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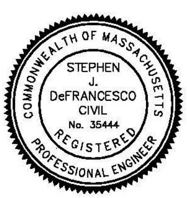

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EXECUTIVE SUMMARY

Overview

The Tewksbury Water Treatment Plant (TWTP) is a 7 MGD facility located on the Merrimack River. Originally constructed in 1988, the plant capacity was doubled with a plant expansion in 2000. A dewatering building was added in 2005. The treatment train consists of conventional rapid mix, flocculation, and sedimentation basins, followed by automatic backwash filters.

Source water obtained from the Merrimack River can be variable due to the confluence of the Merrimack and Concord Rivers immediately upstream of the facility. Water quality is also impacted by the upstream Lowell Wastewater Treatment Plant, which can lead to the presence of ammonia and a correspondingly higher chlorine demand.

The TWTP is a well operated and maintained facility. However, it is now over 20 years old and requires refurbishment and improvements. This Water Treatment Plant Evaluation had four primary goals:

- Assess the existing TWTP capacity and the plant's ability to meet future demands,
- Evaluate the effectiveness of the existing chemical treatment processes,
- Complete a facility condition assessment to determine what is required to extend the life of the plant another 20 years, and
- Develop a capital plan for recommended improvements.

Future Demands and Water Treatment Plant Capacity

The TWTP has sufficient capacity to meet projected flow demands through the 20-year planning period without expansion. Current Town population per the U.S. Census is approximately 29,000 with a projected build-out population of 34,000. Build-out was assumed to occur over the next 20 years.

Average daily demands (ADD) have been trending downwards over the last decade. The ADD in 2011 was 2.23 MGD, build-out ADD is projected to be 2.5 MGD, and build-out maximum day demand (MDD) is projected to be 5.3 MGD. The treatment plant's firm capacity, based on one filter out of service, was determined to be approximately 6.2 MGD. This treatment capacity is adequate to meet the build-out MDD.

Evaluation of Treatment Processes

Existing treatment processes and chemicals are providing excellent treated water quality. However, there are enhancements that could further optimize treatment. Findings with respect to the chemical treatment processes include:

- Disinfection byproduct (DBP) formation is the primary treatment concern,
- Although a number of alternatives were evaluated, the existing combination of chlorine dioxide and sodium hypochlorite is effective and should continue to be used,
- Potential process enhancements include air stripping, chlorine dosing control, as well as the optimization of coagulation and powdered activated carbon (PAC) addition,
- Pilot testing is recommended for air stripping DBPs in the chlorine contact basin or clearwell, and
- Laboratory bench testing is recommended for coagulation and PAC optimization.

Water Treatment Plant Condition Assessment

Treatment plant structures and equipment are between 7 and 24 years old. Treatment infrastructure was found to generally be in adequate condition, but many of the pumps, venturi flow meters, and chemical tanks are nearing the end of their useful service life. Further, maintenance of precast concrete, topping slabs, and architectural finishes are required. Lastly, the existing laboratory is inefficiently designed and requires upgrading. Findings are summarized below.

Civil

The east side of the TWTP drains towards the building, resulting in flooding during periods of high rainfall. An interceptor swale should be installed at the base of the steep slope to the east of the building to divert runoff and prevent water from entering rear of the building.

Structural

Structural components were found to be in good condition, although interior inspections of process tanks could not be conducted. Spalling and thin linear cracking on most exterior topping slabs require repair, as does spalling on exterior stairs.

Architectural

Although much of the architectural items are in relatively good condition, there are issues that require attention. Integral copper gutters on both the pump station and main water treatment building are leaking in places, some windows require replacement, and a number of doors require refurbishment. Joint sealant around all precast elements has reached the end of its life and requires replacement. Most of the interior walls and floors require cleaning and/or refurbishment.

The laboratory layout is inefficient, there is no dedicated space for the chemist, and cabinetry and flooring require replacement. Rather than simply refurbishing the existing laboratory space, it is recommended to move the outside building wall of the laboratory and break room to the east and renovate the larger spaces.

Chemical Systems

Most of the chemical systems, including metering pumps, transfer pumps, and storage tanks, are reaching the end of their service life and should be replaced. The current sodium hypochlorite tank is undersized and should be replaced with a larger tank. Currently, most of the chemical systems do not have day tanks, which should be installed as part of upgrades to comply with current state standards. The chemical fill station has no spill protection, and requires upgraded locking and labeling.

Unit Processes and General Treatment Items

Major unit processes, including the filters and the pretreatment trains, are in good condition, although the mechanical equipment within the sedimentation basins were not inspected. Regular maintenance on the filters has been effective and should be continued.

Treated flow is currently measured by a Badger magnetic flow meter. However, all other flow measurement uses venturi meters. Venturi meters should be replaced with magnetic flow meters and flow metering capability should be added to the original pretreatment train.

An equalization tank should be constructed to store and equalize spent washwater, water from the sampling table, and dewatering filtrate that are currently conveyed to the site pump stations and recycled back to the front of pretreatment. An equalization tank will improve chemical dosing, reduce loading on the facility during filter backwashes, and provide a location for carbon lost in backwash to settle out.

Large Water Pumps

Two of the original large raw water and distribution pumps have been replaced, and the remaining pumps should now also be replaced. At least one new 3.6 MGD raw water pump and one new 3.5 MGD distribution pump, both with variable frequency drives (VFDs), should replace the smaller pairs of raw water and distribution pumps. Replacing both raw water and distribution pumps with the recommended 3.6 MGD and 3.5 MGD pumps (for a total of four new pumps) would provide more capacity than is required, but will provide the Town with significant pumping flexibility.

HVAC

With the exception of the new filter building extension, the entire HVAC system is at the end of its life and requires replacement. The existing air conditioning system cannon handle hot summer days. The new system should have simple control, use split ductless cooling in the administration areas, and use a new natural gas fired boiler. The HVAC system in the pump station is in good condition.

Electrical, Instrumentation & Controls

The electrical systems were found to be in good condition with a few areas of concern. The main switchgear is located outside within an enclosure that is rusting and allowing moisture to enter. This should be refurbished and a walk-in enclosure should be installed over the existing equipment. The automatic transfer switch also requires replacement.

The existing generator does not have sufficient capacity to run the entire facility and should be replaced with a 750 KW diesel generator set that is installed outside in a walk-in enclosure. It should be purchased with a 'belly' tank and the existing buried storage tank should be removed. Surge protection is required for the main switchgear and all of the MCCs.

The instrumentation and controls system is in good condition, but lacks some control flexibility. Individual RTUs and/or PLCs should be installed at various locations within the plant for start/stop and signal operation of equipment. Lastly, the fire alarm system in the dewatering building should be migrated to the main plant system.

Opinion of Cost

A concept level opinion of cost was prepared for the recommended improvements assuming that all of the work would occur in one phase. Costs reflect the current ENR construction cost index as of the fourth quarter of 2012. An average wage rate of $85.45 was calculated from 2012 RS Means Labor rates (ENR of 9398) based on costs in the Boston area. The estimate includes contractor overhead and profit, a 30% allowance for final design elements, and an additional 40% for engineering and contingency.

The total cost of the recommended improvements was estimated to be **$7.5 million**. A summary of the cost estimate is provided in Table ES-1.

Table ES-1: TWTP Capital Cost Estimate

Item	Area	Cost
1.0	Site Work	$ 40,000
2.0	Structural	280,000
3.0	Architectural	255,000
4.0	Laboratory and Break room Expansion	275,000
5.0	Process and Mechanical	1,365,000
6.0	Equalization Tank	375,000
7.0	Chemical System	295,000
8.0	Heating, Ventilation, and Air Conditioning	250,000
9.0	Electrical and SCADA	960,000
Sub-Total		**$ 4,095,000**
Allowance for Final Design Elements (30%)		1,229,000
Estimated Construction Cost		**$ 5,324,000**
Engineering and Contingency (40%)		2,130,000
PROJECT TOTAL (2012)		**$ 7,454,000**
		Use $7.5 million

Along with the proposed upgrades, the Town should consider an annual maintenance budget to maintain equipment and plant structures. Regular maintenance will improve day to day operation and extend the life of facility.

In addition to the plant upgrades summarized in Table ES-1, there are costs associated with the recommended chlorine dioxide byproduct testing and air stripping pilot testing. These total approximately **$200 thousand** and are summarized in Table ES-2.

Table ES-2: TWTP Cost Estimate for Chlorine Dioxide Byproduct and Pilot Testing

Item	Description	Cost
10.0	Chlorine Dioxide Byproduct Sampling	$ 17,600
11.0	Air Stripping Pilot Testing	175,000
TOTAL (2012)		**$ 192,600**
		Use $200 thousand

1 INTRODUCTION

AECOM was retained by the Town of Tewksbury, MA (Town) to complete an evaluation of the Tewksbury Water Treatment Plant (TWTP). This evaluation offers opinions on upgrades necessary to meet projected future water treatment needs, and includes an assessment of existing process chemistry, infrastructure, chemical systems, pumps and piping, HVAC, electrical systems, SCADA system, and architectural components. It also assesses the existing laboratory and offers an opinion on future water demands.

1.1 Background

1.1.1 Area Served

The Town of Tewksbury is bordered by Andover to the northeast, Wilmington to the east and south, Billerica to the southwest, Lowell to the west and northwest, and Dracut to the north. The water treatment plant is located in the extreme north of the Town adjacent to the Merrimack River and serves the residential and commercial needs of approximately 30,000 residents. Interconnections between the Andover and Lowell water distribution systems allow the TWTP to extend its service area if required or receive water from the adjacent systems.

1.1.2 Source Water

The Merrimack River is a Class B river (MassDEP, 2000), originating at the confluence of the Winnipesaukee and Pemigewasset rivers. It flows through New Hampshire and Massachusetts before emptying into the Atlantic Ocean at Newburyport, MA. The Merrimack River watershed is impacted by agricultural runoff, storm drains, combined sewer overflows, industrial discharges, and wastewater treatment plant (WWTP) discharges. Major cities located upstream of Tewksbury include Concord, Manchester and Nashua, NH, as well as Lowell, MA.

While upstream discharges influence the overall water quality of the river, the TWTP is more immediately impacted by the Lowell WWTP and inflow from the adjoining Concord River. Discharges from the Lowell WWTP and Concord River are located approximately 2 miles and 2.75 miles upstream, respectively. The Concord River flow makes up approximately 10% of the downstream Merrimack River flow. An aerial view showing the Lowell WWTP, TWTP, and Concord River is shown in Figure 1.

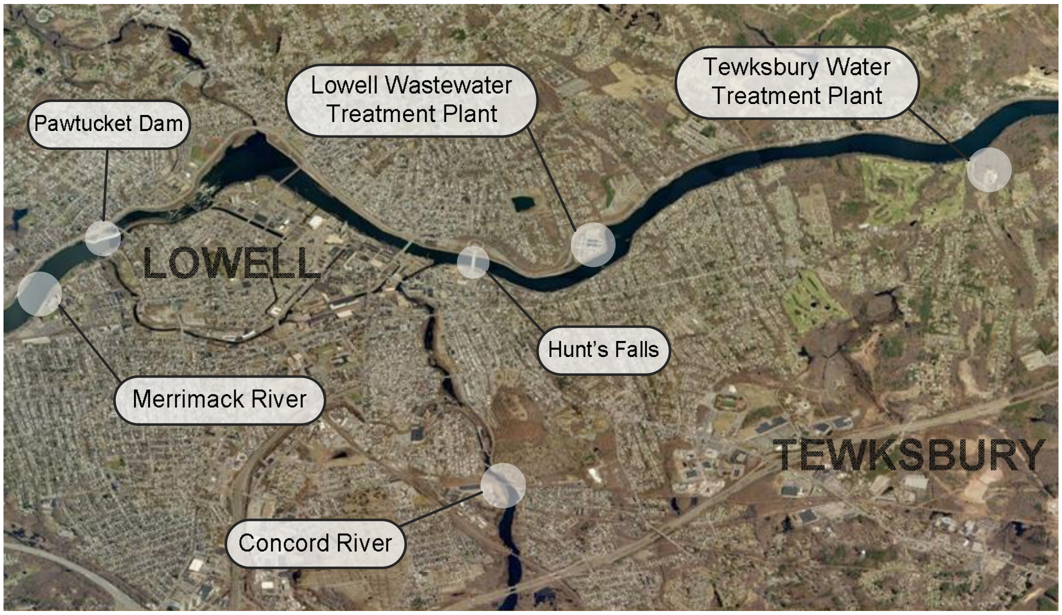

Figure 1: Aerial View of the Merrimack River

Water quality of the Merrimack River is typical for a river passing through populated and agricultural areas. The river experiences wide turbidity swings associated with run-off in the spring. Between 2010 and 2011, turbidity was below 10 Nephelometric Turbidity Units (NTU) 80% of the time, but was measured as high as 1,540 NTU. Raw water typically contains moderate levels of total organic carbon (TOC) and low alkalinity. Between 2005 and 2009, TOC was measured between 2.9 mg/L and 8.2 mg/L. Alkalinity is typically below 20 mg/L as $CaCO_3$ and averaged approximately 12 mg/L as $CaCO_3$ in 2010 and 2011. Raw water quality at the TWTP compiled from a number of raw water data sources is detailed in Table 1.

Table 1: TWTP Raw Water Quality

Parameter	Units	Average	Range
Turbidity[a]	NTU	15.4	2 – 1,540
pH[a]	S.U.	6.9	4.6 – 7.2
Alkalinity[a]	mg/L $CaCO_3$	12.3	4 – 29
Apparent Color[b]	TCU	30	10 – 180
Total Organic Carbon[c]	mg/L	4.6	2.9 – 8.2
Temperature[b,d]	°C	-	2 – 30

Notes
a) Daily raw water data from January 2010 to December 2011
b) Raw water data measured every four hours between January 2009 and June 2010 (See Appendix D)
c) Monthly raw water TOC samples between January 2005 and July 2009
d) Temperature measured at Filter influent

The proximity of the Lowell WWTP and the confluence of the Concord River presents a challenging source water. These factors result in the presence of organics and ammonia throughout the year, both of which can change rapidly thus requiring TWTP process adjustments. Although ammonia levels are typically below 0.05 mg/L, they can increase during a bypass event in the WWTP, and have been found to be generally higher during the winter. Water treatment facilities further downstream, including those at Methuen and Lawrence do not face the same challenges, as outflows from the Concord River and Lowell WWTP have greater time to attenuate.

Also a concern are the presence of 'microconstituents', including personal care products, pharmaceuticals, and endocrine disrupting chemicals that are introduced from the upstream WWTPs. These are also referred to as contaminants of emerging concern (CECs).

1.1.3 Water Treatment Plant

The TWTP is a 7 million gallons per day (MGD) facility consisting of conventional rapid mix, flocculation, and sedimentation basins, followed by automatic backwash (ABW) filters. The facility, originally constructed in 1988, was expanded in 2000 with the addition of two pretreatment trains (rapid mix, flocculation, and sedimentation) and two ABW filters. Vacuum filters were added as part of a dewatering addition in 2005. An aerial view of the facility is shown in Figure 2. Note that the powdered activated carbon (PAC) building had not yet been built at the time of this aerial photo. A process schematic is provided in Appendix A.

Raw water is withdrawn through a pump station located north of the TWTP on the southern bank of the Merrimack River. The intake system consists of two 1/8 inch (3 mm) mesh Johnson Screens located approximately 5 feet above the river bottom. Screens are connected to a 24 inch diameter intake pipe installed below the river bed. Compressed air is periodically blown out through the screen for cleaning. Four vacuum primed, raw water pumps are located in the raw water pump station, two with a capacity of 3.5 MGD and two with a capacity of 1.8 MGD. Chlorine dioxide is dosed at the raw water pump station.

Raw water is pumped through a raw water meter vault (Meter Vault No. 1) where flow is metered and sodium hydroxide (caustic soda) and sodium hypochlorite (hypochlorite) can be added. Aluminum sulfate (alum) is subsequently dosed in the rapid mix basins. PAC is added just downstream of alum injection.

Figure 2: Aerial View of the Tewksbury Water Treatment Plant

Spent backwash water from the filters and filtrate from dewatering are returned upstream of Raw Meter Vault No. 1 through the Filtered Backwash Recycle Meter Vault. All water going to the new pretreatment basins (No. 3 & 4) passes through Raw Water Meter Vault No. 2. Flow going to the existing pretreatment basins (No. 1 & 2) is not metered separately.

Each pretreatment train consists of two rapid mixing basins that can be operated in series or in parallel. These are followed by two, two-stage flocculation basins and two sedimentation basins in each pretreatment train. Sedimentation basins were designed with two levels to maximize the settling area. Flow enters into the bottom of each basin, travelling to the end of the lower floor before changing direction and passing along the upper floor. Settled water is discharged into a collection channel on the upper level, above where the water enters the sedimentation basin, and is conveyed to the filters.

There are two trains of ABW filters, each with two cells for a total of four filter cells. Each cell contains 36 inches of granulated activated carbon (GAC) over 12 inches of sand. Cells are divided into 32 distinct segments that are backwashed individually by a travelling bridge mechanism. This allows the filter to remain in service during backwashing. Filtered water is collected and conveyed through the Filtered Water Meter Vault where sodium hypochlorite and hydrofluorosilicic acid (fluoride) are added. Water then passes through the Chlorine Contact Chamber and into the clearwell.

There are four distribution pumps, two 3.5 MGD pumps and two 1.8 MGD pumps. A surge tank is located on the discharge header. Finished water is pumped through the Finished Water Meter Vault to the distribution system. Sodium hydroxide is added between the Chlorine Contact Chamber and the clearwell. Zinc orthophosphate is added in the Finished Water Meter Vault.

Settled sludge from the sedimentation basins is transferred to sludge hoppers at the bottom of each sedimentation basin through chain and flight mechanisms. Collected sludge is then transferred to sludge storage through telescoping valves. There are three sludge storage tanks, two to the north of the sedimentation basin and one additional tank that has been converted from the original PAC system. Stored sludge is periodically dewatered with a diatomaceous earth (DE) vacuum filtration system.

1.1.4 Distribution System

The Tewksbury distribution system consists of approximately 150 miles of pipe of sizes ranging between 2 inches and 36 inches, two booster pump stations, and four water storage tanks. Storage is comprised of two 500,000 gallon underground concrete storage tanks on Ames Hill, a 1,000,000 gallon elevated steel tank on Astle Street, and a relatively recently constructed 5,000,000 gallon pumped storage concrete tank on Colonial Drive. The combination of hydrostatic and pumped storage gives the Town operational flexibility. Distribution storage tank information is summarized in Table 2.

Table 2: Tewksbury Distribution Storage Summary

Name	Volume (gal)	Type of Storage	Year Built
Ames Hill No. 1	500,000	Buried	1951
Ames Hill No. 2	500,000	Buried	1958
Astle Street	1,000,000*	Elevated	1971
Colonial	5,000,000	Pumped	2007

** Only 400,000 gallons are usable*

Distribution pumping is controlled based on level in the Astle Street and Ames Hill storage tanks. Overflow centerline elevations are approximately the same at both locations. A flow control valve has been installed between the TWTP and the Astle Street tank to throttle the flow and balance the water levels at the two locations.

Two pumping stations are located in the distribution system. The Ames Lodge Booster Pump Station, which serves the top of Ames Hill, and the Colonial Tank Pump Station. Pumping capacities at the Ames Hill and Colonial Pump Stations are approximately 1.7 MGD and 4.0 MGD, respectively.

Interconnections to both the Lowell and Andover distribution systems are available for emergency situations. The Lowell interconnection is located at Andover St. (Route 133). The Andover interconnection is located at Dascomb Road, west of Interstate 93.

1.2 Scope

Objectives of this evaluation are to evaluate the TWTP and develop a five year capital improvement plan. The facility evaluation explores:

- Future water demands and the capacity of the TWTP (Section 2),
- The efficacy of the current chemical treatment processes and whether or not the Town should pursue modifications to its treatment train (Section 3), and
- The condition of the structural, architectural, chemical, mechanical, heating and cooling, chemical, electrical, and SCADA systems, as well as the laboratory (Section 4).

Recommendations arising from the plant evaluation are reviewed in Section 5. Using these recommendations, an opinion of costs was developed and included in Section 6. Based on feedback from the Town, all capital improvements will occur in one phase. The initial Scope of Work included in the contract is included in Appendix G.

2 FUTURE WATER DEMANDS AND WATER TREATMENT CAPACITY

2.1 Population and Flow Trends

2.1.1 Population

Tewksbury is a mature community and has experienced little recent population growth. Its population was 28,961 per the 2010 U.S. Census, representing a 0.4% increase from the 2000 population. Growth was just 5.8% between 1990 and 2000, 10.7% between 1980 and 1990, and 8.3% between 1970 and 1980 per U.S. Census data.

In addition to the U.S. Census, population growth is tracked by the Town through the office of the Town Clerk. While population growth determined by the office largely followed federal population numbers between 1950 and 2000, deviations occurred between 2000 and 2010. U.S. Census and Town Clerk population numbers are shown in Figure 3. Population data are included in Appendix C.

