the distribution system, it is recommended that the City include replacement of existing ground level storage tanks with new elevated storage in their long-term CIP. However, the tank inspection reports provided by World International Testing (WIT, dated December 2010 – Carr Tank, April 2011 – Hunting Hill Tank, May 2011 – Talbot Tank), indicate that the tanks are in good condition, and if properly maintained and rehabbed, the life cycle of the tanks (structural integrity) will be between 40 and 50 years. Additionally, source trace analysis performed within the study indicates that the majority of water at the Stage 2 DBPR compliance locations is provided directly from the WTP flow. As a result, the impact of the tank

water age reduction on the immediate goal of Stage 2 DBPR compliance will likely be minimal compared to implementation of GAC at the WTP. Because both options are capital intensive, implementation of GAC is recommended in lieu of tank replacement if an additional compliance strategy is needed to achieve Stage 2 DBPR compliance.

Summary. In summary, the strategies which are recommended for immediate inclusion in the City's compliance program toolbox are:

- Continue to optimize chlorine dosage to provide the minimal concentration at the WTP while ensuring adequate residual at monitored locations in the system
- Continue to utilize UV absorbance at 254nm to estimate raw and settled water TOC, and as a tool for determining coagulant dose in an effort to maximize TOC and turbidity removal.
- Change coagulant to ferric chloride
- Continue distribution system flushing practices
- Continue to develop strategies to address low residual chlorine areas
- Continue to optimize tank operation by increasing turnover and periodically draining and flushing the tanks
- Remove Talbott Tank from service and rezone the Twinbrook pressure zone incrementally to gain water quality and hydraulic benefits
- Aeration/Mixing at Carr Tank
- Aeration/Mixing at Hunting Hill Tank

Additional identified strategies include GAC and storage tank replacements, are available to the City if implementation of the strategies outlined above are unable to achieve compliance with a margin of safety. A detailed analysis of system DBP levels was performed to help prioritize and evaluate implementation of improvements. The analysis is described below.

LRAA AND OEL CALCULATIONS

To help identify a preferred compliance program, an evaluation of DBP levels at Stage 2 DBPR monitoring locations in 2011 was performed, accounting for many of the suggested process and operational changes outlined above. In 2011, operations at the WTP included optimizing residual chlorine dose, optimizing coagulant dose based upon UV_{254} absorbance as well as turbidity performance, and periodic ferric chloride coagulation trials (winter/spring and summer). In the distribution system, tank levels were adjusted to reduce water age and a DPW custom designed aeration/mixing system was placed in Carr Tank in the summer for DBP control. To evaluate the impact of implementation of these strategies, DBP data was collected from each of the future Stage 2 compliance sites according to the schedule outlined in the Stage 2 DBPR (second week of the second month of each quarter, plus or minus one week as allowed in the regulation). Values for the LRAA and OEL were then calculated with this 2011 data, and are summarized below in Figures ES-2 – ES-5.