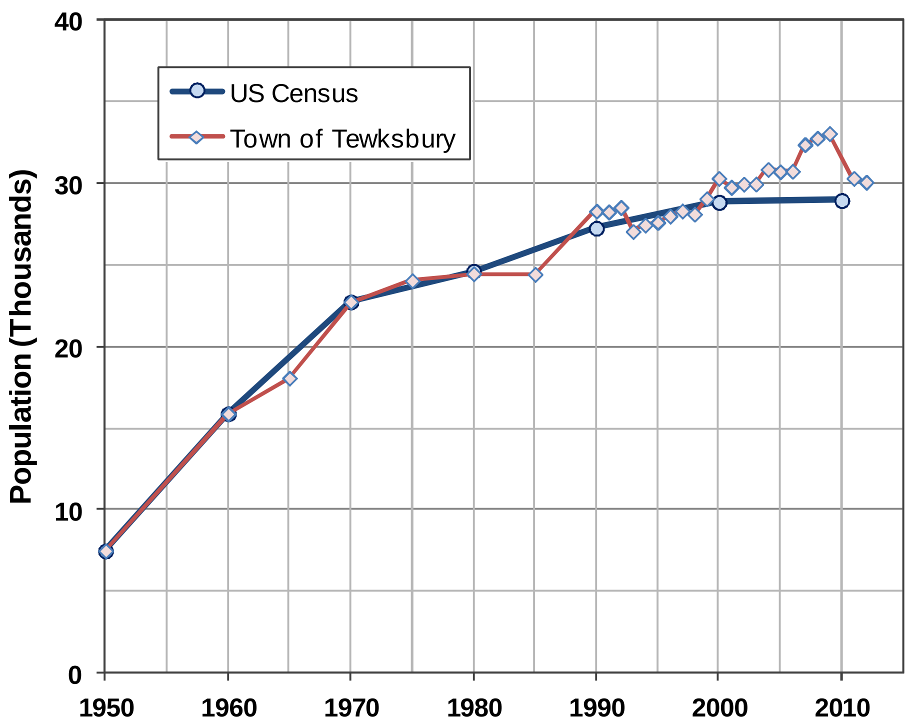

Figure 3: Tewksbury Population Growth (1950 – 2010)

A Master Plan was most recently completed for the Town of Tewksbury in 2003 (Tewksbury Planning Board, 2003). An update to this plan based on 2010 U.S. Census data is currently underway. Included in the 2003 Master Plan was a review of a build-out study completed in 2001 by the Northern Middlesex Council of Governments (NMCOG), of which the Town is a member. The NMCOG study found that the Town could support an additional 1,268 housing units, equating to a population increase of 3,688 new residents over the 2000 U.S. Census population of 28,851. This results in a total population of 32,539, 12% higher than the current 2010 U.S. Census population of 28,961.

Although there are a number of factors that may impact the accuracy of the assessment completed by the NMCOG, in particular the potential for redevelopment at a higher density and the fact that the study is over a decade old, it was assumed adequate for the purposes of the present flow projections. Further, the slow development of Tewksbury over the last census period makes it likely that the 2001 NMCOG population projections are conservative over the short and mid-term.

NMCOG build-out numbers were applied to the 2011 data determined by the Town Clerk in order to develop a build-out population number for the present evaluation. Using Town Clerk data as a baseline provides consistency with the data presented in the *Public Water Supply Annual Statistical Reports* (ASRs) submitted to the state by TWTP staff.

In 2011, the last full year of data available, the Town population was estimated to be 30,309 by the Town Clerk. Applying the additional residential growth from the 2003 Master Plan to this population yields a build-out population of 33,997 (30,309 + 3,688).

2.1.2 Flow

Average Day Demand (ADD), which corresponds to finished water pumping at the TWTP, has typically ranged between 2 MGD and 4 MGD over the last 10 years. The ADD was 2.40 MGD in 2010 and 2.23 MGD in 2011. The 2011 ADD was lower than the ADD in any of the preceding 10 years. TWTP flow between 2001 and 2011, including the annual average and the maximum and minimum monthly averages for each year is shown in Figure 4.

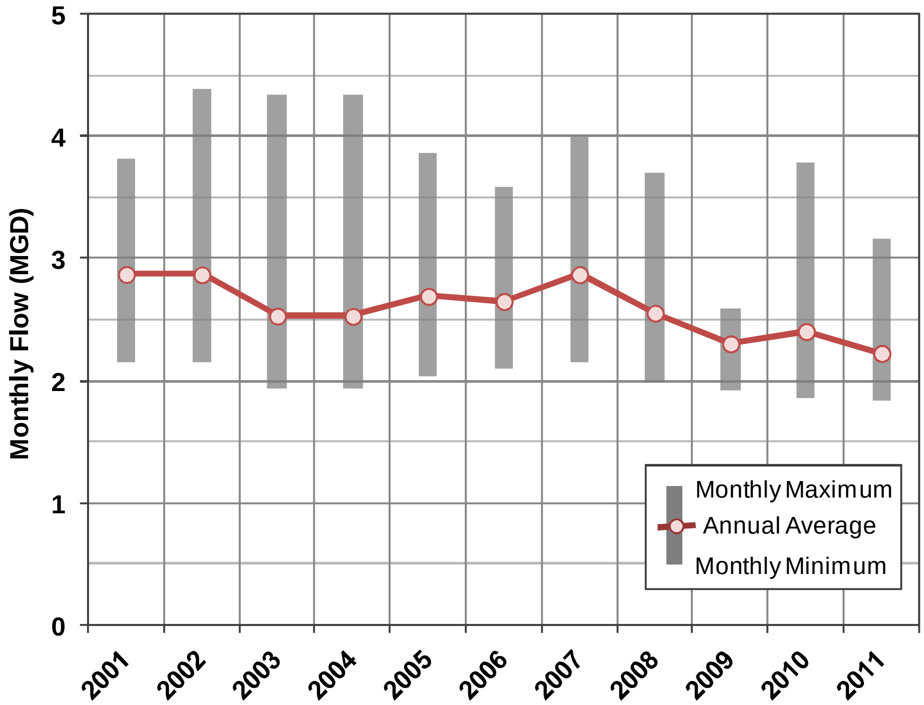

Figure 4: TWTP Monthly Finished Water Flow (2001 – 2011)

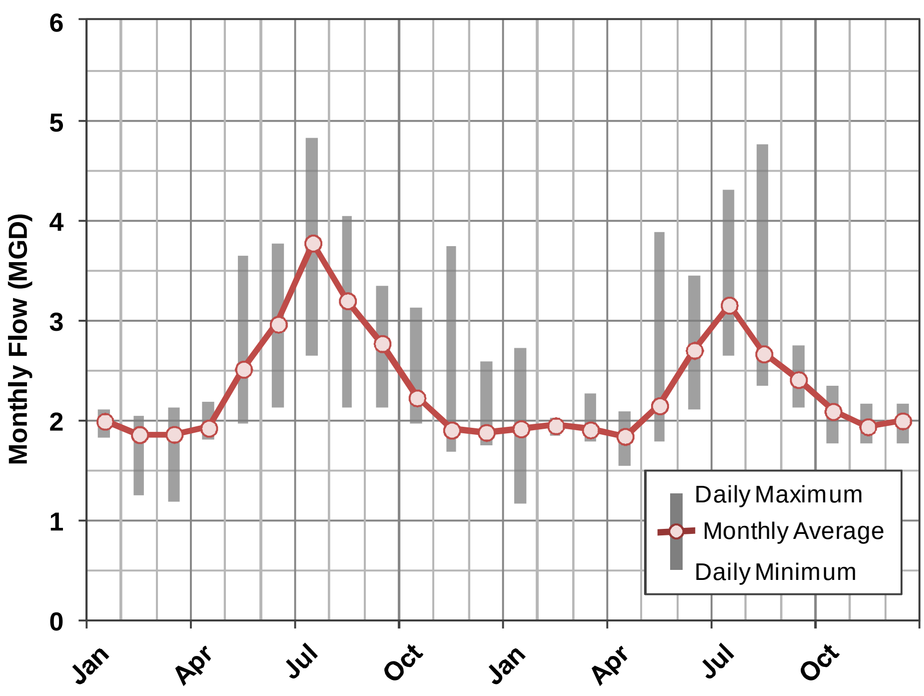

Figure 5: TWTP Daily Finished Water Flow (2010 – 2011)

The maximum day demand (MDD) over the 2010 to 2011 period was 4.83 MGD, occurring in July 2010. The MDD in 2011 was 4.76 MGD. The ratio of MDD to ADD, or the peaking factor (PF), was 2.01 and 2.14 in 2010 and 2011, respectively. Note that raw water 2010 flows were adjusted downwards to account for a flow measurement error that was corrected early in 2010. Flow data, including unadjusted 2010 flow rates, are included in Appendix C.

Daily flows from 2010 and 2011 were looked at more closely and shown in Figure 5. Maximum and minimum daily flows are shown alongside monthly averages. As expected, the flow variability is highest during the warmer periods and is minimized in the winter months.

2.2 Water Demand Projections

For the purpose of this evaluation, a planning horizon of 20 years was used to assess the ability of the current TWTP to meet the projected 2032 ADD and MDD. It was assumed that the build-out population growth (up to 33,997) discussed in Section 2.1.1 would occur by 2032. This would result in an annual rate of population increase approximately equal to that experienced in the 1990s (0.58%), or 176 people per year. Projected population growth through 2032 is shown in Figure 6.

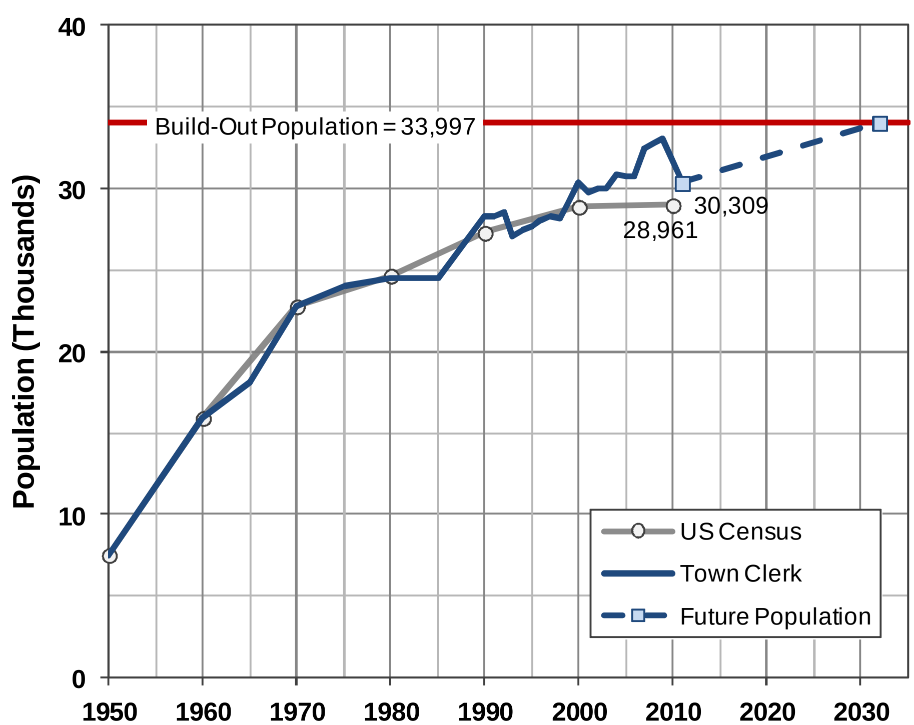

Figure 6: Tewksbury Projected Future Population Growth (2010 – 2032)

Finished water demands fall into four primary categories:

1) Residential
2) Municipal, Industrial, and Commercial
3) Unaccounted-for Water
4) Water used by Town (e.g. flushing)

The 2011 ASR reported a residential water use of approximately 50 gallons per capita per day (gpcd), or 1.52 MGD. Assuming water remains at 50 gpcd, total residential use in 2032 would increase to 1.70 MGD based on the developed build-out population of 33,997.

The NMCOG build-out study also determined that the Town could absorb 4.7 million square feet of industrial and commercial space. However, discussions with the Town Planner indicated that there is currently no expected increase in industrial or commercial demands. Although planning is underway for a large commercial (mall) development, it is not expected to be built in the near to mid-term. Most of the available industrial land in the Town is located in the Great Swamp and is therefore unusable. In order to be conservative, an increase of 10% over 2011 volumes for commercial, municipal, and industrial water was carried in the analysis.

Unaccounted for water has decreased after 2010 due to improvements in flow measurement at the TWTP. It was determined that a previously used venturi meter was over-calculating finished water production by approximately 9% and inflating unaccounted for water volumes. Unaccounted for water was conservatively assumed to increase by 10% over 2011 volumes to account for the increase in finished water pumping. Volumes used by the Town for flushing were assumed to be the same.

Existing and future water demands based on the assumptions for the four categories described above are reviewed in Table 3. The methodology used generally follows that of the *Policy for Developing Water Needs Forecasts for Public Water Suppliers and Communities and Methodology for Implementation* outlined by the Massachusetts Water Resources Commission (MA WRC, 2009).

Note that the Tewksbury Hospital has an approximate demand of 160,000 gpd, but is on wells and does not draw from the distribution system. Well supply for the hospital is not anticipated to change during the planning period.

Table 3: TWTP Design and Future Demand Summary

Demand	Year		Notes
	2011	2032	
Residential			Used Town Clerk 2011 population, increase based on 2003 Master Plan and NMCOG Build-Out Study.
Population	30,309	33,997	
Per Capita Water Use (gpcd)	50	50	
ADD (MGD)	1.52	1.70	
Total Water Use (MG)	554	622	
% of Total	68.2%	68.7%	
Non-Residential			Non-residential includes commercial, industrial, and municipal. Predicted to increase by 10%.
ADD (MGD)	0.42	0.46	
Total Water Use (MG)	154.2	169.6	
% of Total	19.0%	18.8%	
Unaccounted for Water			Predicted to increase by 10%.
ADD (MGD)	0.24	0.26	
Total Water Use (MG)	87.9	96.7	
% of Total	10.8%	10.7%	
Flushing			Projected to remain the same as in 2011.
ADD (MGD)	0.05	0.05	
Total Water Use (MG)	17	17	
% of Total	2.1%	1.8%	
Total ADD (MGD)	2.23	2.48	
Total Water Use (MG)	813	905	

Assuming an ultimate population of 33,997 and a per capita ADD of 50 gpcd, the 2032 ADD was calculated to be 2.48 MGD, which includes non-residential water uses. Using the 2011 PF of 2.14 yields a 2032 MDD of 5.31 MGD. Existing and future demands are summarized in Table 4. The original design assumes an MDD of 7 MGD with a peaking factor of 2.

A residential water efficiency goal of 65 gpcd is recommended as a target in the *Water Conservation Standards* (WRC, 2006). Communities in Massachusetts typically have higher per capita residential water use. Per capita residential water use of 50 gpcd reported in the 2011 ASR appears low. Due to the small size of anticipated population growth, flow projections and outcomes of the present analysis will not be significantly impacted if residential water use is underreported.

In general, the flow leaving the TWTP is equal to the raw water pumping less the water lost in the dewatered sludge. Spent filter backwash water is not part of the overall mass balance because it is recycled through the site pumping stations back through pretreatment. However, as long as spent washwater from the ABW filters is being recycled to pretreatment there is an internal flow loop that is higher than either the raw water coming into the facility or the finished water going out. Therefore, flow through pretreatment and the filters is made up of the flow that is ultimately leaving the facility, but also includes all of the recycled backwash water. This internal loop of higher flow impacts the loading on the pretreatment basins and the filters, and therefore must be considered.

Recycle flows are made up of the following residual streams:

- Spent Washwater (190 gpm)
- Filtrate from Dewatering (20 gpm)
- Cooling Water for Dewatering Vacuum Pumps (10 gpm)
- Sample Table Drain (15 gpm)

These recycle streams will increase the flow and loading through pretreatment and filtration. Filter backwashing and dewatering do not occur at the same time and therefore have independent impacts on the volume of water being processed. However, the sample table drain is active during filter backwashes. Therefore, the maximum instantaneous recycle flow occurs during a backwash and is made up of the spent washwater and sample drain flow. This combination of 205 gpm was considered to calculate what the internal flow rate will be at design, current, and future ADD and MDD flow conditions. Both the finished water and internal plant flow rates are shown in Table 4.

Table 4: TWTP Design and Future Demand Summary

Condition	Finished Water Flow Rate (MGD)		Internal Plant Flow Rate[a] (MGD)	
	ADD	MDD	ADD	MDD
Design	3.5	7.0	3.41	7.30
Year 2012	2.23	4.76	2.36	5.06
Year 2032	2.48	5.31	2.62	5.61

Notes
a – Maximum instantaneous recycle flow of 205 gpm is added to the finished water flow.

The TWTP is currently permitted to withdraw an annual average of 3.17 MGD from the Merrimack River. Permitted withdrawal is over 40% higher than the 2011 annual ADD of 2.23 MGD and approximately 28% higher than the 2.48 MGD developed for the 2032 condition. Therefore, an increase in permitted withdrawal will not likely be required through the planning period.

2.3 Water Treatment Plant Capacity Evaluation

2.3.1 Unit Processes

The original water treatment facility was constructed with a capacity of 3.5 MGD. The 1998 expansion mirrored the original facility to double the capacity to 7.0 MGD. Design criteria for each of the major unit processes at the original design, 2011 flows, and 2032 flows are summarized in Table 5. The 2011 peaking factor was applied to the 2011 MDD and 2032 MDD to determine respective ADDs. Massachusetts Department of Environmental Protection (MassDEP) operational goals are listed for each design criterion.

Water treatment facilities are constructed with multiple equipment and unit processes to accommodate maintenance while maintaining operation. Capacity with the largest unit out of service is referred to as the firm capacity. Ideally, redundancy is built into the design of a facility so that firm capacity is equal to or greater than the MDD. Design criteria for each of the major unit processes with one unit out of service are summarized in Table 6.

Table 5: TWTP Unit Process Flows and Loads with all Trains in Service

Unit Process Criteria	Operational Goals[a]	MDD			ADD		
		Design	2011	2032	Design	2011	2032
Finished Water Flow	MGD	7.00	4.76	5.31	3.27	2.23	2.48
Internal Plant Flow	MGD	7.30	5.06	5.61	3.41	2.36	2.62
Trains in Service		4	4	4	4	4	4
Flow per Train		1,267	878	973	592	410	455
Rapid Mix							
Detention Time	< 30 s	57	83	75	123	177	160
Flocculation							
Detention Time	> 30 min	29	42	38	62	90	81
Sedimentation							
Overflow Rate[b]	< 800 gpd/ft^2	884	613	679	413	286	317
Horizontal Velocity[c]	< 0.5 ft/min	1.53	1.06	1.17	0.71	0.49	0.55
Detention Time	> 240 min	94	136	123	202	291	263
Filtration							
Loading Rate	3 gpm/ft^2 (ADD)	2.53	1.76	1.95	1.18	0.82	0.91

Notes

a – Operational goals from *Guidelines for Public Water Systems* (MassDEP, 2011)

b – Overflow rate determined using settling surface area of stacked sedimentation basins.

c – Horizontal velocity calculated using bottom pass of stacked sedimentation basins.

Table 6: TWTP Unit Process Flows and Loads with one Train out of Service (Firm Capacity)

Unit Process Criteria	Operational Goals[a]	MDD			ADD		
		Design	2011	2032	Design	2011	2032
Finished Water Flow	MGD	7.00	4.76	5.31	3.27	2.22	2.48
Internal Plant Flow	MGD	7.30	5.06	5.61	3.41	2.36	2.62
Trains in Service		3	3	3	3	3	3
Flow per Train		1,689	1,170	1,298	789	547	606
Rapid Mix							
Detention Time	< 30 s	43	62	56	92	133	120
Flocculation							
Detention Time	> 30 min	22	31	28	47	67	61
Sedimentation							
Overflow Rate[b]	< 800 gpd/ft^2	1,179	817	906	551	382	423
Horizontal Velocity[c]	< 0.5 ft/min	2.03	1.41	1.56	0.95	0.66	0.73
Detention Time	> 240 min	71	102	92	151	218	197
Filtration							
Loading Rate	3 gpm/ft^2	3.38	2.34	2.59	1.58	1.09	1.21

Notes

a – Operational goals from *Guidelines for Public Water Systems* (MassDEP, 2011)

b – Overflow rate determined using settling surface area of stacked sedimentation basins.

c – Horizontal velocity calculated using bottom pass of stacked sedimentation basins.

With all units in service, detention times in the rapid mix basins are above those recommended by MassDEP. However, the recommended detention time is based on higher velocity gradients than currently used by the TWTP and are therefore not applicable. The rapid mix basins are adequately sized for current and future flows through 2032. Based on current performance, they are not considered a process liability.

Flocculation detention times are just below the recommended 30 minutes at design flow with all units in service, and above 30 minutes under all other flow conditions. Detention times under 2032 MDD conditions with one unit out of service are also slightly below the recommended 30 minutes, and above the recommended detention time for all ADD conditions. The flocculation basins are adequately sized for current and future flows through 2032.

Sedimentation basis overflow rates exceed the recommended rate of 800 gpd/ft^2 under MDD conditions when one train is out of service, as shown in Table 6. However, filter loading rates under these same conditions are conservatively low. Therefore, any loss in clarifier performance resulting from higher sedimentation basin loading rates will be mitigated by filtration loading rates. Although horizontal velocities are higher than the operational goals, they were not developed for the two tray TWTP sedimentation basin design. The sedimentation basis are adequately sized for current and future flows through 2032.

Filters are adequately sized for current and future flows with all units in service and with one filter offline. The loading rate at the design MDD of 7.0 MGD with three filters in service is approximately 3.53 gallons per minute per square foot (gpm/ft^2). Design ADD loading rates are below 3.0 gpm/ft^2 with only two filters in service. Although it is preferable to keep filter loading rates below 3.0 gpm/ft^2, an increase to 3.53 gpm/ft^2 under MDD conditions can easily be processed by the filters on a temporary basis. The filters are adequately sized for current and future flows through 2032.

Other important criteria include velocities of the coagulated, flocculated, and clarified water. Velocities of coagulated water between the rapid mix basins and flocculation basins should be between 1.5 feet per second (ft/s) and 3 ft/s to prevent shearing of floc. To prevent breaking up of larger flocs, flocculated water velocity should be no greater than 1.5 ft/s. Clarified water velocity should not exceed 2 ft/s in order to deliver water with as little turbulence as possible. TWTP velocities are within these parameters at MDD design conditions when all units in service.

2.3.2 Raw Water and Distribution Pumping

Pumping is currently provided by four horizontal split case raw water pumps and four vertical turbine distribution pumps. Two of the original raw water pumps were replaced in 1999 and two of the original distribution pumps were replaced in 2000. The TWTP has firm capacity in excess of the 2032 MDD for both raw water and distribution pumping. Pumping data are reviewed in Table 7. Pumping is assessed in Section 4.6.

Table 7: TWTP Pumping Capacity Summary

Pumps	Year Installed	VFD	HP	Rated Capacity (MGD)		
				Design	Max.	Firm
Raw Water Pumps (Hor. Split Case)					10.8	7.2
Pump No. 1	1999	Yes	125	3.6		
Pump No. 2	1988	No	60	1.8		
Pump No. 3	1988	No	60	1.8		
Pump No. 4	1999	Yes	125	3.6		
Distribution (Vertical Turbine)					10.8	7.2
Pump No. 1	2000	Yes	200	3.5		
Pump No. 2	1987	No	100	1.8		
Pump No. 3	1987	Yes	100	1.8		
Pump No. 4	2000	No	200	3.5		

2.3.3 Plant Capacity Assessment Summary

The 2032 MDD was projected to be 5.31 MGD, which is below the existing treatment and pumping capacity. As a result, expansion should not be required over the planning period. Water treatment plant design criteria, including unit process loadings and detention times, are adequate for the existing plant flows up to the capacity of 7 MGD with all units in service. Although more stress is placed on the facility when one unit of each unit process is out of service, unit processes are adequately sized to handle temporary loading increases.

The most important unit process with respect to firm capacity is filtration. Operating at a hydraulic loading rate of 3 gpm/ft^2, filters have a firm capacity of 6.48 MGD. Assuming this includes recycle flows (205 gpm), actual firm capacity with respect to raw water flow is 6.19 MGD. That said, increasing filter hydraulic loading to 3.5 gpm/ft^2 as a temporary measure during peak flows should not negatively impact overall plant performance and will increase the filter firm capacity above 7 MGD.

3 EVALUATION OF CHEMICAL TREATMENT PROCESSES

Chemical treatment at the TWTP generally consists of alum coagulation with pre-oxidation and disinfection accomplished through chlorine dioxide and sodium hypochlorite addition. PAC, sodium hydroxide, hydrofluorosilicic acid, and zinc orthophosphate are also used at the facility. A process flow diagram of the facility is included in Appendix A.

Although this chemical regime has proven effective, concerns with disinfection byproduct (DBP) formation have led plant staff to explore other means of achieving the necessary oxidation and disinfection. This section evaluates the effectiveness of the existing chemical processes and reviews current and future regulations. While coagulation and finished water stabilization are discussed generally, only alternatives to the existing oxidation and disinfection systems are evaluated. Additional information on the chemical systems is included in Section 4.

3.1 Regulatory Review

3.1.1 Existing Regulations

It is important to explore both the current and future regulatory implications when reviewing an existing treatment process. Water treatment is regulated broadly at the federal level through the United States Environmental Protection Agency (EPA). The state level regulatory agency, MassDEP, is responsible for enforcing EPA standards and can set more stringent requirements.

EPA drinking water standards fall into four broad categories: microbiological, disinfectants and disinfection byproducts (DBPs), inorganic compounds, and organic compounds. Microbiological, DBP, and inorganic contaminant primary standards pertinent to the TWTP are listed in Table 8. A full discussion of drinking water regulations is included in Appendix B.

Table 8: Key Primary Drinking Water Regulations Applicable to the TWTP

Category	MCL[a]	Applicable Treatment/Sampling Requirements
Microbiological		
Filtered Water Turbidity	N/A	$\leq$0.3 NTU in 95% of samples, not to exceed 1.0 NTU
Giardia	N/A	3-log (99.9%) Removal/Inactivation
Cryptosporidium	N/A	2-log (99%) Removal[b]
Viruses	N/A	4-log (99.99%) removal/inactivation
Coliform bacteria	N/A	No more than 5% positive samples
Disinfectants and Disinfection Byproducts		
Total Trihalomethanes (TTHM)	0.080 mg/L	
Total of 5 Haloacetic Acids (HAA5)	0.060 mg/L	
Total Organic Carbon (TOC)	N/A	15%-50% removal based on source TOC & Alkalinity
Bromate	0.01 mg/L	
Chlorite	1.0 mg/L	
Chlorine Dioxide	0.8 mg/L	
Chlorine	4 mg/L	
Inorganic Compounds		
Fluoride	4 mg/L	
Copper	1.3 mg/L[c]	Samples from residential kitchen or bathroom sinks must be below Action Limit in 90% of samples.
Lead	0.015 mg/L[c]	
Perchlorate	0.002 mg/L[d]	

a: Maximum Contaminant Level
b: Based on source water sampling, TWTP does not require additional *Cryptosporidium* log removal credit.
c: Represents Action Limit
d: State Regulation (MA)

All of the various drinking water regulations are under the purview of the Safe Drinking Water Act (SDWA), although there are various rules within the SDWA that govern the parameters listed in Table 8 individually. Regulations of primary concern include:

- Surface Water Treatment Rule (SWTR)
- Enhanced Surface Water Treatment Rule Long Term 1 and 2 (ESWTR)
- Disinfectants and Disinfection Byproducts Rule Stage 1 and 2 (DBPR)
- Filter Backwash Recycling Rule (FBRR)
- Lead and Copper Rule (LCR)

The SWTR was promulgated by the EPA in 1989. It was superseded by the Interim Enhanced Surface Water Treatment Rule (IESWTR) in 1998, which was subsequently strengthened by the Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) in 2002 and most recently, the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) in 2006.

The Stage 1 Disinfectants and Disinfection Byproducts Rule (DBPR) was promulgated in 1998 and was the first regulation to address DBPs. The Stage 1 DBPR is still in effect for the TWTP, but will be superseded by the more stringent Stage 2 DBPR as of October, 2013. The Lead and Copper Rule (LCR) and Filter Backwash Recycling Rule (FBRR) were promulgated in 1991 and 2001, respectively.

The TWTP is currently compliant with all of the aforementioned regulations. Distribution system DBPs briefly exceeded regulated levels in the fourth quarter of 2009. Treatment modifications were made in response, and compliance with the Stage 1 DBPR has not been an issue since. Each of these regulations, along with an assessment of TWTP's compliance, are discussed in Appendix B.

3.2 Existing Chemical Treatment Processes

3.2.1 Pre-Treatment Oxidation

Chlorine dioxide and sodium hypochlorite are both dosed at the headworks of the facility. Chlorine dioxide is applied in the raw water pumphouse and sodium hypochlorite is applied in Raw Water Meter Vault No. 1. Both chemicals can be dosed at either location. Although doses change based on the raw water conditions, chlorine dioxide is typically dosed between 2 mg/L and 3 mg/L, and hypochlorite is typically dosed to maintain a free chlorine residual of approximately 0.5 mg/L to 0.8 mg/L in the flocculation basins.

Chlorine dioxide is generated on site using sodium chlorite, sodium hypochlorite, and hydrochloric acid. It is used to oxidize certain organic compounds as well as iron and manganese, although iron and manganese have not typically been a significant concern. Chlorine dioxide residence time through the pretreatment train can be used for disinfection concentration-contact time (CT) credits as well, although this is currently being provided by sodium hypochlorite.

Chlorine dioxide is a highly selective oxidant and is effective in oxidizing iron and manganese. Its use minimizes DBP formation because it is also relatively un-reactive with the DBP precursor natural organic matter (NOM) relative to free chlorine. It does not react fully with NOM, but has the ability to change its charge distribution and weight fractions. By doing so, it can improve coagulation and therefore suppress DBP formation through the physical removal of DBP precursors. Although there is minimal trihalomethane (THM) and haloacetic acid (HAA) formation with chlorine dioxide, its major byproduct, chlorite, is a regulated DBP with an MCL of 1.0 mg/L.

Because of chlorine dioxide's effectiveness as an oxidant, sodium hypochlorite is only required for the removal of ammonia and the maintenance of a chlorine residual used for disinfection credits. Ammonia, which is an intermittent concern related to the upstream Lowell WWTP, cannot be removed with chlorine dioxide. The facility's location immediately downstream of the Lowell WWTP and the confluence of the Concord River can result in the potential for rapid changes in ammonia concentrations and organic loading. The use of hypochlorite also acts to dampen these impacts to ensure that chlorine demand does not carry through treatment and impact disinfection in the chlorine contact chamber. Raw water ammonia levels are usually highest in winter when there is ice cover on the river.

Residual chlorine is measured every four hours at the flocculator influent and in the filter influent. Dosing level in Raw Water Meter Vault No. 1 is controlled manually by the operators based on residual chlorine concentrations found in the samples. If the residual begins to drop, operators increase the pre-chlorination dose so that raw water chlorine demand does not impact disinfection and CT downstream of the filters.

There is an opportunity to improve pre-chlorination through an automated dosing control loop. This would allow the plant to respond to the rapidly changing raw water conditions and chlorine demands without over-dosing and promoting DBP formation.

3.2.2 Coagulation and PAC Addition

Alum, one of the most commonly used coagulants in water treatment, is added into the rapid mix basins, typically at a dose between 25 mg/L and 35 mg/L (as alum). Dosing has been increased to as high as 50 mg/L at times when the raw water is more influenced by source water from the Concord River (likely due to higher NOM).

Alum is most effective between a pH of 6 and 6.5 for warm waters and 6.5 and 7 for cold waters. These ranges favor both the destabilization of negatively charged particles, reactions with NOM, and sweep floc formation. Alum is less effective above a pH of 7 and below a pH of 6 due to the dissolution chemistry for aluminum hydroxide. Raw water pH at the TWTP is typically between 6.5 and 7.0. Because raw water alkalinity is low, typically between 5 and 15 mg/L as $CaCO_3$, sodium hydroxide is added upstream of rapid mixing in Raw Water Meter Vault No. 1.

Alum has been effective in consistently removing turbidity and TOC at the TWTP. It is unlikely that using an alternative coagulant such as ferric sulfate/chloride or polyaluminum chloride (PACl) would provide any significant additional removal. However, PACl would reduce the sodium hydroxide requirement by reducing the alkalinity demand and can be more effective for cold water coagulation compared to alum. Jar testing to compare alum to PACl may be useful. The addition of a streaming current monitor to measure the surface charge on particles in coagulated water may assist in coagulation control.

PAC is added into the raw water influent channel upstream of rapid mixing, typically at a dose of 1 mg/L. Its purpose is to remove TOC and chlorite through adsorption. PAC also has the ability to remove some DBPs that have already formed from pre-chlorination, and can help with taste and odor control.

There are a number of carbon sources for PAC, including wood, lignite, and bituminous coal. The type of carbon source used depends on the compounds targeted for removal. For instance, certain types of PAC can be effective in removing pesticides, but are less effective at reducing taste and odor compounds such as MIB and Geosmin. The TWTP currently uses a coal based PAC, which is the most common source for water treatment and is effective in removing large organic molecules as well as chlorite and other taste and odor concerns. Jar testing with various PAC materials would be helpful to determine the efficacy of different materials for removing DBP precursors. However, dosing is likely more important than the type of PAC and jar tests and/or a full scale evaluation of various PAC doses should be considered.

3.2.3 Disinfection

Sodium hypochlorite is used as the primary and secondary disinfectant. It can currently be dosed in four locations: the raw water pump station, Raw Water Meter Vault No. 1, downstream of the filters, and in the Filtered Water Meter Vault. The dosing location directly downstream of the filters is not typically used. It was the original dosing location before the chlorine contact tank was constructed and the injection point was moved to the filtered water metering vault.

Chlorine dioxide also provides primary disinfection (although regulatory credits are not currently obtained). It can currently be dosed in three locations: the raw water pump station, Raw Water Meter Vault No. 1, and in the influent pipe to Filters 1 and 2. The dosing location upstream of the filters is not currently being used. Chlorine dioxide has been shown to be more effective than free chlorine for bacteria and *Giardia* disinfection, but less so for virus inactivation.

Primary disinfection is achieved from the CT obtained through the plant via the pre-chlorination dosing, and through the chlorine contact tank downstream of chlorination in the Filtered Water Meter Vault. As previously described, hypochlorite is dosed to maintain a residual of approximately 0.5 mg/L to 0.8 mg/L in the flocculation basins. A free chlorine residual of between 1.0 mg/L and 1.5 mg/L was targeted upstream of the filters until 2009, after which time the hypochlorite dose was reduced concurrently with an increase in the chlorine dioxide dose in an effort to reduce DBP formation. Hypochlorite is dosed in the Filtered Water Meter Vault to maintain a residual of 0.8 mg/L leaving the TWTP. This was similarly reduced after 2009 from a target dose of 1.0 mg/L.

The TWTP is required to achieve 3-log removal of *Giardia* and 4-log removal of viruses. Because no *Cryptosporidum* was detected in the source water testing program required by LT2ESWTR, the TWTP does not need to provide additional treatment and only needs to demonstrate 2-log removal of *Cryptosporidium* via filter performance. The TWTP is currently meeting its regulatory CT requirements without claiming available credits for chlorine dioxide.

Secondary disinfection for the distribution system is achieved through the free chlorine residual in the chlorine contact tank effluent, maintained through a combination of the remaining pre-treatment free chlorine dose and the added hypochlorite in the Filtered Water Meter Vault. As previously mentioned, the target chlorine residual leaving the TWTP is 0.8 mg/L.

3.2.4 Finished Water

Hydrofluorosilicic acid is added in the Filtered Water Meter Vault, sodium hydroxide is added downstream of the chlorine contact chamber, and zinc orthophosphate is added in the Finished Water Meter Vault. These chemicals are industry standard for finished water stabilization, dental protection, and corrosion control. All three chemicals can still be added at their original dosing location immediately downstream of Filters 1 and 2. Zinc orthophosphate can also be added in the Filtered Water Meter Vault. Sodium hydroxide can also be added downstream of the clearwell.

Injection of sodium hydroxide upstream of the clearwell influent piping provides corrosion control in the piping between the contact chamber and the clearwell, as well as within the distribution header and pumps. At the same time, injection downstream of the chlorine contact chamber maintains a lower pH for the bulk of the primary disinfection, which improves the efficacy of free chlorine and reduces the required CT.

Dosing of sodium hydroxide and zinc orthophosphate is controlled to adequately stabilize the treated water to prevent corrosion and scaling in the distribution system. Hydrofluorosilicic acid is used for dental protection and is typically dosed at 0.8 mg/L. The pH of the finished water in 2009 and 2010 is shown in Figure 7.

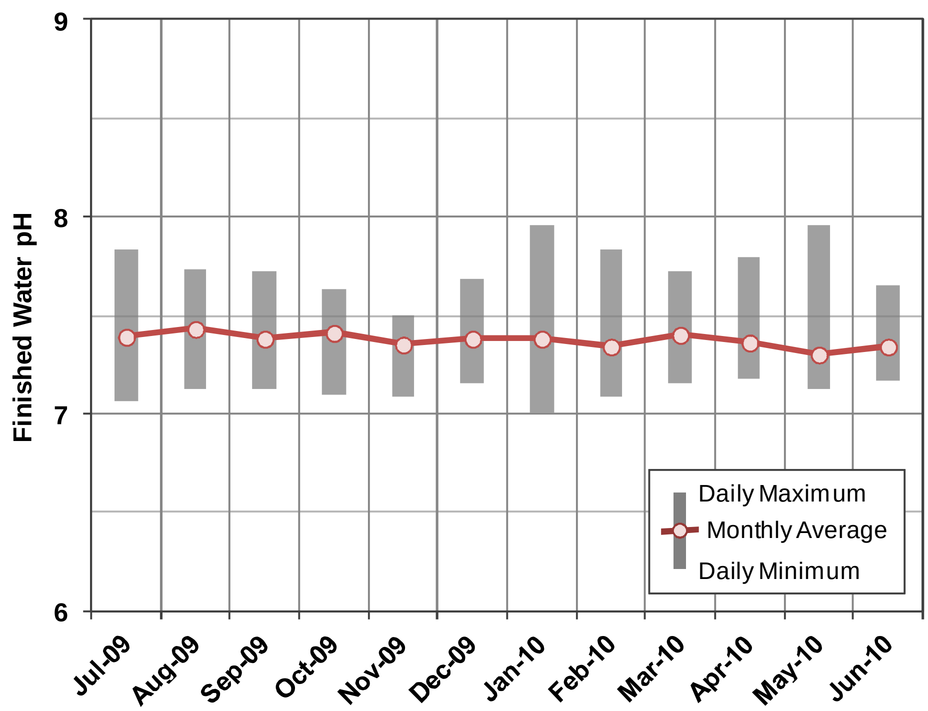

Figure 7: TWTP Finished Water pH (2009-2010)

Although other chemicals could be used for stabilization and fluoridation, those currently used are effective. As shown in Figure 7, the finished pH is in an appropriate range for zinc orthophosphate and the Town has had no issues complying with the Lead and Copper Rule. Changes in the stabilization regime are not recommended as it may disrupt a currently stable distribution system. Cost would be the primary driver of looking at alternates, and current chemicals are cost effective.

3.3 Concerns with Existing Chemical Treatment Processes

Overall, TWTP staff are satisfied with the effectiveness of the current chemicals and process regime. Both alum and PAC have proven to be effective, as have the finished water chemicals. The primary concerns are attributed to the sodium hypochlorite and chlorine dioxide chemicals used for oxidation and disinfection, and the subsequent impact on DBP formation.

Using a combination of chlorine dioxide and hypochlorite allows the TWTP to address ammonia and taste and odor concerns while minimizing DBP formation. It also provides a means of obtaining disinfection credits in a way that can reliably meet current regulations. However, DBPs from the use of sodium hypochlorite are a concern, and chlorine dioxide generation is relatively expensive. Also, sodium chlorite has limited availability and can pose handling concerns.

Numerous WWTP outfalls are situated upstream of the TWTP intake. For this reason, there is a concern with currently unregulated contaminants of emerging concern, such as endocrine disrupting chemicals (EDCs).

3.3.1 Disinfection Byproducts

THMs are the most significant DBPs generated and cause the greatest concern, although HAAs and chlorite are also present. As is typical in New England source waters where bromide levels are low, chlorinated DBPs are favored. Chloroform, one of the regulated THMs, dominates the Town's finished water as it has faster formation kinetics than other chlorinated DBPs.

While HAAs have been in compliance, TTHMs have been tested above the maximum MCL of 80 ppb in the past, resulting in a short period of non-compliance in the fourth quarter of 2008 and the first quarter of 2009. Distribution system TTHM and HAA running annual averages (RAAs) from June 2002 to 2012 are shown in Figure 8.

In order to address high TTHMs measured in 2009, TWTP staff lowered the free chlorine dose while raising the chlorine dioxide dose. As shown in Figure 8, dosing changes to the hypochlorite and chlorine dioxide have been effective at reducing TTHM formation.

Chlorine dioxide use leads to both chlorite and chlorate production. Chlorite is a regulated DBP with an MCL of 1.0 mg/L and a maximum contaminant level goal (MCLG) of 0.8 mg/L. Chlorite is formed as a product from the reduction of chlorine dioxide in oxidation reactions with constituents in the source water. Unreacted sodium chlorite also adds chlorite to the water. Chlorate can be introduced through the degradation of stored sodium hypochlorite, sodium chlorite impurities, or through the oxidation of chlorite be free chlorine.