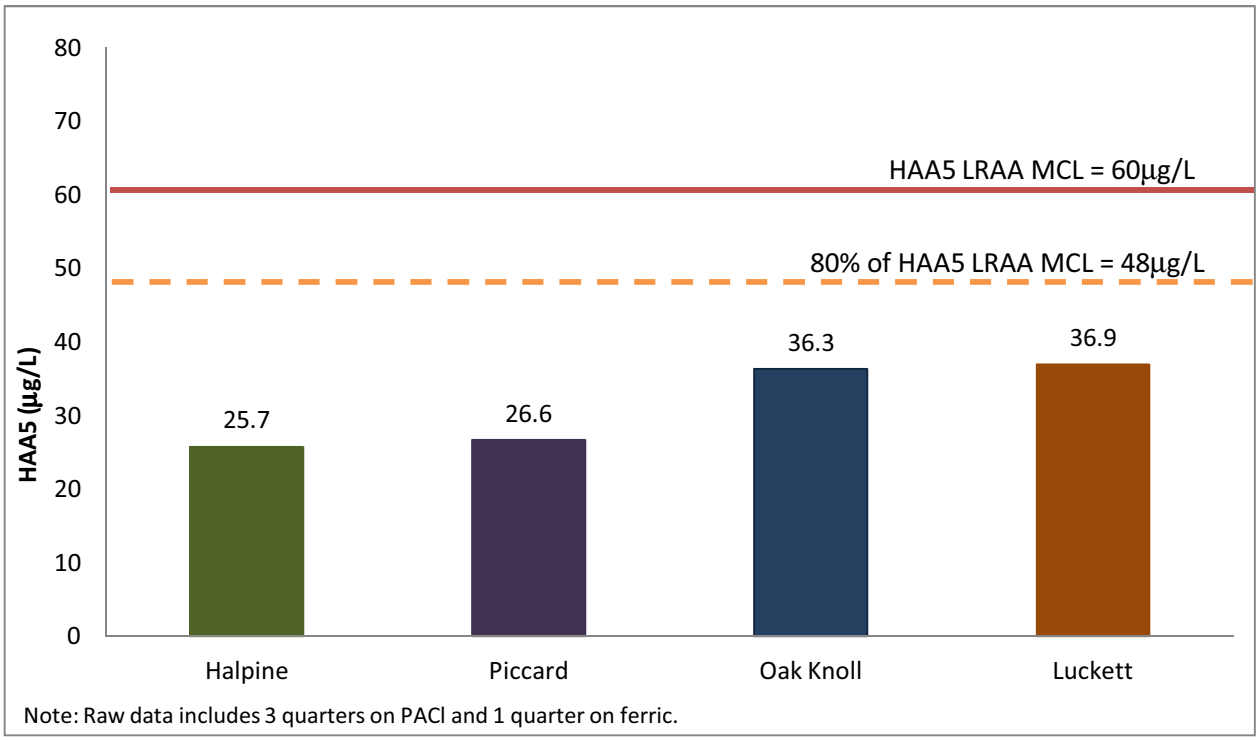

Figure ES-2: 2011 HAA5 LRAA

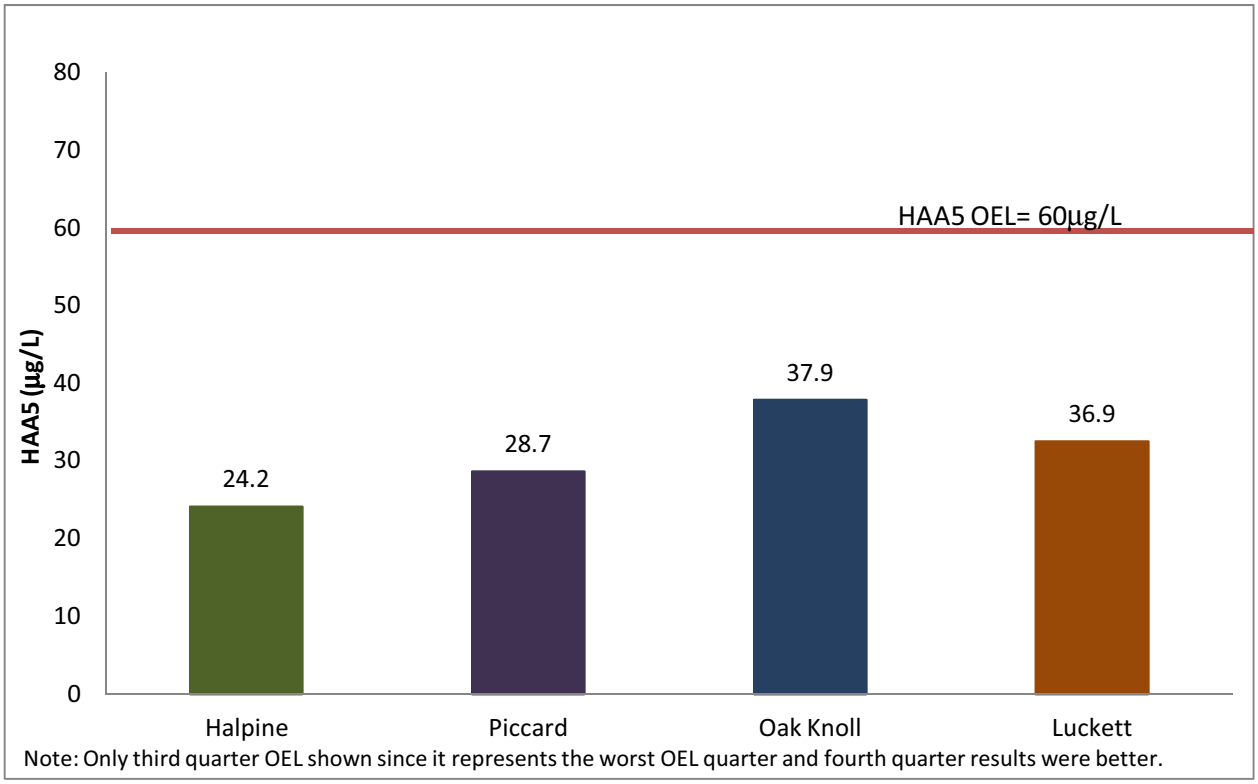

Figure ES-3: Third Quarter 2011 HAA5 OEL.