Both chlorite and chlorate are adsorbed by the PAC added upstream of the rapid mix as well as the GAC media in the filters. The capacity for adsorption in the filters is a function of the age of the media. Chlorite concentrations observed at the TWTP effluent have been in compliance with the MCL and are consistently below 0.5 mg/L. The concentration profiles of chlorite and chlorate through the TWTP treatment process are not well understood and should be investigated.

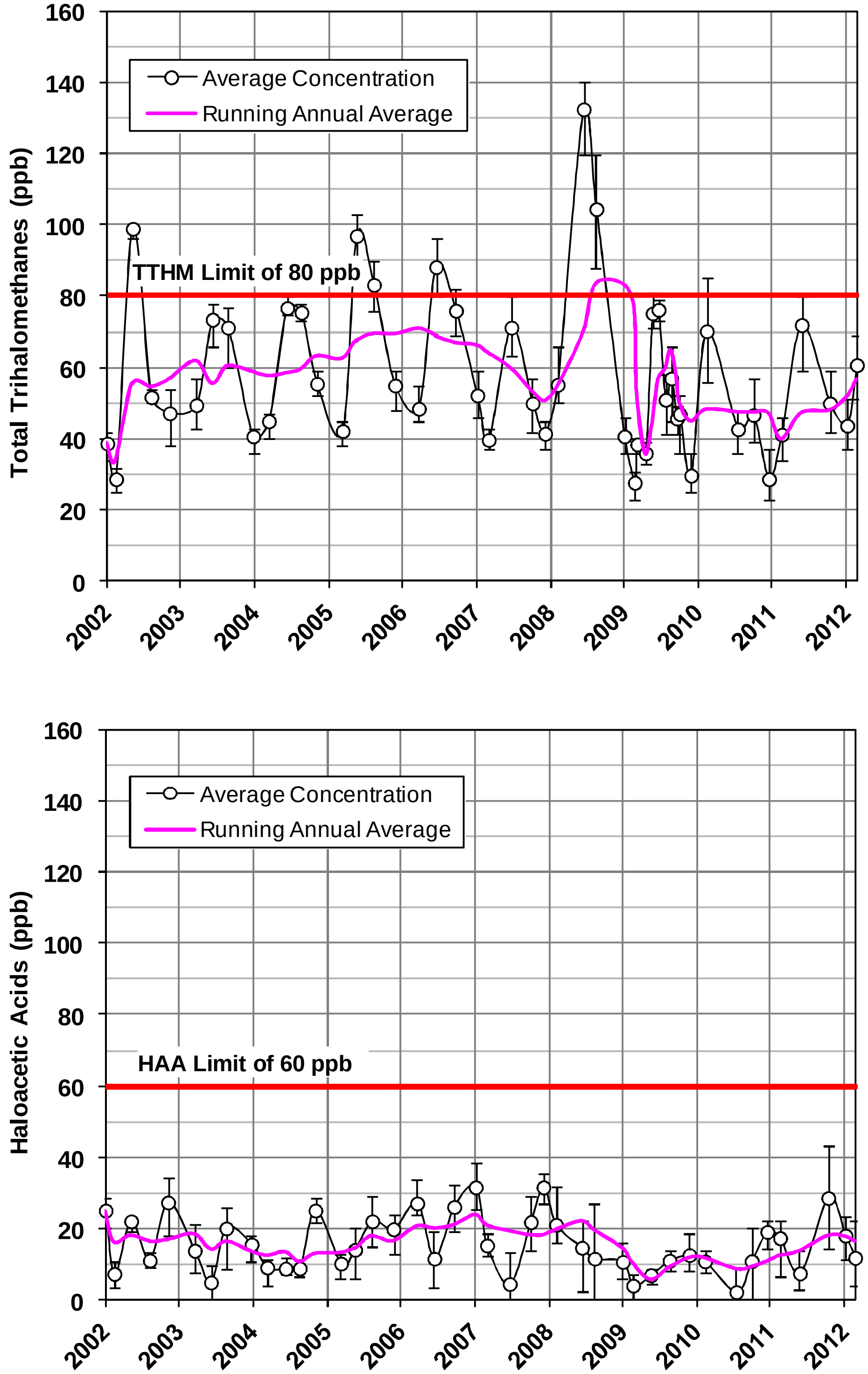

Figure 8: TTHM and HAA Compliance (2002-2012)

3.3.2 Safety and Cost of Chlorine Dioxide

Chlorine dioxide is generated at the TWTP using hydrochloric acid, sodium hypochlorite, and sodium chlorite. Sodium chlorite is a strong oxidizing agent and is flammable when dry. If it were to react with acid outside of the generation and feed system, toxic chlorine dioxide gas would be formed.

The use of chlorine dioxide is more expensive than sodium hypochlorite. Although increasing its dose while concurrently lowering the hypochlorite dose has lowered TTHM formation, its cost is a concern for the TWTP.

3.3.3 Contaminants of Emerging Concern

Contaminants of emerging concern refer to more recently recognized groups of contaminants, most commonly pharmaceuticals and personal care products. They are present in trace concentrations and are not removed effectively through traditional water or wastewater treatment. Water treatment facilities that draw from surface water sources with wastewater discharges are especially susceptible.

Because of the TWTP location on the Merrimack River, downstream of the Lowell WWTP outfall among others, staff are concerned with impact of CECs on the safety of their treated water. Because of their small size and low concentrations, they cannot be significantly removed through traditional physical treatment processes. However, the use of carbon filtration has been found to be effective for removal of many compounds provided that the carbon is not exhausted. Advanced oxidation processes (AOPs) can be effective at destroying these microconstituents.

3.4 Disinfection and Oxidation Alternatives

A number of options were evaluated that would continue to provide effective oxidation and disinfection, but also minimize DBP formation and in some cases address CECs. As the conventional filtration process achieves 2 log removal of *Cryptosporidium* (no additional removal is needed), 2.5 log removal of *Giardia*, and 2 log removal of viruses, alternatives must achieve a 0.5 log removal of *Giardia* and a 2 log removal for viruses through primary disinfection.
Alternatives identified include:

- Maintaining hypochlorite with chlorine dioxide systems (existing),
- Adding additional carbon for adsorption,
- Chloramines,

- Ozone,
- UV disinfection,
- Advanced oxidation processes, and
- Air stripping.

Each of these processes, excluding the existing system, are described in the subsequent sections. A comparison of the advantages and disadvantages of the alternatives follows.

3.4.1 Additional Carbon

GAC has the ability to remove DBP precursors through adsorption. It has also been shown to have the ability to remove significant levels of CECs. Typical carbon adsorbers have empty bed contact times (EBCTs) of between 15 and 20 minutes and are typically constructed as pressure vessels. The installation of carbon adsorbers would occur downstream of current filtration and would require pumping.

Alternatively, additional carbon could be added to the GAC filters. The filters consist of 3 feet of carbon on top of 1 foot of sand for a total media depth of 4 feet. Replacing all of the sand, or even 6 inches of the sand, with carbon would extend the adsorption period. Current EBCT through the carbon bed at the 2011 ADD and all filters in service is 10 minutes. The addition of one foot of carbon would increase the EBCT to over 13 min. Although EBCT would not be in the range of an adsorber, it may reduce DBP formation in the distribution system and remove some CECs. However, modifications to the filter cell dividers would be required, which would be costly and time consuming.

3.4.2 Chloramines

Chloramines are created through the addition of ammonia to chlorinated water. Chloramines provide an adequate secondary disinfectant and generally produce less DBPs than free chlorine. However, chloramines may add the potential for nitrification in the distribution system, create problems for dialysis patients and aquatic life in fish tanks and ponds, and may also impact compliance with the Lead and Copper Rule. Converting from free chlorine to chloramine secondary disinfection has been shown to impact certain types of pipe scales, resulting in the leaching of lead from household plumbing in certain situations.

Chloramines would only minimize DBPs formed in the distribution system and not those created through the treatment process. AECOM's previous study of DBP control options at the TWTP

(September, 2009) showed that a majority of the TTHMs are formed at the plant, which does not favor the use of chloramines.

3.4.3 Ozone

Ozone (O_3) is a powerful disinfectant and can therefore be used for disinfection, taste and odor control, as well as oxidation of iron and manganese, NOM, and more recalcitrant emerging contaminants. It can reduce the formation of TTHMs and HAAs by modifying the structure and charge balance of NOM in such a way that improves coagulation (similar but more effective that the use of chlorine dioxide), and by eliminating or reducing the amount of free chlorine required. Although it does not form chlorinated DBPs, ozone can react with bromide in the raw water to form brominated DBPs such as bromate. However, bromide concentrations are low in the Merrimack River.

Ozone can be effective at improving coagulation and overall treatment performance when used at the head of the plant for pre-oxidation. However, there will be a high oxidant demand and therefore a substantial amount of ozone may be required. Adding ozone midway through the process (after sedimentation) would involve a lower oxidant demand and allow the ozone to be more effective against remaining TOC and any recalcitrant compounds.

Ozone is not stable as a gas or liquid and therefore must be generated on-site as a gas and then dissolved into the water being treated. Ozone is produced through the addition of electrical energy to pure oxygen, first splitting the oxygen molecule and then combining each split oxygen radical to oxygen molecules to form O_3. The use of ozone would require construction of contact basins and a building for ozone generation equipment.

3.4.4 UV Disinfection

Ultraviolet (UV) light disinfects through irradiating pathogens and altering their DNA. It is most effective for bacteria, *Giardia*, and *Cryptosporidium*, and least effective against viruses. Its efficacy is determined by the generated UV dose and the transmittance of the water to be treated.

Because free chlorine is most effective against viruses, its use could be retained only at doses required for viruses and secondary disinfection, with bacteria, *Giardia*, and *Cryptosporidium* disinfection credits obtained from UV treatment. Lowering the chlorine dose will therefore reduce DBP formation.

3.4.5 Advanced Oxidation Processes (AOPs)

Advanced oxidation processes (AOPs) involve the generation of hydroxyl radicals (•OH). Hydroxyl radicals are highly reactive and speed up oxidation reactions, usually leading to mineralization of pollutants (i.e. conversion to carbon dioxide and water). Unlike ozone or chlorine by itself, the oxidative power available with the hydroxyl radicals is sufficiently strong to oxidize many CECs.

AOPs have traditionally been used for industrial applications, or for targeted pollutants such as MBTE, NDMA, or pesticides. They typically involve UV treatment combined with a hydroxyl radical source, with the combination of UV and hydrogen peroxide (H_2O_2) being the most common. Other process combinations are available but less economical, including UV with ozone and ozone with hydrogen peroxide.

3.4.6 Air Stripping

THMs are volatile organic compounds (VOCs) and therefore can be removed from water through volatilization given sufficient gas transfer opportunities. Chloroform (trichloromethane), which has been shown to the most prevalent THM in TWTP treated water, is the most volatile of the primary THMs.

Packed towers, spray aeration, diffused aeration, and tray aeration are all methods of THM removal through air stripping. Each method has associated costs and gas transfer efficiencies. Diffused aeration and packed towers would be the most expensive approaches due to the infrastructure and electrical requirements. Tray aeration, while possible, may not be practical in storage tanks due to the additional height required and the potential need for double pumping. Air stripping using a combination of mixing and spray nozzles is best applied in clearwells and/or distribution storage tanks and would be applicable to the TWTP.

3.4.7 Advantages and Disadvantages of Disinfection and Oxidation Alternatives

The primary goal of exploring alternatives to disinfection and oxidation at the TWTP is to reduce DBP levels in the distribution system. Secondary goals are to address the expense of chlorine dioxide reagent chemicals and the treatment of CECs. With this in mind, advantages and disadvantages of the alternatives discussed in the preceding sections are reviewed in Table 9.

Table 9: Advantages and Disadvantages of Chemical Alternatives

Option		Advantages	Disadvantages
1	Keep Existing Chlorine Dioxide and Sodium Hypochlorite System	• Town is familiar with system • Addresses ammonia, taste and odor, and oxidation of organics • Chlorine dioxide use minimizes TTHM and HAA formation • Provides disinfection credits with free chlorine residual and chlorine dioxide application • Provides flexibility	• Chlorine dioxide is relatively expensive and feed chemicals can have limited availability at times • There are safety concerns with on-site chlorine dioxide generation • The use of hypochlorite forms DBPs • Relies on the carbon filters to address contaminants of emerging concern and adsorption of chlorite
2	Replace Portion of Sand in GAC filters with Additional Carbon	• Remove DBP precursors • Remove some CECs • Simple and inexpensive to implement	• Benefits may be marginal • May require changes to filter cell dividers • Carbon is more expensive to replace than sand, and would have to be regularly replaced.
3	Replace Chlorine Dioxide with Ozone for Pre-Treatment (Raw Water or Clarified Water)	• Can address taste and odor, oxidize iron and manganese • Does not form chlorinated DBPs • Will eliminate chlorite and chlorate production • As there is limited bromide in source water, few brominated ozone DBPs will form • May improve coagulation if applied to raw water • Can address some contaminants of emerging concern	• Generation will have high electrical demand and will require new infrastructure – will be relatively expensive • Will promote biological filtration, which requires deeper media in the filters. • TTHM and HAA production is primarily caused by free chlorine and not chlorine dioxide • Oxidant demand at front of plant will be high, requiring high ozone doses
4	Replace Free Chlorine with Ozone for Primary Disinfection	• Will reduce TTHM and HAA production by eliminating chlorine addition for CT credit • As there is limited bromide in source water, few brominated ozone DBPs will form • Can address some contaminants of emerging concern • Can address taste and odor concerns	• Hypochlorite will still be required for removal of ammonia • Generation will have high electrical demand and will require new infrastructure – will be relatively expensive • Will promote biological filtration, which requires deeper media in the filters. • Does not provide a residual for secondary disinfection, chlorine will still have to be added
5	Add UV for Primary Disinfection	• Will reduce TTHM and HAA formation by eliminating chlorine addition downstream of filters • UV is more effective than free chlorine against protozoa • Does not produce disinfection byproducts	• Hypochlorite will still be required for removal of ammonia • Will require infrastructure and the purchase of new equipment • High electrical demand • Lamp disposal (mercury) issues • Chlorine would still be required for virus CT and distribution system residual

Option		Advantages	Disadvantages
6	Add Advanced Oxidation Process for Disinfection (i.e. UV + H_2O_2)	• Can remove some CECs in source water • May reduce chlorinated DBP formation by removing chlorine as a primary disinfectant • Will address taste and odor concerns • Will remove some DBP pre-cursers	• Relatively expensive and adds process complexity • Would require piloting and permitting • Does not provide any regulatory credit at this time beyond that provided by UV • Difficult to assess its efficacy due to costs associated with detecting CECs
7	Aerate in Clearwell and Distribution Storage to Remove DBPs	• Potentially low cost • Non-chemical approach to removing chloroform • System will ensure mixing of stored water and eliminate short circuiting and dead zones • Would give the plant more flexibility with respect to chlorine dosing • Does not form additional DBPs	• Its use as a THM removal process is a relatively recent application • Does not address contaminants of emerging concern or taste and odor concerns • Does not address HAAs
8	Use of Chloramines for Secondary Disinfection	• Do not need to remove ammonia in source water • Relatively low cost	• Nitrification is a concern in the distribution system • NDMA and subsequent nitrosomines a concern • Impacts dialysis patients and aquatic life in fish tanks • May cause taste and odor concerns • May create potential compliance issues with Lead and Copper Rule

3.4.8 Summary

The TWTP is a well run surface water facility that currently meets its treatment goals. With the exception of a short period where the RAA of TTHMs was calculated to be slightly above 0.08 mg/L, the TWTP has been in compliance with federal and state regulations. However, improvements are always possible from process, public health, and cost perspectives. Alternative processes were evaluated to specifically address concerns with DBP generation, but also to explore their impact on CEC removal. Summaries of each process segment are provided below:

Pretreatment Oxidation

- Chlorine dioxide is effective at addressing taste and odor concerns, oxidizing any iron and manganese that may be in the source water, and may be improving coagulation through its partial oxidation of NOM. Un-reacted chlorite from its generation or chlorite that is formed as it is reduced has not been a problem as it appears to be adsorbed by the GAC filters. However, the generation and fate of chlorite (and chlorate) within the treatment process is not well understood.
- Hypochlorite is dosed in Raw Water Meter Vault No. 1 in order to remove ammonia from the source water and provide a chlorine residual through the sedimentation basins. Chlorine remaining in the filter influent is then converted to chloride by the GAC filter media.
- Ozone would be an effective pre-oxidant, addressing taste and odor concerns, iron and manganese, and NOM. Chlorine would still be required should the TWTP want to remove raw water ammonia (a high pH is required for removal of ammonia with ozone).
- Ozone could be applied at one of two locations for pre-treatment, upstream of rapid mixing or just before filtration (intermediate ozone). Installation before coagulation and sedimentation would require a higher oxidant demand and more cost, but may improve coagulation and reduce DBP formation. Ozone would require the construction of concrete contactors, housing for generation and bulk storage equipment, and may require pumping.

Coagulation

- Although alum appears to be working effectively, polyaluminum chloride consumes less alkalinity and is more effective in colder waters. Because the Merrimack River has low raw water alkalinity, PACl may eliminate or reduce the addition of sodium hydroxide.
- PAC is capable of removing organics through adsorption. Its use upstream of rapid mixing may be helping to remove chlorite, organics that would otherwise contribute to further DBP formation, and taste and odor forming compounds.

- GAC and PAC function using the same adsorption mechanisms. As a result, PAC is likley taking a limited burden off of the GAC filters. A benefit of PAC is that it can be used only when needed and the dose can be adjusted to respond to various source water quality issues. PAC may be removing substances that would have been otherwise removed through coagulation and may be removing some chlorine.

Disinfection

- The TWTP must provide 4-log removal of viruses, 3-log removal of *Giardia*, and 2-log removal of *Cryptosporidium*. Based on the reviewed data, the TWTP has been meeting its CT requirements through chlorination in the contact chamber and pre-filter chlorination is not required to meet regulatory requirements.
- Although not currently reported for disinfection credits, chlorine dioxide can achieve 0.5 log removal of *Giardia* at 1°C with a CT of 10 mg/L-min. This provides additional support for reducing pre-chlorination dosing.
- Disinfection methods that would reduce the amount of free chlorine required for primary disinfection, including UV and ozone, would be effective but relatively expensive. The installation of ozone would require not only the generation equipment, but also a contact chamber and injection system.
- Both UV and ozone would provide adequate disinfection credits. It is important to note that chlorine will still be required for secondary disinfection and virus CT if UV is used for primary disinfection.
- Using chloramines for secondary disinfection would reduce the amount of DBPs formed in the distribution system. However, most DBPs are formed in the treatment plant itself and adding chloramines may introduce other problems (e.g. taste and odor complaints, Lead and Copper Rule compliance, nitrification, and NDMA occurrence).
- Both AOPs and ozone would be more effective than chlorine at treating CECs. However, because the TWTP uses GAC filters, significant CEC removal may already be occurring.
- Air stripping should remove the most prevalent THM, chloroform. This can be done within the existing chlorine contact chamber and would not require any additional chemicals.

Water Stabilization

- Existing sodium hydroxide and zinc orthophosphate systems are effective. Available alternates would offer little to no additional benefits and may be less cost effective.

3.4.9 Recommendations

Recommendations for each process segment are provided below:

Pretreatment Oxidation

- Chlorine dioxide has been effective and its use should be continued. Although it is more expensive than free chlorine, it can provide effective oxidation, assist with coagulation, and minimizes DBP formation.
- Chlorite profiling through the treatment process is recommended in order to better understand its production and fate. Chlorite levels could be measured upstream and downstream of PAC addition, in the sedimentation basins, and in the filtered water at varying doses of chlorine dioxide or over a number of days. Chlorate is also a concern and should be profiled at the same time.
- Because chlorine dioxide has been effective, oxidation with ozone, a much more expensive practice, is not recommended. Although ozone may be more effective at removing recalcitrant compounds, these would be better addressed using advanced treatment (ozone being an option) downstream of the filters.
- Pretreatment chlorination dosing should be minimized only to the concentration necessary to provide ammonia removal. This can be controlled by maintaining a lower residual upstream of the filters (e.g. maintaining a free chlorine residual of approximately 0.25 mg/L).
- An automated pre-chlorination dosing control loop should be investigated.

Coagulation

- Jar testing to compare alum and PACl is recommended to determine the relative effectiveness of each coagulant. If PACl is demonstrated to be as effective as alum, a cost analysis should be undertaken to determine if it would be more economical. The cost analysis should consider all equipment modifications necessary, shipping costs, operations and maintenance, as well as any reductions in sodium hydroxide use that would be realized. Ferric based coagulants should also be included in jar testing.
- The use of a streaming current meter for coagulation control should be investigated.
- An analysis of plant performance before and after PAC use began should be undertaken. TOC removals and DBP concentrations through the plant with and without PAC, or at varying doses of PAC should be explored. This can be done at full scale or as a bench top study. Jar testing using different PAC bases to determine efficacy at removing DBP precursors is also recommended.

Disinfection

- Pre-chlorination dosing should not be based on obtaining disinfection credits. As discussed under Section 3.2.1, adequate CT is obtained in the contact chamber. Combined with the CT that could be claimed through chlorine dioxide use, the TWTP should be able to meet their regulatory requirements.
- Ozone, UV, and AOPs have the benefit of being able to address recalcitrant compounds. Piloting of an AOP process would allow for its efficacy in contaminant removal to be determined.
- If any AOP pilot testing is to occur, representative microconstituent concentrations should be sampled in the full scale raw water, post filtration, and pilot post-AOP process to determine how much removal is taking place with the existing process, so that the added benefit of the AOP can be assessed. The intent would be to compare removals of CECs through the existing GAC filters to the removal achieved via the piloted process.
- Air stripping should be pilot tested at full scale to determine its ability to remove THMs. AECOM is currently evaluating air stripping for THM removal with a number of New England clients. Results from these projects should also be evaluated.

4 WATER TREATMENT PLANT CONDITION ASSESSMENT

On May 24, 2012, AECOM conducted a facility evaluation during a site visit to the TWTP. Civil, structural, architectural, unit process, chemical, HVAC, and electrical components of the facility were evaluated. The following sections review the findings of this evaluation and provides the basis for the opinion of cost included in Section 6.

4.1 Civil

The TWTP site is relatively congested, with buried structures and pipes located throughout the property around the pretreatment area and the water treatment building. Grading is generally from the east to the west, with the property sheet draining to drains in the parking lot and roadways, or through a swale to the south of the filter addition.

Figure 9: Grading East of Water Treatment Building

A cursory review of the TWTP site was completed with no major deficiencies found. The only concern appears to be the accumulation of water against the east side of the treatment building during heavy rains. There is a significant slope from the eastern back of the site to the treatment building, and existing drainage is inadequate to convey the water to the southern drainage swale. This has resulted in flooding in the building and significant damage.

Recommendations

The installation of an interceptor swale at the base of the back hill is recommended. This swale could direct runoff away from the facility to the existing swale located off of the southeast corner of the building.

Figure 10: Existing Swale on Southeast Corner of TWTP

4.2 Structural

Areas investigated as part of the structural assessment include the following:

- Raw Water Pump Station
- Administration & Process Building (Including Filters)
- PAC Tank
- Pretreatment Basins
- Clearwell

Observations regarding each of these areas are reviewed in the following sections, along with recommended upgrades. A prioritization of recommendations follows.

4.2.1 Raw Water Pump Station

The Raw Water Pump Station is a two-story, reinforced concrete and masonry structure with structural steel roof support. It is approximately 27 feet x 41 feet in plan dimension, and extends approximately 11 feet below grade. The structure was completed as part of the 1985 construction package, with minor maintenance and structural upgrades completed since the original construction.

Figure 11: Freeze-Thaw Damage at RW Pump Station

The structure appeared to be in "as-built" condition with some cosmetic faults discovered. There is freeze-thaw damage to the foundation concrete at the downspouts and concrete spalls and pockets are apparent in places on interior wall surfaces. Grating over the pipe trench is worn and a section is missing.

Recommendations

Freeze-thaw damage to foundation and deficiencies on interior walls should be repaired. Missing and worn grating should be replaced with grating clips installed. The condition of the concrete floors should be monitored and the monorail hoist and crane beam should continue to be maintained.

The importance of maintaining concrete structures can never be understated, however, the structure as a whole is in good condition with the exception of small areas that do not impact the performance of the overall structure.

4.2.2 Administration & Process Building (Including Filters)

The Administration and Process Building is a single story, reinforced concrete and masonry structure with structural steel framing. The structure houses numerous administrative and process functions, including the filter beds, which are reinforced concrete tanks that extend below grade. The structural component of this facility was completed as part of the original construction in 1985, with two filter beds added in the 1998 expansion and a dewatered sludge loading room added in 2005.

Figure 12: Chlorine Damage on Filter Wall

The structure appeared to be in fair condition with some cosmetic damage discovered that if left unchecked could lead to compromising the integrity of the structure. On the exterior of the building, there is freeze-thaw damage at the foundation concrete at downspouts. Filter walls exhibit early signs of corrosion due to chlorine damage at the water surface and outfall areas exhibit early signs of corrosion due to erosion caused by flowing water. Concrete coatings in the chemical area are damaged and are in need of repair.

Figure 13: Erosion Damage in Filters

<u>*Recommendations*</u>

Freeze-thaw damage should be repaired as should the concrete walls in the filter tank. The interior of the filters should be sealed with an epoxy coating to prevent further damage. Coatings in the chemical containment areas should also be repaired. Stair concrete should be maintained in a manner similar to repairs that have been made in the past.

Concrete in the containment areas of the chemical room should be repaired if required. As part of a preliminary design effort of improvements, a seismic loading analysis and code review should be performed so that the suitability of pipe and equipment supports can be assessed (there are no seismic restraints observed for any hanging piping).

4.2.3 Sludge Holding Tank

The sludge holding tank is a single reinforced concrete process tank located mostly below grade. The concrete tank has a top slab, preventing viewing of the interior other than by performing a confined space inspection.

Figure 14: Freeze-Thaw Damage and Spalling on Sludge Tank

The top of the structure appeared to be in an 'exhibiting distress' condition with some cosmetic faults discovered that if left unchecked could lead to structural failure. This condition is due to the presence of spalling and cracked concrete that is apparent on the top surface of the entire tank.

Recommendations

A general repair of the entire tank top surface to repair spalling/cracked concrete should be completed. Stair concrete should be maintained in a similar manner to repairs that have been performed in the past. A confined space entry inspection of the tank is recommended to determine its structural condition.

4.2.4 Pretreatment Basins

The pretreatment basins are reinforced concrete tanks that are located mostly below grade. Two of the tanks are from the 1985 construction and the remaining two (separated from the originals by an expansion joint) are from the 1998 expansion. The concrete tanks have a top slab, preventing viewing of the interior other than by performing a confined space entry inspection.

The structure appeared to be in fair condition with some cosmetic damage that if left unchecked could lead to compromising the integrity of the structure. Some areas of spalled and cracked concrete are apparent on the surface of the basins.

Figure 15: Spalled and Cracked Concrete on Pre-treatment Top Slab

Recommendations

Localized repairs of the tank top surfaces should be completed. Stair concrete should be maintained in a similar manner to repairs that have been performed in the past. A confined space entry inspection of the tank is recommended to determine its structural condition.

4.2.5 Clearwell

The clearwell is a reinforced concrete, finished water storage tank that was constructed as part of the 1998 expansion. The concrete tank has a top slab, preventing viewing of the interior other than by performing a confined space entry inspection.

Figure 16: Evidence of Drying Shrinkage of Outer Concrete Layer of Clearwell

The structure appeared to be in fair condition with some cosmetic damage that if left unchecked could lead to compromising the integrity of the structure. Some areas of spalled and cracked concrete are apparent on the surface of the basins.

Recommendations

General repairs of the tank top surfaces should be completed. Stair concrete should be maintained in a similar manner to repairs that have been performed in the past. A confined space entry inspection of the tank is recommended to determine its structural condition.

4.2.6 Recommendation Summary

Recommendations are prioritized on a numerical scale from 1 to 4, where 1 indicates the need to repair or replace immediately, 2 indicates that repair or replacement should occur soon, 3 indicates good condition, and 4 describes excellent condition. Each of the recommendations described in the previous sections are assigned a number and summarized in Table 10.

The priority of repairs listed below is intended to place emphasis upon items that have the greatest potential to cause harm to humans, followed by those that have the greatest economic impact upon the facility if left unchecked.

Table 10: Summary of Structural Recommendations

No.	Item	Description	Condition
S1	Raw Water Pump Station	Replace missing or worn grating and install grating clips	2
S2		Continue to maintain monorail hoist and crane beam	4
S3		Repair concrete spalls and pockets at interior wall surfaces	3
S4		Repair foundation concrete at downspouts	2
S5		Maintain concrete floor surface	4
S6	Administration & Process Building	Upgrade pipe and equipment supports to reduce potential for damage due to seismic loading (if required by code review)	3
S7		During repair of coating within chemical containment areas, perform condition assessment and repair concrete if required	2
S8		Repair concrete walls in filter tanks at water surface and outfall area	2
S9		Repair foundation concrete at downspouts	2
S10		Continue to maintain stair concrete, similar to repairs that have been performed in the past	3
S11	PAC Tank	Perform confined space entry inspection of tank to assess condition	1
S12		Perform general repair of entire tank top	2
S13		Continue to maintain the stair concrete	3
S14	Pretreatment Basins	Perform confined space entry inspection of tank to assess condition	1
S15		Perform general repair of entire tank top surface	2
S16		Continue to maintain the stair concrete	3
S17	Clearwell	Perform confined space entry inspection of tank to assess condition	1
S18		Perform general repair of entire tank top surface	2

Condition Grading Scale

1 – Repair and Replace Immediately

2 – Repair and Replace Soon

3 – Good Condition

4 – Excellent Condition

4.3 Architectural

The architectural assessment involved the following areas of the main treatment building and raw water pump station:

- Interior of the main treatment building
- Exterior of the main treatment building
- Interior of the raw water pump station
- Exterior of the raw water pump station

Observations regarding each of these areas are reviewed in the following sections, along with recommended upgrades. A prioritization of recommendations follows.

4.3.1 Water Treatment Plant Interiors

The lunch room/meeting space is a small room consisting of worn and stained finishes. The carpet, panel board wainscoting, ceramic tile behind the kitchenette, and ceiling tile are stained and worn. The kitchenette base and upper cabinets are in poor condition and there is rusting at the base cabinets.

Acoustical ceiling tiles (ACTs) in the other interior areas of the administrative area (east and west entry vestibules, control room, two offices and men's and women's lavatories) are stained and dirty. Also in these areas, fluorescent light fixtures universally have cracked lenses, carpeting is worn, and the painted concrete block wall (CMU) is dirty with localized staining. The coated floor in the lavatories are stained and worn. Offices have panelboard walls. File cabinets stacked behind the control panel against vision glass are evidence of a need for additional storage area.

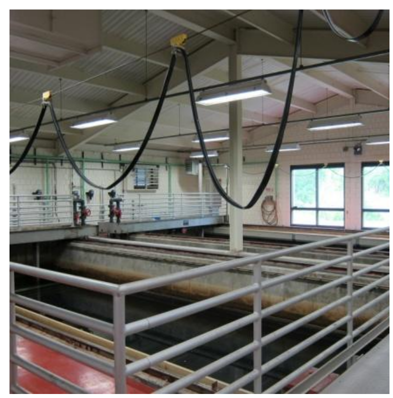

Figure 17: Interior of Filter Expansion

Interiors of the plant's Filter Expansion and Dewatering Building Addition are in good condition. The Chemical Room and Filter/Pump Room areas are generally in good condition, but with a universal need for cleaning and recoating of wall and floor surfaces. Shop cabinets are rusting and require prepping and painting.

Guardrails do not exist along the long sides of the Filter 1 and Filter 2. If the areas adjacent to the filters are not exclusively work areas (if these areas are visited by the public), then guardrails should be made compliant with Massachusetts State Building Code by the addition of a compliant screen or baluster system. There is some algae growth in the filter effluent channels, which could be addressed by tinting the windows in the filter area.

The east and west vestibule storefront window and door systems exhibit rusting at their base and chipped and peeling paint. The windows are single pane and do not conform to contemporary standards of thermal efficiency. The steel door at the lab exhibits peeling paint. The door for Office 112 is missing its lockset. Clerestory windows in the Filter Pump Room are full of condensate. All other exterior doors appear to be acceptable.

Figure 18: West Entrance Doors

Recommendations

All finishes in the lunch room/meeting space should be replaced, along with the kitchenette. As a communal room that serves dual purpose as an eating space and a group meeting space, this room is undersized. In conjunction with an addition to the lab space, this room could also be expanded to a more appropriate size.

ACTs in the administrative areas should be replaced, as should light fixture lenses and carpeting. Concrete floors should be cleaned and re-coated, and walls should be cleaned and painted. Panelboard walls should be replaced with a more suitable material.

Chemical room floors should be re-coated and walls should be painted. The metal deck ceiling should be cleaned. CMU walls in the filter room should be painted and the electrical room floors should be re-coated. Sealant at CMU/steel joints in the filter gallery is in adequate condition, but should be reviewed periodically as it is nearing the end of its life expectancy.

Figure 19: Break Room

Guardrails should be installed along the sides of Filter 1 and Filter 2. Any guardrails that may be in contact with non-employees should be retrofitted for compliance. Guardrails must be removable to allow access during carbon replacement. Windows in the filter area should be tinted to prevent further algae growth in the filter effluent channels.

The exterior storefront window system should be replaced with double pane windows. The interior storefront systems could be cleaned and treated prior to re-coating in their entirety. Failed clerestory glass should be replaced.

4.3.2 Water Treatment Plant Exteriors

Sealant at precast concrete joints in exterior original walls exhibit shrinking and cracking. Masonry weeps are missing in the original plant structure at the base of brick walls. Copper downspouts at original plant require maintenance and repair.

Figure 20: Staining from Leaking Gutters

The standing seam copper roofs are generally in good condition. However, a greenish stain on precast and brick runs out from under roof fascia onto exterior walls at several locations of the original plant and the filter addition. This is evidence of leaking at the integral copper gutters in the roof directly above the walls. Snow guards are missing at locations above doors and some sections of copper fascia need repair.

The two large louvers on the west face of the original plant are in poor condition with an insect screen temporarily attached with unfinished wood frame. Interior cracking is evident at the mortar joints running from the louver opening.

Figure 21: Holes Cored into West Façade

Three holes have been cored through the brick on the west façade of the original plant, with all or part of the core set loosely back in place. Evidence of pest activity is present within the wall.

<u>*Recommendations*</u>

The original exterior wall sealant has reached the end of its life expectancy. Sealant joints should be repointed with a suitable polyurethane sealant in order to minimize infiltration of moisture, pests, and insects into the cavity wall. It is suggested that a maintenance program be developed to review the performance of the joint sealant once replaced. A typical maintenance program would be to review the joints one year following installation, with additional investigations ten years following installation and every five years thereafter.

Weep holes are required at the base of brick walls in order to provide a place for moisture to escape out of the cavity of the wall. If metal flashing exists in the wall as should be the case, a mortar joint should be opened up one course high all the way through to the cavity every 24 inches at the base of brick walls. An insect barrier should be applied to the opened joint.

Soldering of cracks and open joints of the original copper downspouts may be required. Sealant needs to be replaced at vertical joints between copper and precast panels and weeps with insect barriers need to be installed at the base of these joints.

Copper gutters should be inspected further for defect and wear as part of the design effort for any refurbishments. Any holes, cracks, or open seams should be mended with sheet copper and solder. The copper gutters are integral to the roof at the top of the wall. Leaking allows water directly into the wall cavity and requires remedy due to the resulting water infiltration into walls that can cause deterioration of all aspects of the wall system.

Snow guards that are compatible with copper roofs should be placed on the roof at all locations above doors and at risk equipment to prevent snow slides from harming pedestrians or wall mounted or at grade equipment. Snow guards prevent snow and ice fall from roofs and address a safety hazard and liability concern. Snow crickets could be installed at any vent or piping penetration locations to prevent large sheets of snow from sliding off of the roof.

The cavity wall at the west façade louvers should be investigated to determine the cause of mortar joint cracks, which may be the result of expansion of rusting wall ties in the wall cavity. Louvers should be repaired or replaced, and integral insect screens should be installed. Replacement brick should be toothed in to replace the effected masonry where the three holes have been cored through the brick.

Upon completion of all exterior fixes, it would be prudent to clean the exterior walls and precast panels of efflorescence and copper staining from roof. An appropriate cleaning product and procedure needs to be selected that will be compatible with all materials that may be effected (copper, precast concrete, brick, mortar, factory finished metal flashings and copings and finished steel storefront systems).

4.3.3 Raw Water Pump Station

Sealant at precast concrete joints on the exterior of the raw water pump station exhibits shrinking and cracking. Entrance door is in need of re-painting and a new lockset. Spray painted graffiti on the entrance façade and paint splatters on lateral facade are apparent.

The standing seam copper roof is generally in good condition. However, a greenish stain on precast and brick runs out from under roof fascia onto exterior walls along its length. This is evidence of leaking of the integral copper gutters in the roof directly above the walls. The exterior security light on the southwest facing wall has a cracked lens, likely due to damage from accumulated snow sliding off of the roof.

Spalling and flaking of finish occurs at the lower, below grade portion of the interior walls. Exposed ends of rods remaining from previously cut back/removed equipment supports are evident throughout. The floor is in good condition with some staining. No leaking is evident from the exposed metal deck ceiling.

Figure 22: Cracked Light at Raw Water Pump Station

Recommendations

The original sealant on the exterior façade has reached the end of its life expectancy and sealant joints should be repointed with a suitable polyurethane sealant. Given that the life expectancy of the total wall system is dependent on the integrity of the individual parts, replacing sealant no longer doing its job is an essential task to ensure that the walls stay sound.

Copper gutters should be carefully inspected for defect and wear, mending holes, cracks and open seams with sheet copper and solder. The copper gutters are integral to the roof at the top of the wall. Leaking from these gutters allows water directly into the wall cavity and requires remedy due to the resulting water infiltration into walls that causes substantial deterioration of all aspects of the wall system. The broken light lens should be replaced and snow guards should be installed on the roof to prevent future damage.

The pump station door should be repainted and the lockset changed. A variety of treatments are available to remove the graffiti without damaging the masonry surface. Removal techniques, which are chosen according to the type of graffiti and the masonry, range from poulticing with water (with or without detergents), poulticing with organic solvents or alkali-based paint removers, or applying bleach to remove painted graffiti. Delicate and controlled abrasive means may be necessary in some situations.

Figure 23: Graffiti on Wall of Raw Water Pump Station

Successful graffiti removal often requires a combination of cleaning materials and methods. Given the remote location of this structure and its vulnerability, it may be advisable for an anti-graffiti coating to be applied to the masonry surfaces to prevent paints and inks from adhering to or penetrating wall surfaces. Maintaining the facades and ridding them of graffiti and other evidence of vandalism serves to discourage the recurrence of vandalism and the decreased need for future similar corrective maintenance.

Interior walls should be filled and parged at breaks in the finish. Painting of the interior floor with a liquid hardener would improve longevity.

4.3.4 Recommendation Summary

Recommendations are prioritized on a numerical scale from 1 to 4, where 1 indicates the need to repair or replace immediately, 2 indicates that repair or replacement should occur soon, 3 indicates good condition, and 4 describes excellent condition. Each of the recommendations described in the previous sections are assigned a number and summarized in Table 11.

Table 11: Summary of Architectural Recommendations

No.	Item	Description	Condition
A1	Raw Water Pump House	Repair and recoat interior walls and floor	2
A2		Repair roof gutter and broken light fixture cover	2
A3		Remove graffiti and paint splatters on exterior walls and entrance door	2
A4		Install snow guards	2
A5		Precast sealant replacement of exterior walls	2
A6	Pretreatment	Replace domed hatches on Pretreatment Basins No. 1 & 2 with flush style hatches	2
A7	Treatment Plant Interior	Maintain/re-coat process area interiors	2
A8		Retrofit generator room for chemical day tanks	2
A9		Overall upgrade of administration area interiors	2
A10		Tint windows in filter room to reduce algae growth in filters	3
A11		Install missing filter guardrails and retrofit existing guardrails	1
A12		Miscellaneous repair/replacement of doors and windows	2
A13	Treatment Plant Exterior	Precast sealant replacement of exterior walls	2
A14		Repair for missing weep joints in masonry	2
A15		Repair issues at copper downspout locations	2
A16		Repair roof gutter and snow guards	2
A17		Repair or replace west façade lovers	2
A18		Repair cored holes in brick wall	2
A19		Clean exterior wall surface	2
A20		Replace exterior windows	2

Condition Grading Scale

1 – Repair and Replace Immediately

2 – Repair and Replace Soon

3 – Good Condition

4 – Excellent Condition

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4.4 Laboratory

The assessment of the laboratory involved a general review of the condition of the laboratory space, as well as the development of alternate layouts that would address concerns that have been expressed by plant staff. Observations regarding the condition of the laboratory are first reviewed, followed by recommended layouts.

4.4.1 Condition Assessment

The laboratory has been in constant use since 1988, with little improvements made in that time. Cabinets exhibit rusting on their faces and have thoroughly rusted interiors in locations adjacent to wet areas. Painted CMU walls and ceiling tiles are stained, the latter from overhead pipe condensate. The seamless floor is marred in places from chemical spills and exhibits wear. Epoxy counter tops are largely in acceptable condition with some high use areas exhibiting chipping and flaking. There are no floor drains for general cleaning or to accommodate the emergency shower, and the emergency shower water is not tempered.