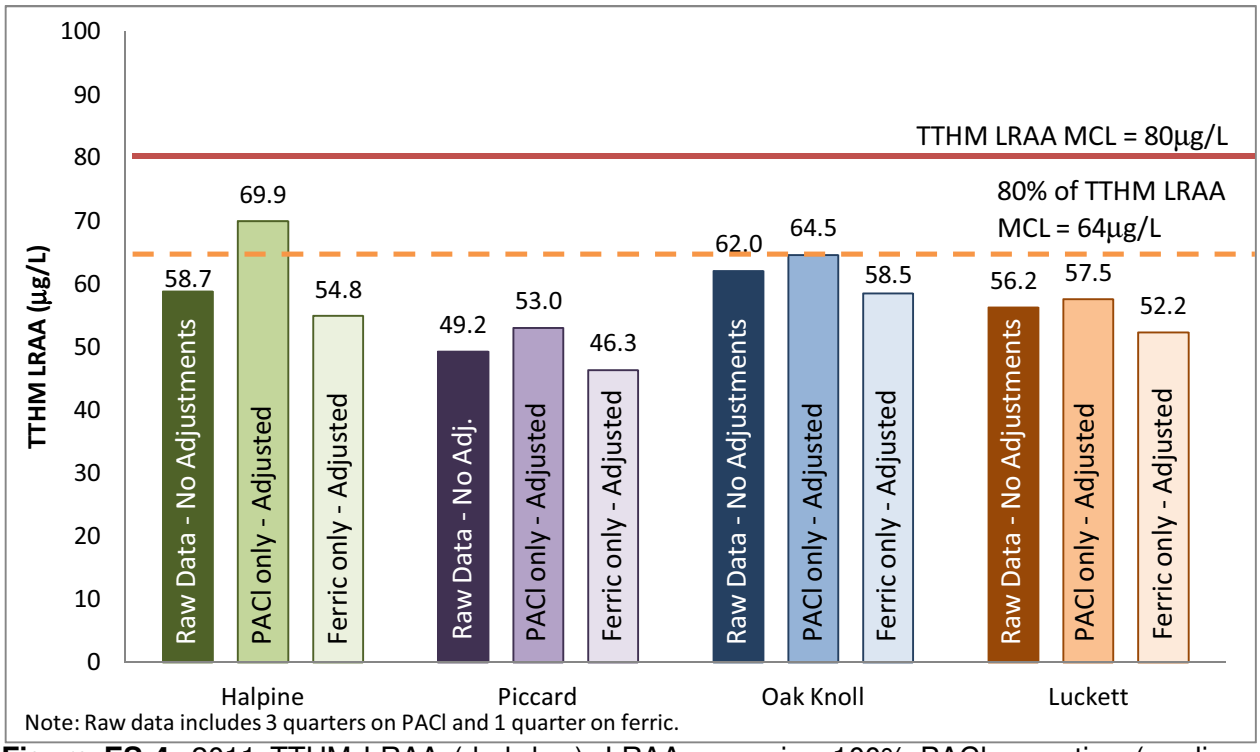

Figure ES-4: 2011 TTHM LRAA (dark bar), LRAA assuming 100% PACl operation (medium shaded bar), and LRAA assuming 100% Ferric operation (light bar).