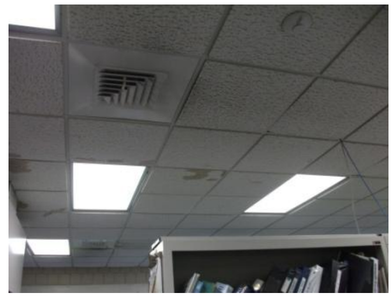

Figure 24: ACTs in Laboratory

Recommendations

Ceiling grid and tiles should be replaced, as should the flooring and cabinets. Walls should be cleaned and painted. Pipes in the ceiling should be insulated to prevent further staining. Floor drains for cleaning and to support the eye-wash and emergency shower should be installed, and cup sinks should be replaced with larger lab sinks.

Figure 25: Laboratory Sample Taps

4.4.2 Suggested Laboratory Layouts

The layout of the laboratory is inefficient, does not support the natural workflow for the procedures required, and there is no dedicated office or storage space for the chemist. Eleven sample faucets run continuously, creating an unacceptably loud ambient noise level that is well above a normal work environment. Sample faucets are also a source of very high humidity. Filing cabinets are up against the interior vision glass. The in-house testing regimen does not require the existing full fume hood, only a table-top unit.

Recommendations

The existing laboratory space should be redesigned in order to improve functionality and address major deficiencies. As part of a new design, an office space should be constructed to provide spatial and acoustical separation for administrative duties. Online analyzers should be moved to a common location with a sink and a floor drain.

An addition of an office coupled with a revised and improved lab layout would best be accomplished by extending the east wall and expanding the available space. Laboratory space must be functional during construction. While this can be accomplished with a temporary lab trailer, it may be possible to stage construction between old and new lab spaces such that there is an ongoing useable lab space throughout construction.

In order to provide a continuous wall, the break room/meeting space should be expanded simultaneously. This will improve the structural and architectural continuity between the two spaces at the same time as addressing space concerns in the break room/meeting space. An expanded break room would also provide sufficient space to hold training sessions, potentially with organizations such as the New England Water Works Association (NEWWA).

Three laboratory layouts have been developed. Sketches that show both the interior and exterior of a modified building and are provided in Appendix E along with sketches of the existing building. A description of each, along with a smaller version of the sketch included in Appendix E, are included below:

- **Layout 1**: **Office and Storage Room**

  This layout, shown in Figure 26, creates an outside corner office and a windowless storage room in an enlarged lab space. The walls would be comprised of painted CMU. The perimeter of the room would be lined with work surfaces and equipment with space for file storage and a work surface island adjacent to the lab entry door. There are views into the lab from the control room via the existing glass, and a view into the lab from the office via vision glass in the office wall.

- **Layout 2**: **Office at Outside Corner**

  This layout, shown in Figure 27, creates an office at the outside corner of the lab space. A wider space for work surfaces and islands adjacent on the control room provides a wider open lab area. The existing window wall provides a view into the lab area from the control room, and a window in the office wall provides a view to the lab entry and control room from the office.

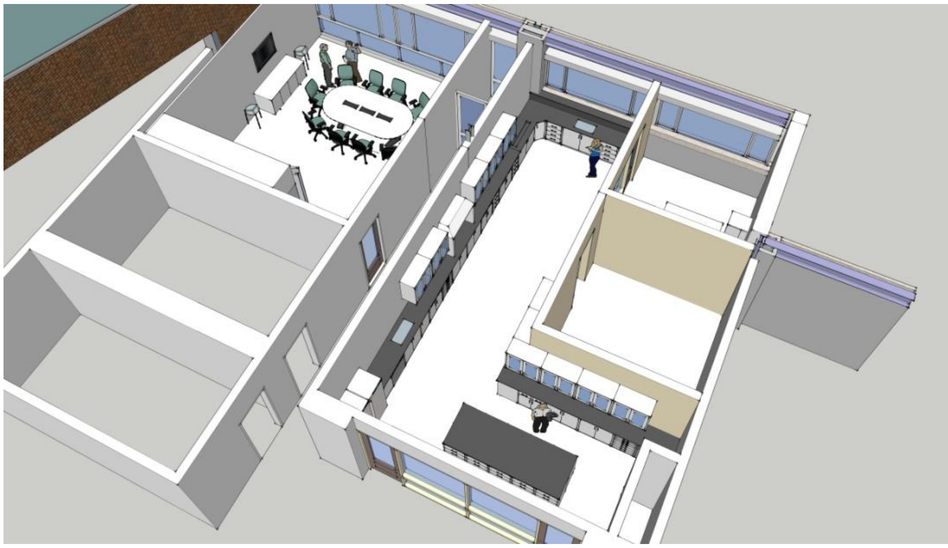

Figure 26: Laboratory Layout 1 – Office and Storage Room

Figure 27: Laboratory Layout 2 – Office at Outside Corner

- **Layout 3**: **Office at Inside Corner**

  This layout, shown in Figure 28, places the office at the inside corner of the lab space, giving the office a dedicated entry door from the control room. This office also has a window into the lab space. The layout depicts regeant racks and shelves on the center island in the lab work space.

Figure 28: Laboratory Layout 3 – Office at Inside Corner

In order to accommodate the extension of the laboratory, the roof line has to be modified. Simply continuing the existing slope for the extension would result in an inadequate door height at the outside wall. A flat metal roof system for the extended area with a slope of 5/8 inch per foot is recommended for the building extension. This is the maximum slope after accounting for a transition area between the existing and new roof systems, as well as adequate room for the outside door and a beam above the door. A slope as shallow of 1/2 inch per foot would be acceptable. Maintaining a slope on the building is both aesthetically pleasing and still allows snow to slide off. Figure 29 shows the recommended building exterior.

Figure 29: Laboratory Extension Roof Line

The developed layouts have moved the laboratory and break room eastern wall out so that it is flush to the eastern wall of the existing chemical/boiler room wall. It would also be possible to recess the wall slightly from the outside of the boiler room wall. This would allow a slightly steeper pitch and retain the precast corner of the existing building.

4.4.3 Recommendation Summary

Recommendations are prioritized on a numerical scale from 1 to 4, where 1 indicates the need to repair or replace immediately, 2 indicates that repair or replacement should occur soon, 3 indicates good condition, and 4 describes excellent condition. Each of the recommendations described in the previous sections are assigned a number and summarized in Table 12.

Table 12: Summary of Laboratory Recommendations

No.	Item	Description	Condition
L1	Existing Condition	Replace ceiling grid and tiles	2
L2		Replace flooring and cabinets	2
L3		Insulate pipes in ceiling	2
L4		Replace cup sinks with larger lab sinks	2
L5		Remove fume hood and replace with tabletop unit	2
L6		Install floor drains	2
L7		Move online analyzers to common location	2
L8		Replace lab equipment as necessary	2
L9	Expansion	Expand laboratory and break room	2

<u>Condition Grading Scale</u>

1 – Repair and Replace Immediately

2 – Repair and Replace Soon

3 – Good Condition

4 – Excellent Condition

4.5 Unit Processes and General Treatment Items

4.5.1 Flow Measurement

Flow measurement at the TWTP is provided by a magnetic meter (Badger) on the finished water line, as well as a combination of venturi meters in Raw Water Vault No. 1, Raw Water Vault No. 2, the Filtered Backwash Recycle Meter Vault, and the Filtered Water Meter Vault. Raw water flow is calculated by summing the flow in Raw Water Meter Vault No. 1 and the Filtered Backwash Recycle Meter Vault. Flow to Pretreatment Basins No. 3 and No. 4 is metered in Raw Water Meter Vault No. 2, and flow to Pretreatment Basins No. 1 and No. 2 is calculated by subtracting flow measured through Raw Water Meter Vault No. 2 from the total raw water flow. Accurate flow measurement throughout the facility is difficult due to the number of flow devices in use, as well as age and accuracy concerns with the venturi flow meters.

Recommendations

All venturi flow meters should be replaced with magnetic meters, and a new magnetic meter should be installed to measure flows to Pretreatment Basins No. 1 and No. 2. The new flow meter should either be installed in a new vault, or Raw Water Meter Vault No. 2 should be replaced with a larger vault that houses flow meters for both sets of pretreatment trains. It may also be possible to arrange the piping in the existing Raw Water Meter Vault No. 2 so that there is space for both flow meters. However, some of the isolation valves would have to be installed outside of the vault. Any modifications to pretreatment influent piping should include a hydraulic analysis to ensure that the additional piping does not have negative implications on the hydraulic grade line.

4.5.2 Pretreatment

Pretreatment includes the raw water and recycled water meter vaults, as well as the rapid mix, flocculation, and sedimentation basins. A full assessment of these areas was not possible with all of the units in service, but a number of items were investigated at the Town's request. These items include:

- Rapid Mix Motors
- Sludge Tanks and Telescoping Valve

Figure 30: Pretreatment

There is one rapid mix and two flocculator mixers in each pretreatment train, for a total of eight flocculator mixers and four rapid mixers. Although all equipment appears to be in good condition, plant staff have found the newer mixers installed in Pretreatment Basins No. 3 and No. 4 more effective.

Sludge is transferred from the sump in each sedimentation basin to a sludge drain-off chamber via two 6 inch diameter telescoping sludge valves. Plant staff have indicated that the telescoping valves have had freezing issues in the winter, the sludge tanks require improved level measurement, some of the sludge piping needs to be replaced, and the mixer in the sludge holding tank (the old PAC storage tank) is oversized.

Figure 31: Telescoping Sludge Valve

Recommendations

Mixer motors in the Pretreatment Basins No. 1 and No. 2 should be replaced to match those on the newer basins. Insulated pre-fabricated metal buildings could be placed over the sludge tanks and the north end of the sedimentation basins in order to prevent the telescoping valves from freezing in the winter. Level floats should be replaced with ultrasonic level transmitters for each of the sludge tanks.

Sludge is currently transferred to the old PAC storage tank before dewatering. Because dewatering only takes place overnight, settling occurs in the storage tank during the day. In order to reduce the hydraulic loading on the vacuum filters and increase the feed solids concentration, the installation of a decanting mechanism in the sludge tank is recommended. Decanted water could be transferred to the site pump stations and then directly to pretreatment, or preferably to an equalization tank (see Section 4.5.4).

The sludge collectors in the pretreatment basins were not inspected as all of the process units were in service during the site visit. Consideration should be given to refurbishment of the chain and flight mechanisms as required during process upgrades.

4.5.3 Filters

The existing GAC filters are located in the main operations building within the treatment plant. Although the filters appear to be in good working order, the travelling bridges are worn and several other items were indicated to need upgrading during the site visit.

Figure 32: GAC Filter

Each filter is reported to be in need of a number of new bottom plates, dividers with spacing rods, as well as drive bearing and gear boxes. During the site visit it was difficult to analyze any of these items since all filters were in operation. Another concern with the filters is the lack of filter-to-waste capacity.

Plant staff have indicated that the carbon media is replaced every two years (two filters each year). Although this is a frequent replacement interval, it is reasonable considering the filters must remove chlorite generated from the chlorine dioxide degradation reactions.

Filters are backwashed on a time basis every 24 hours. Backwashing is completed in two passes over 135 minutes at a rate of 10 gpm/ft^2. ABW filters are considered rising head filters because filtered effluent feeds a fixed elevation effluent weir and there is no flow control valve. As headloss builds up within the filter media, the water level on top of the filter rises to maintain a constant flow rate.

Because headloss is not measured in the ABW filters, backwashes must be set on time. Whether or not 24 hours is an appropriate filter run time is based on experience. Although filter run times of 24 hours have been effective, they may be overly conservative. Spent washwater is recycled, so the facility is not wasting water. However, pumping and energy costs could be reduced with lengthened filter run times. Because it is difficult to measure headloss within the ABW filters, lengthening the filter run times would have to be an experimental process.

Figure 33: Filter Effluent Channel

Recommendations

Filter bottom plates, cell dividers, and cell divider rods should be replaced as necessary. Replacement of the drive bearings and gear boxes of the travelling bridges should be considered, as should VFDs for the backwash pumps.

Filter-to-waste capability would allow water produced during filter ripening to be disposed of. The ABW filter supplier, Infilco Degremont, can provide a filter-to-waste travelling bridge upgrade. A dedicated filter-to-waste pump would have to be added to the bridge assembly and controls would have to be modified. Each cell would first backwash and then go through a filter-to-waste cycle before the bridge would proceed to the next cell. Filter-to-waste water would be directed to the site pump stations for recycling to pretreatment.

Because ABW filters only backwash a fraction of the filter bed at a time, filtered water from the ripening period makes up a small portion of the overall filtered flow. Plant staff have indicated that the performance of the TWTP ABW filters has not been effected during backwashing. Although good practice, filter-to-waste may not be provide an appreciable benefit for the TWTP.

4.5.4 Recycled Water Equalization

Water treatment facilities that recycle spent washwater typically have equalization storage. This allows backwash flows to be collected and then fed back into the headworks of a facility at a constant flow rate, thereby eliminating hydraulic surges during a backwash. Equalization also provides a means to settle out particles in the spent washwater.

Because backwashing occurs over a period of 135 minutes for each filter and through only one filter cell at a time, there is a consistent washwater recycle flow of approximately 190 gpm for a large portion of the day. This is a lower spent washwater flow rate than conventional filters. As a result, equalization is not a necessity. However, the addition of an equalization tank accompanied by recycle pumps with VFDs would smooth out plant hydraulics, help with chemical dosing control, and provide a location where particles could settle out of the spent washwater.

Recommendations

The feasibility of constructing an equalization tank should be investigated. If an equalization tank were to be built, a two cell, 80,000 gallon tank is recommended. In order to accommodate this volume, a 34 feet by 32 feet tank with a side water depth of 10 feet could be constructed south of both the pretreatment trains and the filter influent pipe.

A volume of 80,000 gallon would provide sufficient storage to equalize the washwater from all four filters over 24 hours through the existing site pump stations. Recycle flows from the vacuum pump cooling, filtrate, and sample table would also be directed to the equalization tank. Recycle flow could be decanted off of the top of the tank to prevent solids from the recycled water from passing through to pretreatment. Each equalization cell could be isolated for periodic cleaning or maintenance.

Although the ability to fully equalize recycle flows would be lost when one cell was out of service, the ability to partially equalize and settle solids would remain. Equalization volume was calculated based on 24 hour filter run times. Extending filter run times and reducing the volume required for equalization is likely possible at certain times of the year.

4.5.5 Clearwell Operation

There are two cells in the clearwell with an interconnecting butterfly valve. Each cell has a separate treated water feed line from the chlorine contact chamber with a isolation gate valve. Two distribution pumps are located above each cell.

Because treated water from the chlorine contact chamber flows into both cells concurrently, there is a risk of short circuiting through one of the two cells when only one or two pumps are in operation. For instance, when Pump No. 1 and Pump No. 2 are in service, the water in the opposite clearwell cell may become stagnant.

Recommendations

Electric actuators are recommended for the gate valves at the treated water pipe entry into each clearwell cell. Setting up a control strategy that modulates the clearwell influent gate valves based on which pumps are in service will minimize short circuiting. The influent valve of the cell from which pumps are in operation would be closed to force the two clearwell cells to operate in series. Although the TWTP does not rely on the clearwell for CT, minimizing stagnant water is good practice and will reduce TTHM formation.

4.5.6 Recommendation Summary

Recommendations are prioritized on a numerical scale from 1 to 4, where 1 indicates the need to repair or replace immediately, 2 indicates that repair or replacement should occur soon, 3 indicates good condition, and 4 describes excellent condition. Each of the recommendations described in the previous sections are assigned a number and summarized in Table 13.

Table 13: Summary of Unit Process and General Treatment Recommendations

No.	Item	Description	Condition
M1	Flow Measurement	Replace flow tubes with magnetic flow meters	2
M2		Install magnetic flow meter for Basin No. 1 and 2	2
M3	Pretreatment	Replace mixers in Basin No. 1 and 2	2
M4		Install enclosure to prevent sludge valves from freezing	2
M5		Add floating decanter and return pump for recycle	3
M6		Replace 50 HP sludge mixer with smaller unit	3
M7		Ultrasonic level measurement in sludge tanks	3
M8	Filters	Inspect and replace filter bottom plates, cell dividers, and divider rods as necessary	2
M9		Refurbish travelling bridges as necessary	3
M10		Continue filter media replacement	3
M11		Add filter to waste capability	4
M12		Explore lengthening filter run times	3
M13	Clearwell Operation	Install actuators on clearwell gate valves	2
M14	Equalization	Explore the feasibility and cost of equalization	2

Condition Grading Scale

1 – Repair and Replace Immediately

2 – Repair and Replace Soon

3 – Good Condition

4 – Excellent Condition

4.6 Large Water Pumps

4.6.1 Raw Water Pumps

There are four raw water pumps located in the lower level of the raw water pump station. All four pumps are connected to an existing vacuum priming system that operates when low river water levels are experienced. Pumps are all horizontal split case type and were originally constant speed. Parco control valves were installed on the original pumps.

Pump No. 1 and No. 4 were replaced in 2000 with larger pumps rated for 3.6 MGD with 125 HP motors. Although new Parco control valves were installed in 2000, VFDs were subsequently added for flow control. These pumps appear to be in good working condition, have had no reported issues, and have reasonably even run times to date (22,536 hours for Pump No. 1 versus 27,851 hours for Pump No. 4). Piping and valves associated with these pumps appear to be in good working condition.

Figure 34: Raw Water Pumps

Pump No. 2 and No. 3 were installed in 1988. They are over 20 years old and have exceeded their service life. These two pumps have 60 HP motors and have a capacity of approximately 1.8 MGD. Piping and valves associated with these pumps are from the original installation in 1988. There were no reported complaints with the valves.

Recommendations

In any replacement scheme, the resulting pumping system must provide sufficient raw water pumping capacity to supply the future MDD with the largest pump out of service, and the ability to supply low flow conditions in an efficient manner. There are two options for replacing the two existing 1.8 MGD pumps; the installation of one large pump with a capacity of 3.6 MGD to match the newer pumps, or the installation of two pumps with a capacity of 1.8 MGD, which is the same as the existing smaller pumps.

A pump system analysis determined that 2032 MDD could be achieved with two large pumps in operation. Furthermore, pump speed can be sufficiently turned down to provide minimum flow with one pump. As these conditions can be met, installing one pump of equal capacity to the existing larger pumps with a VFD is recommended. Advantages of single pump installation include; less capital cost by only requiring one pump and associated valves and appurtenances to be installed, operational simplicity with three pumps of the same capacity, and more available floor space in the pump room. Furthermore, installation of one pump does not preclude an additional pump from being added in the future if needed. Although installing a second pump immediately would provide the TWTP with more capacity than required, it would provide significant pumping flexibility.

With the addition of the VFDs on Pumps No. 1 and No. 4, the Parco valves are redundant and should be replaced with check valves. A VFD should be installed on the new pump in order to save energy and match existing pumps. Control of all pumps should be through the SCADA system.

While work is completed in the raw water pump house, the air burst system for the raw water screens should be upgraded so that it can be controlled through SCADA. The intake screens should be inspected as part of the upgrades.

4.6.2 Distribution Pumps

The existing finished water pumps are located within the main operations building of the plant. The pumps are all vertical turbine pumps with motors and discharge piping located on the upper level of the operations building.

Pump No. 1 and No. 4 were upgraded and replaced in 1999. These pumps appear to be in good working order and have not yet had any rebuilding required. Pump No. 1 has a VFD and Pump No. 4 is constant speed; both are rated for 3.5 MGD. The associated piping and valves appear to be in good working order. However, it was noted that check valves slam and do not have a cushioned close.

Figure 35: Distribution Pumps

Pump No. 2 and No. 3 were installed in 1988 and appear to be in working condition. However, they are now over 20 years old and have exceeded their service life. Both pumps have been rebuilt several times and can no longer be rebuilt. Each pump is rated for 1.8 MGD. Pump No. 2 is constant speed and pump No. 3 has a VFD. The associated piping and valves appear to be in good working order with the exception of an issue with the check valves slamming.

<u>*Recommendations*</u>

Similar to the raw water pumps, the two original vertical turbine pumps should be replaced with one larger, VFD driven vertical turbine pump with matching capacity. This option would provide sufficient capacity to supply the 2032 future MDD with the one pump out of service, adequately supply minimum flows with single pump operation, and would result in an operational simple and efficient system. Although installing a second pump immediately would provide the TWTP with more capacity than required, it would provide significant pumping flexibility.

Discharge check valves on Pump No. 1 and No. 4 should be replaced with non-slamming type check valves. Discharge piping and valves should be upgraded when the new pump is installed.

4.6.3 Recommendation Summary

Recommendations are prioritized on a numerical scale from 1 to 4, where 1 indicates the need to repair or replace immediately, 2 indicates that repair or replacement should occur soon, 3 indicates good condition, and 4 describes excellent condition. Each of the recommendations described in the previous sections are assigned a number and summarized in Table 14.

Table 14: Summary of Large Water Pump Recommendations

No.	Item	Description	Condition
P1	Raw Water Pumps	Replace Pump No. 2 and 3 with new larger pump and associated fittings	2
P2		Add VFD for new pump	2
P3		Control air burst system through SCADA and screen inspection	3
P4	Distribution Pumps	Replace Pump No. 2 and 3 with new larger pump and associated fittings	2
P5		Add VFDs to all pumps	2

Condition Grading Scale
1 – Repair and Replace Immediately
2 – Repair and Replace Soon
3 – Good Condition
4 – Excellent Condition

4.7 Chemical Systems

Chemical systems investigated as part of the assessment include the following:

- Chlorine dioxide
- Sodium chlorite
- Sodium hypochlorite
- Hydrochloric acid
- Sodium hydroxide
- Aluminum sulfate
- Hydrofluorosilicic acid
- Zinc orthophosphate
- Powdered activated carbon

Observations specific to each of these areas are reviewed in the following sections, along with recommended upgrades. Areas of the chemical systems that apply to multiple chemicals, including containment, the fill station, day tanks, and metering pumps are also reviewed. A prioritization of recommendations follows.

4.7.1 General Chemical Observations

Chemicals are stored in a large room with adjacent smaller rooms for hydrofluorosilicic acid and hydrochloric acid storage. Generation of chlorine dioxide occurs within the hydrochloric acid storage room.

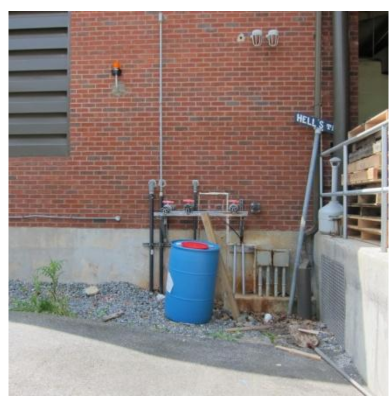

Figure 36: Chemical Fill Area

Individual containment is provided for hydrochloric acid and hydrofluosilicic acid in their storage rooms. Containment for alum, hypochlorite, and sodium hydroxide are located outside the building in three individual, buried, 6,000 gallon storage tanks. Overflow pipes connected to the exterior containment tanks have been installed within the curbed containment in the chemical area. Sodium chlorite and zinc orthophosphate containment is provided by the concrete berms in the chemical room. MassDEP (2009) requires that containment must be sufficiently large to store 110 percent of the total bulk storage tank volume. Any changes to bulk storage will require the plant to maintain compliance with MassDEP containment requirements.

The current fill station is located on the north wall of the chemical area, just to the east of the overhead door. Access is difficult due to the PAC tank and the loading dock. Adding concrete containment at the base of the fill area is recommended to capture any spilled chemicals. Placing all of the chemical feed points into a lockable cabinet is also recommended.

The majority of the stored chemicals have no day tanks. Day tanks provide a safeguard against emptying of the bulk storage tank into the water being treated in the event of an equipment failure. They also provide a means to accurately measure the amount of chemical used. MassDEP (2009) requires the provision of day tanks for each chemical for any new facility, or any facility that has been substantially modified. Although the lack of day tanks has not been identified as a concern by MassDEP at the TWTP, major modifications to the chemical area will most likely require their addition.

Where day tanks are recommended, material should match bulk storage tank material. Transfer pumps between the day tank and bulk storage should be provided as non-metallic, magnetic drive, horizontal end suction centrifugal pump. Day tanks should be vented to the exterior of the building and provided with insect screens.

The removal of the emergency generator will free up room within the chemical area for the rearrangement of some of the chemicals. For example, the sodium chlorite bulk tank could be moved to the generator room along with its day tank. This would provide compliance with current MassDEP requirements of storing sodium chlorite in a separate room. Day tanks for the hypochlorite, alum, and sodium hydroxide could then be installed where the sodium chlorite is currently located. Alternatively, the room could be used for the hypochlorite, alum, and sodium hydroxide day tanks.

Figure 37: Metering Pumps

Existing metering pumps appear to be working without any issues. Solenoid operated diaphragm pumps that have been operating for ten to twelve years are near the end of their design life. Although rebuilding the metering pumps has been effective to date, pumps should be replaced. Standby pumps should be installed to provide redundancy. Even if rebuild kits are provided, standby pumps are still recommended. Controls for the metering pumps should comply with MassDEP drinking water regulations.

4.7.2 Chlorine Dioxide

The existing chlorine dioxide system is 10 to 12 years old and was built by TWTP staff. To date, the system has been operating efficiently since installation, although some corrosion was observed on the generation unit hardware.

The plant currently uses sodium chlorite as a part of the chlorine dioxide generation system. The sodium chlorite system is located within a dedicated containment area in the main chemical room. The system has been provided with a polyethylene bulk storage tank, which is vented to the inside of the building and filled from a connection located on the inside of building. The system currently has a single solenoid operated diaphragm metering pump, which is connected to the bulk storage tank and pumps to the chlorine dioxide system. The bulk storage tank and metering pumps are approximately 10 to 12 years old.

Figure 38: Chlorine Dioxide Generator

The current capacity of the bulk storage tank does not allow for sufficient capacity between deliveries. Delivery time for sodium chlorite can take several weeks and has been very unpredictable. The result of these delivery issues has forced the plant to store additional sodium chlorite in drums on a containment pallet adjacent to the bulk storage tank.

The plant currently uses hydrochloric acid as a part of the chlorine dioxide generation system. Hydrochloric acid storage is located in a separate room with the chlorine dioxide generator. Two polypropylene bulk storage tanks are filled from a connection on the exterior of the building. The system currently has a single solenoid operated diaphragm metering pump, which is connected to the bulk storage tanks and pumps to the chlorine dioxide system. The bulk storage tanks and metering pumps are approximately 10 to 12 years old.

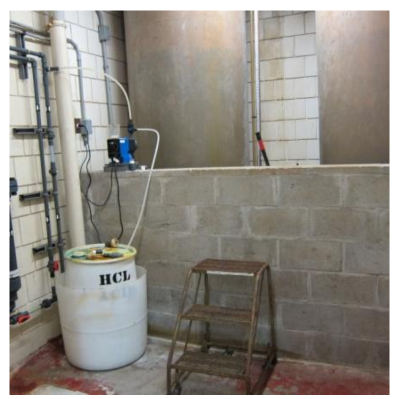

Figure 39: HCl Storage

Modern chlorine dioxide generators typically feature a vacuum system to generate a chlorine dioxide solution from chlorine dioxide gas. The vacuum is created with an eductor that is provided with the generation unit. This feature minimizes the risk of releasing chlorine dioxide gas into the room during an equipment failure. A vacuum chlorine dioxide generator is typically provided with a low vacuum safety shut down, which will shut off the feed of the reagent chemicals to the unit. The unit can be provided with an alarm output for safety shutdowns.

Recommendations

While the chlorine dioxide generation system works under a vacuum and appears to be operating well, the existing system does not have the safety features of a modern vacuum based system. An upgraded chlorine dioxide system should be installed that continues to use the three chemical generation system. The chlorine dioxide room should be provided with a chlorine dioxide gas detector.

Reactant chemicals (sodium chlorite and hydrochloric acid) should be supplied to the generation unit from day tanks, which should be stored in separate rooms to prevent accidental mixing. If the day tanks are stored in the same room, separate containment will be required for each tank. Containment will be required for the entire chlorine dioxide system and reagents.

The sodium chlorite bulk storage tank capacity should be increased sufficiently to meet process demands and extended delivery time. This would eliminate the need to store sodium chlorite drums. The sodium chlorite system should be provided with a transfer pump and day tank. The bulk tank and day tanks should be vented to the exterior of the building and provided with an insect screen. Consideration should be given to moving the sodium chlorite system into the existing generator room to comply with current MassDEP requirements.

Figure 40: Sodium Chlorite Drum Storage

Although the hydrochloric acid system is currently stored in a separate room, it can be stored in a room with other chemicals. Hydrochloric acid should be kept away from sodium chlorite as contact with sodium chlorite could produce toxic and explosive chlorine dioxide gas.

The existing hydrochloric acid tanks appear to be severely aged and should be replaced when other improvements are made to the chemical systems. The new tank should be provided with sufficient capacity to meet process demands as required by MassDEP. The bulk storage tank material shall be polyethylene or as preferred by plant staff. The hydrochloric acid system should be provided with a transfer pump and day tank.

4.7.3 Sodium Hypochlorite

The sodium hypochlorite system is currently 10 to 12 years old. The system has been provided with a polyethylene bulk storage tank, filled from a connection located on the exterior of the building. Sodium hypochlorite is currently pumped from the bulk storage tank to the points of application with solenoid operated diaphragm pumps.

Figure 41: Sodium Hypochlorite Bulk Storage

Access to the sodium hypochlorite area is very limited. Most of the area accessible from the corridor is blocked by the metering pumps, chemical piping, and miscellaneous supports. The bulk storage tank occupies most of the space within the containment area, which limits access around the tank.

In the event of an emergency, and an operator needs to use an emergency shower or eyewash, there are many obstacles in the way to get out of the containment area. These obstacles do not allow the operator to quickly access the emergency shower or eyewash, which may result in greater injury.

Recommendations

The hypochlorite bulk storage tank is over 13 years old, has visual defects, and should be replaced. The tank manufacturer has recommended that a sodium hypochlorite tank of this age should be replaced.

Plant staff has indicated the bulk storage tank capacity needs to be increased to better suit the sodium hypochlorite demands. The bulk tank material should be polyethylene or as preferred by operations staff. If immediate replacement is not required, the tank should be replaced and its capacity increased during the improvements of the other chemical systems. A day tank and transfer pump is recommended. Carrier water should be provided with the system, with manual flow control. Carrier water piping within the chemical area should be provided as PVC.

4.7.4 Sodium Hydroxide

The sodium hydroxide system has been provided with a steel bulk storage tank. The bulk storage tank is filled from a connection located on the exterior of the building. Sodium hydroxide is currently pumped from the bulk storage tank to the points of application with solenoid operated diaphragm pumps.

Access to the sodium hydroxide area is limited. Most of the area accessible from the corridor is blocked by metering pumps, chemical piping and miscellaneous piping. The bulk storage tank occupies most of the space within the containment area, which limits access around the tank and to piping. The sodium hydroxide area is also accessible from the sodium chlorite area.

Figure 42: Sodium Hydroxide Bulk Storage

In the event of an emergency and an operator needs to use an emergency shower or eyewash, there are many obstacles in the way to get out of the containment area. These obstacles do not allow the operator to quickly access the emergency shower or eyewash, which may result in greater injury.

Recommendations

Visual defects on the bulk storage tank were not observed during the site visit and plant staff did not indicate any issues with this tank. For a more accurate assessment of the tank condition, a tank inspection by the manufacturer should be considered.

The sodium hydroxide system should be provided with a transfer pump and day tank. The existing metering pumps should be replaced and a standby pump provided for each application point. Carrier water should be provided with the system, with manual flow control. Carrier water piping within the chemical area should be provided as PVC.

4.7.5 Aluminum Sulfate

The aluminum sulfate system has been provided with a fiberglass bulk storage tank. The bulk storage tank is filled from a connection on the exterior of the building. Alum is currently pumped from the bulk storage tank to the points of application with solenoid operated diaphragm pumps. Visual defects on the bulk storage tank were not observed during the site visit. Plant staff did not identify any issues with this tank.

Access to the alum area is limited. Most of the area accessible from the corridor is blocked by metering pumps, chemical piping and miscellaneous piping. The bulk storage tank occupies most of the space within the containment area, which limits access around the tank and to piping. The alum area is also accessible from the zinc orthophosphate area.

In the event of an emergency and an operator needs to use an emergency shower or eyewash, there are many obstacles in the way to get out of the containment area. These obstacles do not allow the operator to quickly access the emergency shower or eyewash, which may result in greater injury.

Figure 43: Alum Bulk Storage

Recommendations

Although the bulk storage tanks appear to be in good condition, the tank manufacturer should be consulted for a more accurate assessment. The alum system should be provided with a transfer pump and day tank. The day tank material should be polyethylene or as preferred by operations staff. The existing metering pumps should be replaced and a standby pump should also be provided for each application point.

4.7.6 Hydrofluorosilicic Acid

Hydrofluorosilicic acid is stored in drums in a dedicated room and transferred with a drum pump to a day tank. The system currently has two solenoid operated diaphragm pumps mounted to the top of the day tank. Some of the fluoride drums are stored inside the room, but the majority are stored in the main chemical area. Insufficient containment has been provided for fluoride, both inside and outside of the storage room.

Hydrofluorosilicic acid is a corrosive chemical and therefore can make handling difficult. Transferring the chemical to the day tank with the drum pump tanks is a manual operation, which poses a safety concern to operations staff.

Recommendations

Storage of hydrofluorosilicic acid should be modified to eliminate the need for handling by plant staff. Either a bulk storage tank can be provided, or tote delivery could replace the current drum system. The bulk tank material should be polyethylene or as preferred by operations staff.

The fluoride system should be provided with a transfer pump and new day tank. The existing metering pumps should be replaced and a standby pump should be provided for each application point. The metering pumps should be either wall or curb mounted.

Containment should be provided for the fluoride system in accordance with MassDEP and other applicable building codes. Existing curbs will need to be demolished to provide appropriate containment for a new bulk storage and day tank.

Figure 44: Hydrofluorosilicic Acid Storage

4.7.7 Zinc Orthophosphate

The zinc orthophosphate system is 10 to 12 years old. The system has been provided with polyethylene bulk storage and day tanks. Both tanks are vented to the inside of the building. The current bulk tank capacity provides approximately two years of storage, which does not impact efficacy of the chemical. The bulk storage tank is filled from a connection located on the inside of the building. Zinc orthophosphate is currently pumped from the day tank to the point of application with a single solenoid operated diaphragm pump.

There were no visible tank defects observed. However, the expected design life for a polyethylene tank storing zinc orthophosphate is 15 to 20 years. If improvements are being made to other existing chemical systems, the replacement of the zinc orthophosphate tanks should be considered.

Access to the zinc orthophosphate area is limited. Most of the area accessible from the corridor is blocked by the metering pump, analyzers, electrical conduit, and other miscellaneous piping and flexible tubing. The zinc orthophosphate can also be accessed from the adjacent aluminum sulfate area.

Figure 45: Zinc Ortho-phosphate Bulk Storage

In the event of an emergency and an operator needs to use an emergency shower or eyewash, there are many obstacles in the way to get out of the containment area. These obstacles do not allow the operator to quickly access the emergency shower or eyewash, which may result in greater injury.

<u>*Recommendations*</u>

The analyzers mounted within the zinc orthophosphate area should be relocated to increase the accessibility of the area and allow for operators to enter and exit the area safely. A ladder at the current location of the analyzers, with steps on the inside and outside of the curbed area would improve access.

The existing metering pump should be replaced and a standby pump should be provided for each application point. The bulk storage and day tank appear to be in good condition and no repairs or upgrades are required. Tanks should be vented to the exterior of the building and provided with an insect screen. The fill connection for the bulk storage tank should be moved to the exterior of the building.

4.7.8 Powdered Activated Carbon

The PAC system is relatively new and is working well. The only issue identified with the PAC system is the cleaning of the dust collector. A large amount of carbon is released into the room when the dust collector bin has to be periodically emptied. Plant staff would prefer to provide a method to rinse the collected carbon from the dust collector back to the carbon slurry tank.

Figure 46: PAC Feeder

4.7.9 Recommendation Summary

Recommendations are prioritized on a numerical scale from 1 to 4, where 1 indicates the need to repair or replace immediately, 2 indicates that repair or replacement should occur soon, 3 indicates good condition, and 4 describes excellent condition. Each of the recommendations described in the previous sections are assigned a number and summarized in Table 15.

Table 15: Summary of Chemical Systems Recommendations

No.	Item	Description	Condition
Ch1	Zinc Orthophosphate	Bulk Storage Tank Inspection	3
Ch2		Metering Pumps	3
Ch3		Accessibility	2
Ch4	Sodium Chlorite	System in Separate Room	2
Ch5		Increase Capacity of Tank and Fill Station	2
Ch6		Day Tank and Transfer Pump	2
Ch7		Metering Pumps	3
Ch8	Sodium Hydroxide	Bulk Storage Tank Inspection	2
Ch9		Fill Station	3
Ch10		Day Tank and Transfer Pump	2
Ch11		Metering Pumps	3
Ch12		Accessibility	2
Ch13	Sodium Hypochlorite	Bulk Storage Tank	2
Ch14		Fill Station	3
Ch15		Day Tank and Transfer Pump	2
Ch16		Metering Pumps	3
Ch17		Accessibility	2
Ch18	Alum	Bulk Storage Tank Inspection	2
Ch19		Fill Station	3
Ch20		Day Tank and Transfer Pump	2
Ch21		Metering Pumps	3
Ch22		Accessibility	2
Ch23	Fluoride	Bulk Storage Tank	2
Ch24		Day Tank and Transfer Pump	2
Ch25		Metering Pumps	3
Ch26	Hydrochloric Acid	Bulk Storage Tank	2
Ch27		Fill Station	3
Ch28		Provide Day Tank and Transfer Pump	2
Ch29		Metering Pumps	3
Ch30	Chlorine Dioxide	Provide New Generation Unit and Gas Detector	2
Ch31	PAC	Dust Collection Improvements	3

<u>Condition Grading Scale</u>

1 – Repair and Replace Immediately

2 – Repair and Replace Soon

3 – Good Condition

4 – Excellent Condition

4.8 Heating, Ventilation, and Air Conditioning

In general, the HVAC systems throughout the TWTP are at the end of their service life. Plant staff have found that most systems are not working well. At a minimum, controls need to be improved and all ducts should be cleaned. Areas investigated as part of the heating ventilation and air conditioning assessment include the following:

- Administration Area and Laboratory
- Boiler Room
- Electrical Room
- Generator Room
- Chemical Area
- Filter Area
- Dewatering Building
- Raw Water Pump Station

Observations regarding each of these areas are reviewed in the following sections, along with recommended upgrades. A prioritization of recommendations follows.

4.8.1 Administration Area and Laboratory

The existing systems were installed as part of the original facility construction. Air handling and air conditioning units are located on the mezzanine above the restrooms. The exhaust fan that serves the administrative areas is also located in the mezzanine, with separate exhaust fans for the fume hood and canopy hood installed in the laboratory. Access to the equipment is difficult due to limited space within the mezzanine area. Some of the hot water piping to the air handling and air conditioning units was observed to be missing insulation.

Figure 47: HVAC Equipment in Mezzanine

Administration areas are provided with finned tube radiators for perimeter heating. Plant staff have indicated that the system does not work well.

The laboratory fume hood exhaust stack terminates above the roof with a gooseneck. The laboratory fume hood exhaust system should remove hazardous or noxious fumes from the lab and exhaust to a stack or a high plume dilution blower. Fumes should be discharged so that they do not contaminate the roof area or become re-entrained into the building's make-up air system. The exhaust system should meet ANSI Z9.5, NFPA 45, UL 705, and ASHRAE Chapter 44 lab design guidelines.

Recommendations

The existing systems are over 25 years old and are at the end of their useful life. All systems serving the administration and lab areas should be replaced with new more energy efficient systems. The air conditioning system should include an air to air energy recovery system. Plant staff have indicated that the full fume hood is unnecessary for testing performed in the laboratory. A benchtop replacement fumehood is recommended.

Due to their convenience and the ability to provide individual control for each room, split ductless units are recommended for the administration areas. Split ductless units should be installed in the main control area, the laboratory, and in each of the two offices and the break room. A common condensing unit should be installed with the new units.

A new air handling unit with heating and cooling coils is recommended to supply air to the administration areas. An air to air heat exchanger should be installed to improve system efficiency. The existing toilet exhaust fan should be replaced. As with all HVAC upgrades, controls should be made as simple as possible.

4.8.2 Boiler Room

The boiler room systems were installed as part of the original plant construction. Room ventilation consists of a propeller supply fan drawing air from outside to the room. Heat is provided by a hydronic unit heater. Boiler exhaust is passed through the wall and up a stack attached to the side of the exterior wall.

Figure 48: Boiler Stack

Recommendations

The boiler is at the end of its useful life. The boiler should be replaced with a new energy unit. Consideration should be given to a natural gas fired condensing boiler. Opportunities for energy efficiency rebates from National Grid are available and should be explored.

The ventilation system and the unit heater should also be replaced and the necessary combustion air provided. The new boiler should be exhausted directly through the roof with a PVC pipe smaller than the existing exhaust stack.

4.8.3 Electrical Room

The electrical room ventilation system was installed as part of the original plant construction. Ventilation consists of a propeller supply fan drawing air from outside and discharging it through a transfer grille to the chemical room. The room is heated by an electric unit heater.

Recommendations

The electrical room ventilation system is at the end of its useful life. The transfer grille should be removed and the system modified to exhaust directly outside.

4.8.4 Generator Room

The generator room ventilation system was installed as part of the original plant construction. Ventilation consists of four propeller exhaust fans drawing outside air into the room through louvers with motor operated dampers. The room is heated by a hydronic unit heater.

Figure 49: Generator Room Exhaust Fan

Recommendations

The generator room ventilation system is at the end of its useful life. The system should be modified if the generator is replaced to match the requirements of the new generator. If the generator is installed outside the building, heating and ventilation should be coordinated with the rest of the chemical area.