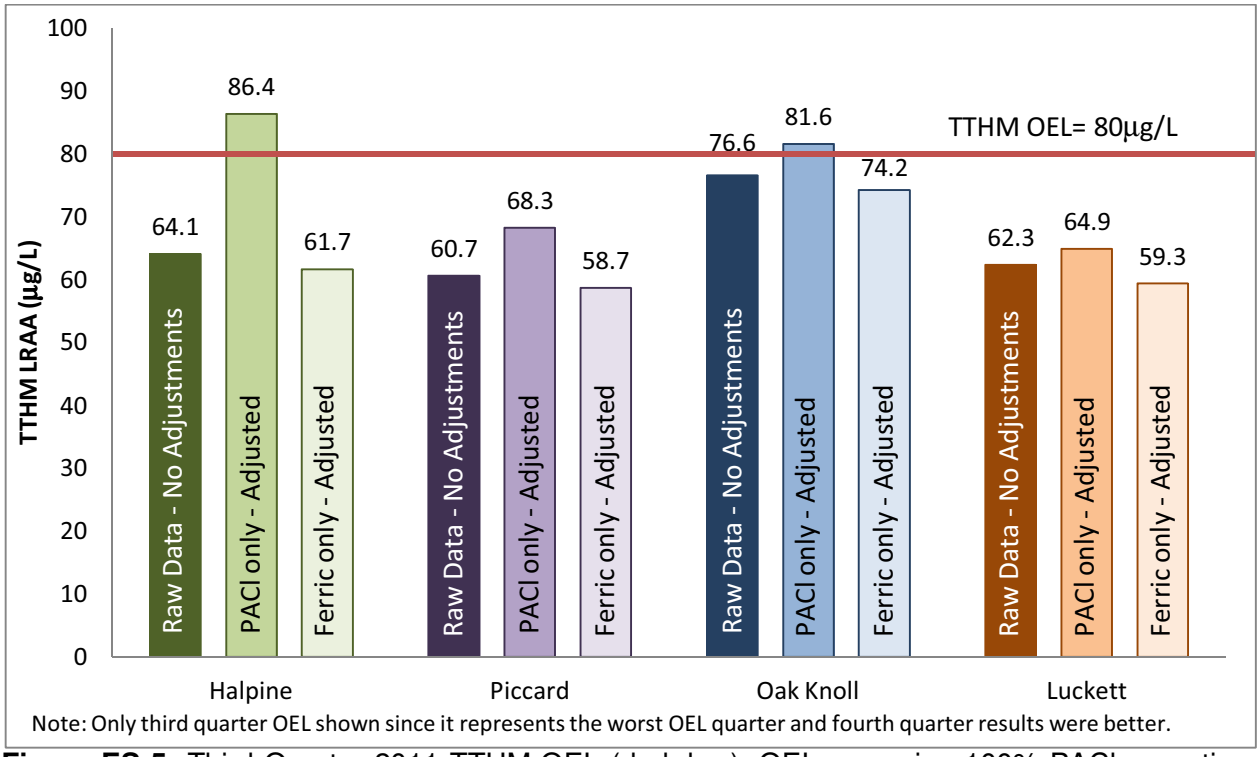

Figure ES-5: Third Quarter 2011 TTHM OEL (dark bar), OEL assuming 100% PACl operation (medium shaded bar), and OEL assuming 100% Ferric operation (light bar).

The data shown in Figures ES-2 and ES-3, collected while using PACl in quarters 1, 2, and 4 and ferric chloride in quarter 3, indicate that HAA5 levels were well below both the LRAA MCL with a margin of safety and OELs. The dark bars shown in Figures ES-4 and ES-5, reflecting the use of PACl in quarters 1, 2, and 4 and ferric chloride in quarter 3, indicate that the 2011 calculated LRAA values at all sites were less than 80% of the MCL, representing TTHM compliance with a margin of safety. Additionally, there were no third quarter TTHM OEL exceedences, although the level at Oak Knoll was 97% of the OEL. The data shown in Figures ES-2 – ES-5 indicate that in 2011, implementing all to-date WTP and system operational improvements (including chlorine and coagulant dosage optimization, adjusted tank operation, and Carr Tank aeration affecting the Luckett Street location), along with a change from PACl to ferric chloride coagulation during the summer quarter 3 data collection period, would achieve Stage 2 DBPR compliance with a margin of safety.

Further analysis was performed to assess the TTHM situation that may have occurred had ferric chloride not been utilized in the summer during the third quarter data collection. Quarter 3 TTHM data was substituted with the nearest PACl summer data, representing TTHM values which would have occurred during the second week of August had PACl been used for coagulation instead of ferric chloride. These data are shown in the medium shaded bars in Figures ES-4 and ES-5. If PACl was used year-round, it is likely that the LRAA with a margin of safety threshold would have been exceeded at two locations (Halpine, 70µg/L and Oak Knoll, 65µg/L). In addition, the OEL would have been violated at these two sites in the third quarter, prompting an operational evaluation at the WTP.

A third TTHM case was also evaluated. To examine the improvement in TTHMs if ferric chloride had been implemented year-round, a 10% adjustment factor was applied to the TTHM data collected in the first, second, and fourth quarters. Described in greater detail in the full text, this assumption is representative of the average measured TTHM improvement when the coagulant at the WTP was ferric instead of PACl (during full-scale trials). These data are shown as the light bars in Figures ES-4 and ES-5, and indicate that a further margin of safety would be achieved had ferric chloride coagulation been used at the WTP for the entirety of 2011.

Although the data in ES-4 indicate that compliance with a margin of safety is likely achieved using either year-round ferric chloride coagulation, or with summer-only ferric (represented with the “raw data”), the latter strategy is not recommended for the City. There are several reasons for this recommendation, focusing on operational constraints associated with the need to avoid mixing ferric and PACl coagulants as well as residuals associated with the coagulants. Mixing of PACl and ferric based residual solids forms a congealed, pasty material which is very difficult to clean from surfaces. Additionally, as the pH is reduced during ferric coagulation, the solubility limit of aluminum is approached, allowing for the release of soluble aluminum from the solids and leading to filter blinding or elevated aluminum concentrations in the finished water. While these consequences can be avoided by segregating the coagulants and solids during transitions, there is currently not enough operational flexibility to ensure this separation at the WTP without impacting production. Therefore, implementing a seasonal strategy would require significant improvements at the WTP, and is not recommended.

The analysis indicates that operating with PACl coagulation would not have ensured compliance with a margin of safety in 2011, even with the implementation of other process operation improvements. However, changing to Ferric for coagulation, in addition to the other process operation improvements instituted in the system, resulted in values achieving Stage 2 DBPR compliance with a margin of safety and to ensure the OEL is not exceeded. By employing ferric chloride coagulation year round, improvements in finished water quality will be observed, particularly with respect to lowering TTHMs at the Stage 2 DBPR compliance sites.

Impact of Potomac Raw Water Quality. Although the data presented in Figures ES-2 through ES - 5 indicates that compliance would have been achieved by using ferric chloride had the Stage 2 DBPR been in effect in 2011, it must be recognized that the variable water quality in the Potomac River has contributed to elevated DBP levels in the Rockville system in the past, indicating that compliance in 2011 may not be indicative of compliance under the worst-case conditions. TOC is a surrogate parameter describing the levels of DBP precursors in water, and a comparison of TOC data from previous years indicates that 2011 levels were consistent and relatively low (average = 2.5 mg/L, maximum = 3.1 mg/L). For comparison, the maximum 2011 TOC value was exceeded in raw water samples 13 times out of 31 total samples collected between 2008 and 2010, with a maximum measured TOC of 11.3 mg/L in September 2008. This indicates that high variability in raw water TOC can be expected in the future, with elevated TOC levels in the Potomac often associated with heavy rains following dry weather patterns. Since there were no elevated TOC events during the ferric testing, it is unclear whether ferric chloride will be capable of removing enough TOC during high TOC events to ensure compliance. With the potential of DBPs up to 50% higher during source TOC excursions (based on max TOC vs. 2011 TOC levels), there is justification for continued monitoring of DBPs as ferric chloride is implemented for coagulation, and for providing a plan for additional TOC removal as necessary.

Based upon the measured DBP levels, it is clear that operational changes combined with the use of ferric chloride coagulation have greatly improved water quality and the compliance situation for the upcoming Stage 2 DBPR. However, considering the variability of TOC levels (DBP precursors) in the Potomac River source, it is not completely certain that these changes will provide an adequate guarantee of Stage 2 DBPR compliance during periods of high TOC, and implementation of other strategic options, including advanced TOC removal at the WTP with GAC, storage tank aeration, or significant reductions in water age with tank replacement, should be considered by the City to ensure compliance with all current regulations and the upcoming Stage 2 DBPR regulation.

PRELIMINARY COST ESTIMATES AND IMPLEMENTATION SCHEDULE

For planning purposes a capital funding schedule was developed for the Rockville WTP and water distribution system improvements based on the alternatives evaluation described above. This capital funding schedule is provided in Table ES-3. The table is organized by Water Fund program areas, as defined by the most recent CIP. The project costs shown on this table are

generally broken down into design/inspection and construction costs. The bottom of the table provides the total funding requirement for each fiscal year. As can be seen from the table, the overall funding requirement for the Rockville WTP and distribution system improvements program is $41.1 million (2011 dollars).

Examining Table ES-3 indicates that the lower cost items, conversion to ferric chloride and tank aeration/mixing, should be implemented immediately. These projects will provide both system-wide and localized improvements in water quality, and may be enough to ensure simultaneous compliance with the SWTR and the Stage 2 DBPR. It is recommended that sampling and monitoring continue to focus on the Stage 2 DBPR compliance sites throughout construction and upon completion of these improvement projects, to assess the effectiveness of these strategies for ensuring compliance.

The capital intensive, post-filter GAC project is not scheduled for funding at this time. The most recent analysis of distribution system TTHM and HAA5 data does not suggest the need for GAC contactors for compliance with the Stage 2 DBPR. Therefore, the piloting and design of GAC contactors will only commence if unacceptable levels of DBPs are detected during the post ferric/aeration monitoring, indicating compliance with Stage 2 DBPR is not likely. The funding requirement for the design and construction of the GAC contactors, $8.36 million, includes the engineering fees for piloting and design services, which have estimated durations of 9 months and 1 year, respectively. Piloting is estimated to incur approximately $150,000 in funding requirements, while detailed design is estimated to incur approximately $680,000 (excluding inspection services).

The most capital intensive project, storage tank replacement, is also not scheduled for funding at this time. While it is recognized that tank replacement will reduce water age throughout the distribution system, source trace analysis performed within this study indicated that the majority of water feeding the Stage 2 DBPR compliance locations is provided directly from the WTP flow, bypassing the tanks. As a result, the impact of the tank related water age reduction on Stage 2 DBPR compliance may be minimal compared to improvements observed with implementation of GAC at the WTP. Additionally, the useful life of the existing tanks can be extended by performing selected rehabilitation work. Because the tank replacement alternative does not support any of the three drivers for implementation (aging infrastructure, capacity or water quality), it is not being funded.

Table ES-3 – Capital Funding Schedule for the Rockville WTP and Distribution System Improvements (by Fiscal Year)

Project	Fiscal Year										Project Driver(s)	Reference Number(s)
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
Water Main Rehabilitation Program (5C34)												
Water Main Rehabilitation											Aging Infrastructure, Water Quality	4.2.10, 7.3.2
Design / Inspection	$553,080	$189,322	$138,700	$142,861	$147,147	$151,561	$156,108	$160,792	$165,615	$170,584		
Construction	$3,845,920	$3,155,363	$2,311,670	$2,381,020	$2,452,451	$2,526,024	$2,601,805	$2,679,859	$2,760,255	$2,843,062		
Water System Facility Improvements (1C34)												
Residuals Handling Improvements - Phase I and Air Scour											Aging Infrastructure, Capacity, Water Quality	7.3.1, (7.7FP) [2]
Design / Inspection	---	---	---	---	---	---	---	---	---	---		
Construction	---	---	---	---	---	---	---	---	---	---		
Ferric Chloride Coagulation											Water Quality	4.2.4, 5.3.3, 7.3.3
Design / Inspection	$60,000	---	---	---	---	---	---	---	---	---		
Construction	$1,200,000	---	---	---	---	---	---	---	---	---		
Process Upgrades – Phase I											Capacity	7.3.5, (5.2.4FP, 8.3.1FP)
Design / Inspection	---	---	---	---	---	$50,000	---	---	---	---		
Construction	---	---	---	---	---	---	$350,000	---	---	---		
Residuals Handling Improvements – Phase II											Water Quality	7.3.7, (7.7FP)
Design / Inspection	---	---	---	---	---	---	---	---	$700,000	---		
Filter Media Rehabilitation											Aging Infrastructure	7.3.10
Design / Inspection	---	---	---	---	---	---	---	---	$100,000	---		
Construction	---	---	---	---	---	---	---	---	---	$500,000		
Water Tank Improvements (7A34)												
Tank Rehabilitation and Aeration											Aging Infrastructure, Water Quality	4.2.16, 5.5, 7.3.4
Design / Inspection	$148,000	$148,000	$149,000	---	---	$80,000	---	---	---	---		
Construction	$1,473,000	---	$2,951,000	---	---	---	---	$200,000	---	---		
Inspection Services	---	---	---	---	---	---	---	---	---	---		
Total Funding	$7,280,000	$3,492,685	$5,550,370	$2,523,881	$2,599,598	$2,807,585	$3,107,913	$3,040,651	$3,725,870	$3,513,646		

1. Costs previously funded in the CIP budget.

2. Reference numbers in parentheses with the designation "FP" following the number refer to the WTP Facility Plan report contained in Appendix B.
3. Potential (unfunded) projects:
    - Conversion to sodium hypochlorite for primary disinfection – (5.2.7FP); $1,030,000 in required funding
    - Installation of post-filter GAC contactors – 5.3.3, 6.3.2; $8,360,000 in required funding
    - Replacement of Hunting Hill and Carr Tanks with elevated storage – 4.2.18, 6.6; $13,300,000 in required funding

CONCLUSIONS AND RECOMMENDATIONS

The City's water treatment plant and distribution system improvements program is driven by three core considerations, namely:

- Aging infrastructure
- Capacity
- Water quality

These driving factors were considered as part of the evaluation of potential WTP and system improvement alternatives. Those alternatives that did not address at least one of the three program drivers were excluded from capital funding, as indicated by the program funding schedule presented in Table ES-3. With these program drivers in mind, and in conjunction with the analyses performed as part of the Water Quality Study, the following are our recommendations:

- The City of Rockville must improve on historical water quality to maintain compliance with the SWTR while achieving compliance with the upcoming Stage 2 DBPR.
- WTP process and distribution system operation optimization practices have improved water quality. The City should continue these practices, including:
    - Optimize chlorine residual to provide the minimum chlorine residual at the WTP while ensuring residual throughout the system and complying with the SWTR.
    - Use UV absorbance at 254nm to estimate TOC and use this information to determine the coagulant dose.
    - Monitor and target water main flushing in low residual areas.
    - Operate tank levels to minimize water age while maintaining required flows and pressure, and periodically drain and refill tanks to refresh water age.
    - Remove Talbott Tank from service to provide some improvement in water quality.
- Figures ES-4 and ES-5 indicate that if the City operated on PACl for the entire year, TTHM LRAA values calculated in the fourth quarter would have exceeded compliance with a margin of safety at two locations (Halpine and Oak Knoll), and third quarter OEL values would have prompted an Operation Evaluation. However, the use of ferric chloride for coagulation resulted in values achieving Stage 2 DBPR compliance with an adequate margin of safety and no OEL exceedence. The City should design and implement ferric chloride coagulation immediately to lower TTHMs in the system, which addresses the water quality program driver.
- Tank aeration/mixing reduced TTHMs at Carr tank and showed localized TTHM improvement at the adjacent Luckett Street Stage 2 compliance location. The City is currently pursuing aeration at Hunting Hill to further address the water quality program driver, and should monitor its impact on TTHMs at all Stage 2 compliance locations.
- Due to the historical variability in water source quality, and the relatively consistent water quality observed during the 2011 study period, it could not be concluded that changing to ferric chloride coagulation alone would ensure Stage 2 DBP compliance during periods of particularly challenging water quality. The City should continually sample TTHM

levels at the Stage 2 compliance locations as ferric chloride coagulation and aeration are implemented to monitor the impact of these improvements.

- Once ferric chloride coagulation is fully implemented at the WTP, certain weather conditions or events (e.g. high turbidity, high water temperatures, etc.) may warrant additional organics removal within the source water, in order to ensure Stage 2 DBPR compliance. GAC should be considered as a future, potential technology to implement for improved organics removal at the WTP. Moving forward TOC levels in the source water, Stage 2 DBP sample results and the OEL will provide the City opportunities in the future to evaluate the need of GAC at the WTP.
- After implementation of ferric chloride coagulation at the plant and subsequent collection of water quality data, the City should evaluate piloting GAC columns at the WTP to determine important GAC specific design parameters if elevated TOC levels are observed and/or Stage 2 DBP LRAA values are consistently above the margin of safety threshold.
    - Because it is not apparent that this alternative will be necessary to address water quality concerns in the distribution system, tasks associated with post-filter GAC contactors (piloting, design and construction) are not being funded at this time.
- Tank replacement to reduce water age was determined to be a less effective option for Stage 2 DBPR compliance than GAC, and so replacement of the tanks should be deferred to the end of their useful life (as identified by WIT). Because of the long-term nature of this system alternative, and because it does not directly address any of the three drivers for the WTP and distribution system improvement program, it is not recommended for funding at this time.