4.8.5 Chemical Area

The existing chemical room systems were installed as part of the original plant construction and equipment are showing signs of corrosion. The air handling unit supplying the space is located on the mezzanine above the restrooms. Ventilation for the smaller chemical rooms, shop, storage room, and utility room is accomplished by drawing in air from the large chemical room and by a transfer fan. Exhaust fans are connected to the hydrofluorosilicic acid and hydrochloric acid rooms. The shop, storage, and utility rooms are exhausted through the hydrochloric acid storage room. A transfer grill located in the wall between the fluoride and hydrochloric acid rooms is corroded.

Recommendations

The existing systems are at the end of their useful life. All systems serving the chemical areas should be replaced. The ventilation systems for the smaller chemical rooms should be kept segregated from each other and the general chemical room. Dampers should be installed in each room so that air is not transferred into the main area should the ventilation system be shut off. The transfer grill in the wall between the fluoride and hydrochloric acid rooms should be eliminated and the wall sealed.

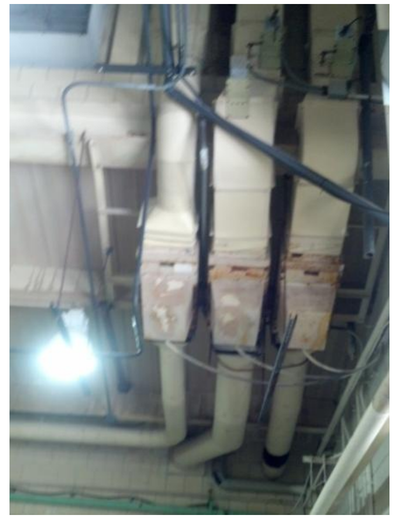

Figure 50: Exhaust Fans in Chemical Area

All HVAC equipment and ductwork in or serving the chemical rooms should be replaced with corrosion resistant materials. New systems with sufficient air changes per hour and proper corrosion resistant materials for the fans and ductwork are recommended.

Plant staff have identified the need for a large dehumidifier for the chemical room. An evaluation of the space does not support a dehumidification system. If condensation is present on water lines, insulation can be installed to prevent sweating or a drain pan can be installed under the sample lines to collect condensation and direct it to a drain.

4.8.6 Filter Rooms

The HVAC system in the original filter room remains from the original plant construction. When the second filter room was added as part of the 1998 expansion, it was integrated with the original room.

Figure 51: Air Handling Units in Filter Room

The original filter room is served by two air handling units, which provide filtered outside air. Air is exhausted through wall louvers with motor operated dampers. Perimeter heating is provided by hydronic unit heaters in the original section, which have visible signs of corrosion.

The newer filter room is served by a separate air handling unit that provides filtered and heated outside air. The air handling unit has hydronic heating coils. A fan was installed with the filter addition to transfer air from the older filter room to the newer section. Air is exhausted through wall louvers with motor operated dampers. Perimeter heating is provided by two gas fire unit heaters. All equipment in the new section appears to be in good condition.

The electrical room in the filter area is served by an intake wall louver with a motor operated damper and a propeller exhaust fan. It appears that a new VFD has been added that was not considered in the original selection of the ventilation system.

Recommendations

Heating coils to one of the air handling units are recommended for heated winter ventilation. A split ductless system for the filter electrical room is recommended to provide sufficient cooling for the VFD. The split ductless unit could be installed above the door of the room.

4.8.7 Dewatering Building

The Dewatering Building's DE storage room has been identified as requiring dust control. The building utilizes transfer air fans to move air to and from the DE storage room and the sludge loading area, and also from the vacuum filter room to the DE storage room.

The DE room and the vacuum filter room are each provided with a gas fired make up air handling unit. The vacuum pump room ventilation is provided by an air handling unit and exhausted through a wall louver with motor operated dampers. The system appears to be in good condition.

The electrical room within the dewatering building is served by a ductless split air conditioning unit. The system appears to be in good condition. Perimeter losses for the process areas are heated by gas fired unit heaters. They are installed over 10 feet above the floor, which may be minimizing their effectiveness.

Recommendations

Consideration should be given to eliminating the air transfer system from the DE room to the sludge loading area as this is the area with the most dust. The remaining opening in the wall needs to be sealed off after this system has been eliminated. As the removed transfer fan provided exhaust for the DE room, a new exhaust fan is needed. This fan should exhaust directly outdoors. The DE room should be kept with a slightly negative pressure to minimize migration of dust to other spaces. All doors to this room should be kept shut. With the elimination of the transfer fan, supply air must be replaced for the sludge loading area from the outside. Methods to arrest dust from the DE systems before it is released into the room should also be explored, This could be either a new bag breaking system or a means of eliminating the screw conveyor.

4.8.8 Raw Water Pump Station

The raw water pump station HVAC system consists of an air handling unit delivering unheated air to the space and a louver with a motor operated damper. The space is heated with two electric unit heaters. Plant staff do not have any issues with the existing systems. There is a VFD panel installed on the upper level near the entrance. The panel is located under the exhaust air damper/louver. This is an area of concern with the possibility of windblown rain coming through the louver and damaging the VFD panel.

Figure 52: Raw Water Air Handling Unit

Recommendations

Although it has not been an issue in the past, the motor operated damper/louver located above the VFD cabinet should have a drain pan with drain and piping added above the VFD cabinet. This will protect it from possible rain intrusion.

4.8.9 Recommendation Summary

Recommendations are prioritized on a numerical scale from 1 to 4, where 1 indicates the need to repair or replace immediately, 2 indicates that repair or replacement should occur soon, 3 indicates good condition, and 4 describes excellent condition. Each of the recommendations described in the previous sections are assigned a number and summarized in Table 16.

Table 16: Summary of HVAC Recommendations

No.	Item	Description	Condition
HV1	Raw Water Pump Station	Install drain pan to collect moisture above VFD	3
HV2	Administration Area	Add split ductless units to offices and break room	1
HV3		Replace air handling unit	2
HV4		Install air to air heat exchanger on intake	2
HV5		Replace toilet exhaust fans	2
HV6	Laboratory	Add split ductless unit for cooling	2
HV7		Install dedicated exhaust fan	2
HV8		Fume hood removal and replacement	2
HV9	Chemical Area	Replace ventilation system	2
HV10	Electrical Room	Remove transfer grille and exhaust directly outside	2
HV11	Generator Room	Replace ventilation system	2
HV12	Boiler Room	Replace boiler	2
HV13		Replace unit heater	2
HV14		Replace ventilation system	2
HV15	Filter Area	Add split ductless unit and heating coals to AHUs	2
HV16	Dewatering Building	Install new exhaust fan	2

Condition Grading Scale

1 – Repair and Replace Immediately

2 – Repair and Replace Soon

3 – Good Condition

4 – Excellent Condition

4.9 Electrical and SCADA

Portions of the original 1985 electrical system are still in operation. The main 480V switchboard, including an automatic transfer switch and additional 480V motor control centers were added approximately 10 years ago as part of a plant expansion. Upgrades to remaining systems are required. The existing 500 kW diesel fueled standby generator was not upgraded as part of the plant expansion, and does not have sufficient capacity for the facility peak electrical load when utility power is lost. The main 480V switchboard, including an automatic transfer switch, is located outside and its operation is problematic due to weather exposure.

The SCADA system has been upgraded relatively recently. The present system employs Eurotherm/Chessel video recorders and an Allen Bradley PLC. A new chemical feed pacing system was also installed as part of the upgrades.

Items evaluated included:

- Main Switchboard
- Electrical Distribution System
- Standby Generator
- Fire Alarm and Security Systems
- SCADA Network and Architecture

Observations regarding each of these items are reviewed in the following sections, along with recommended upgrades. A prioritization of recommendations follows.

4.9.1 Main Switchboard

The main 480V distribution system for the facility is located within an outdoor NEMA 3R metal enclosure adjacent to the facility utility transformer. The facility electrical load was identified to be approximately 269 kW at 0.95 PF during the equipment review.

Figure 53: Main Switchboard

Inspection of the main switchboard found the exterior of the enclosure weathered and paint faded. Warning signage is barely visible. Dirt and sand debris with some frame and aluminum lug oxidation can be seen at the front and within the opening of the enclosure. Although a NEMA 3R enclosure surrounds the electrical switchboard within an envelope that includes doors to prevent direct exposure to the elements, the enclosure is not sealed and has openings that allow moisture and dirt entry. Over time, this type of enclosure could result in premature equipment failure.

The main breaker is a 2,000 ampere Square D Type SE electronic trip circuit breaker with long time, short time, instantaneous and ground fault adjustable protection. Various dial settings are evident but no calibration stickers were found. Drawings indicate that lightning protection at the main service was provided when constructed. However, surge protection to UL 1449 is not provided. A revision of UL 1449 went into effect in 2007. This revision adds intermediate fault current tests for surge protection devices (SPDs). Before the 2007 revision, only high current fault current testing was specified.

Figure 54: Automatic Transfer Switch

The automatic transfer switch (ATS) is an ASCO 940 series, which is an outdated style switch and no longer manufactured. There is a sticker on the enclosure that indicates that an ASCO field representative was at the facility in 2008. This was in response to an incident where transfer to the generator did not occur during a utility outage, resulting in the plant operator having to open the enclosure and manually operate the switch with a removable handle to transfer the facility load to the generator. It is believed that the adverse conditions of the environment caused the ATS to fail to operate. Discussion with plant staff indicated that the generator is tested without using the ATS and not tested under load. The existing electrical system installation has a single point of failure at the ATS. The ATS is not exercised and its status is unknown.

Operation of the transfer switch using the manual operating handle with the ATS protective door open is a hazard due to the dangers of arc flash if one of the two sources are energized. The best way to remove the hazards of an arc flash is to de-energize electrical equipment when interacting with it, however de-energizing electrical equipment by operating circuit breakers is in and of itself an arc flash hazard. No arc flash labels were found on the electrical distribution equipment.

An *Arc Flash Program* is an overall plan that covers all aspects of arc flash safety and compliance. The purpose of an arc flash program is to keep those working on or near an electrical system safe. The *Arc Flash Program*, through a variety of methods, ensures workers and contractors follow the safety rules related to electrical work. The NEC and NFPA 70E both require warning labels on equipment that pose an arc flash hazard. These labels include the incident energy and required personnel protective clothing needed to perform equipment operation.

A 480V breaker distribution section at the end of the switchboard includes molded case circuit breakers feeding motor control centers at the facility. There is space for one additional future circuit breaker to feed any facility expansion.

Recommendations

A pre-fabricated structure placed over the switchboard is recommended to provide a clean and controlled environment for the main switchboard. It appears that there is adequate space in the area of the switchboard to allow this to happen. As part of this work, the following should also be performed:

- The switchboard should be cleaned and inspected, the ATS tested for proper operation, and all breaker trip mechanisms tested by means of injection testing to verify trip settings and breaker operability.
- A bypass switch should be added to permit exercising of the transfer switch.
- A field technician from the ATS manufacturer (ASCO) should be brought on site to perform switch contact timing calibration check and to determine if the switchboard/ATS installation can be modified to provide an external operating handle to allow the operator to manually transfer the load more safely in an emergency (alternatively, the ATS can be replaced).
- The generator system should be periodically tested under facility load using the ATS to verify system operability.
- An arc flash analysis should be performed and arc flash labels added to all electrical distribution equipment. In addition, an *Arc Flash Program* should be adopted at the facility.
- Surge protection to UL 1449, 3rd edition should be added at the main breaker compartment.

The work required at the main switchboard, including placing the equipment within a weather-proof structure, the associated upgrades or replacement of the ATS, and the addition of surge protection should be performed immediately.

4.9.2 Electrical Distribution System

The facility electrical distribution system includes the following motor control centers (MCC):

- **Raw Water Pump Station – MCC-3 and MCC-4:** Both MCCs were manufactured by Westinghouse Company (Series 2100) and date back to the original plant construction. Existing reduced voltage starters for two of the four raw water pumps have been replaced with VFDs and the old starter sections remain in the MCC lineups. The existing MCCs and VFDs are aging but appear in good condition. No surge protection devices were found to be installed at these MCCs. None of the four pump motors were found to be inverter duty rated.
- **Electrical Room – 102 – MCC-5 and MCC-5A:** MCC-5 was manufactured by Westinghouse Company (Series 2100) and dates back to the original plant construction. MCC-5A was manufactured by Square D Company and was installed during the 1998 expansion. All MCCs appear to be in good condition. The existing flocculators at Sedimentation Basin No. 1 and No. 2 are silicon controlled rectifier (SCR) controlled from a control panel in the south-east corner of the electrical room. Newer flocculators at Sedimentation Basin No. 3 and No. 4 are VFD controlled with the VFDs located within MCC-5A. Plant staff have indicated that the older flocculators controlled by SCRs have been more reliable when compared to the newer flocculators controlled by VFDs. Our review of record drawing E-3 from the 1998 drawing set shows that the control wiring and VFD power wiring are routed within the same raceway. Noise radiated from a VFD cable is proportional to the amount of varying electric current within it. As cable lengths grow, so does the magnitude of reflected voltage. This transient over voltage, combined with the high amplitudes of current associated with VFDs, creates a significant source of radiated noise. Radiated noise is often an issue with an existing VFD installation and general practice is to route control cables in separate raceways. In addition, no surge protection devices were found to be installed at these MCCs.
- **Electrical Room – 121 – MCC-1, MCC-1-A, MCC-2 and MCC-2A:** MCC-1 and MCC-2 were manufactured by Westinghouse Company (Series 2100) and date back to the original plant construction, while MCC-1A and MCC-2A were manufactured by Square D Company and were installed during the 1998 expansion. All MCCs appear to be in good condition. MCC-2A is located partially across the aisle from MCC-2 and a working clearance in front of these MCCs is not quite the NEC required

Figure 55: TWTP MCC 1

four feet between 480V distribution enclosures. These MCCs were originally designed with reduced voltage starters to power 2-100 HP and 2-200 HP high lift pumps. Presently, VFDs have been provided to power the 100 HP Pump No. 3 and the 200 HP Pump No. 1. It was noted that of the four pump motors, only the Pump No. 2 motor is inverter duty rated. A VFD-driven general purpose motor can overheat if it is run too slowly as motors can get hot if they are run slower than their rated speed. Since most general purpose motors cool themselves with shaft-mounted fans, slow speeds mean less cooling. If the motor overheats, bearing and insulation life will be reduced. There are therefore minimum speed requirements for all motors. The 'voltage chopping' that occurs in the drive actually sends high-voltage spikes (at the DC bus level) down the wire to the motor where a reflected wave occurs at the motor. The reflected wave can effectively double the voltage on the wire, leading to premature failure of the motor insulation

- **Dewatering Building – MCC-6:** Manufactured by Square D Company (Model 6) from the 2005 addition, MCC-6 appears to be in excellent condition. The transient voltage surge suppressors installed on the face of the MCC are built to the older standard, UL-1449 2nd ed., and each has a failed phase module (red lamp). Surge counters could not be read.

The existing panelboards and distribution transformers were found to be in acceptable condition. However, panelboard P1 was noted to have a rusty enclosure, possibly due to its location adjacent to the door leading to the chemical area.

Large VFDs are installed at the Raw Water Pump Station and in the area adjacent to the filters for two high lift pumps. The existing Safetronics style VFDs appear to be an older vintage and consideration for future replacement of these drives may be warranted since the life expectancy of a drive system is not only based on usage, but improved technology and obsolescence of older parts. The Yaskawa drive for High Lift Pump No. 1 appears to be a recent addition to the facility and includes an integral cooling system.

Figure 56: Raw Water Pump VFD Cabinet

The electrical distribution system within the PAC silo building is not currently classified. NFPA 820 identifies powdered or pulverized activated carbon as a combustible fire and explosion hazard. Typically, precautions are taken in the installation of electrical equipment in buildings of this type in order to provide explosion proof enclosures and conduit seal fittings to limit the fire hazard.

<u>*Recommendations*</u>

Recommendations for the electrical distribution system include:

- Surge protection to UL 1449, 3rd edition should be added to the MCCs.
- Replace Reeves Drives with VFD/motor/gear reducer combos.
- When VFDs are added in the future, new cabling that uses separate raceways for the power conductors to the motors should be provided.
- Motors driven by new VFDs should be changed to inverter duty rated type or dV/dt output filters should be included in the VFD enclosures.
- Panelboard P1 should be designated for interior inspection and possible replacement.
- Further review of the PAC system should be performed as part of the preliminary design effort of upgrades to determine if replacement of the electrical system with explosion proof enclosures and conduit seal fittings is warranted.

The addition of surge protection at all MCCs should be performed immediately including replacing the TVSS at MCC-6. Existing VFD cabling should be reviewed and replaced if found not to be installed in accordance with good engineering practice. Panelboard P1 should be evaluated for condition and possible replacement within the next few years.

Although the PAC building classification was reviewed during its initial design, it should be re-evaluated as part of any facility distribution system improvements.

4.9.3 Standby Generator

The existing 500 kW, 480V 3-phase standby generator system consists of a water cooled Caterpillar diesel engine and generator on a common skid. As reported by plant staff, the system is not tested under load. The jacket water keep warm system was found to be functional. The nickel-cadmium starting batteries were found to have clean terminals and be in good condition.

Figure 57: Standby Generator

The controls for the generator are located in a relay based free-standing control panel manufactured by Enercon. This relay based type control panel is no longer supplied by engine generator manufacturers. Any operational problems with the wiring or devices within the panel would be difficult and time consuming to remedy. Therefore, this type of panel can be considered a 'weak link' with respect to the reliability of the standby power source.

The engine is cooled by a 'once-through' water service that is connected to the engine's heat exchanger and then discharged to the river. Not only is this a waste of water resources, but it could result in direct contact to engine fluids if a crack in the block occurred. Since this installation is contrary to LEED initiatives, replacement of this system should be considered.

Diesel fuel from an underground tank to a day tank in the generator room is the fuel supply to the engine. Regulations and requirements for inspection and testing of underground fuel storage tanks have become more stringent over the last several years. The existing underground storage tank was installed approximately 25 years ago and is at the end of its useful life.

A review of the previous utility historical kW demand for the facility by Christopher Starr of National Grid indicates that the maximum previous demand was 500 kW. This confirms the concern identified by plant staff that the existing generator system is undersized for the facility load.

Recommendations

A replacement diesel fueled standby generator system with a dual walled diesel fuel belly tank in a weather proof walk-in enclosure system should be provided. It should be sized between 600 kW and 750 kW depending on future facility demand needs and the ability to reduce existing kW demand by installing additional VFDs at the facility. Replacement of the standby generator system should be considered immediately.

4.9.4 Fire Alarm and Security System

The facility fire alarm system consists of an addressable Honeywell Fire-Lite Alarms Main Control Panel at the building entrance and a second control panel manufactured by Edwards Systems Technology in the Sludge Building addition. Edwards Systems Technology is now a unit of United Technologies Corp. The Honeywell panel is a recent addition and has served the facility well according to plant staff. The Edwards panel, although only a few years older, is set up with a proprietary software that requires a factory technician to perform modifications and programming changes. This maintenance has been historically costly. Heat detectors were not evident in the raw water pump station, boiler room, or the generator room.

The facility was found to have a working closed circuit television (CCTV) monitoring system and security system at the water treatment plant, the Raw Water Pump Station, and at remote facilities. The outdoor camera and lens at the Raw Water Pump Station is enclosed in a tamper resistant housing. The camera support appears to be robust in design and capable of supporting the camera including any potential wind and ice loading normally encountered at the site. A television monitor at the main control panel in the treatment plant provides split screen viewing of several remote cameras to allow continual surveillance. System signal communications is provided via microwave radio system incorporating a 10/100 Ethernet Bridge/Switch controller to optimize wireless connectivity using remote antennas, and communication towers at the TWTP and the Ames Hill Pump Station.

Recommendations

Consideration should be given to consolidate the fire alarm system and extend the existing addressable devices in the sludge building to the Fire-Lite alarms main control panel. The fire alarm system should be upgraded.

The existing CCTV system was reported to be fully functional. Consideration to expanding the system with an additional switching capability and cameras at all water system facilities is recommended. Relocation of the CCTV at the Raw Water Pump Station from above the entry to the top of the hill would provide better coverage and is recommended. Security monitoring devices including magnetic switches at doors and exterior panels and cabinets should be verified to be installed at all remote facilities and associated alarm contacts wired into the Town water department's SCADA system.

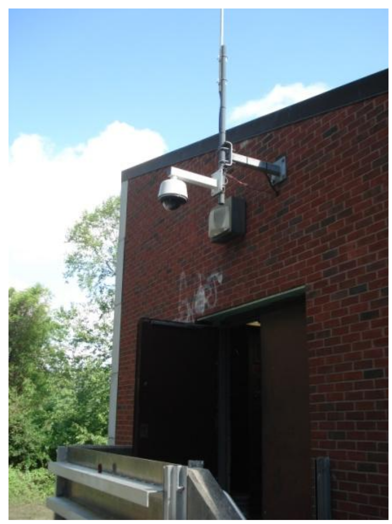

Figure 58: CCTV at Raw Water Pump Station

4.9.5 Instrumentation and Control Systems

In general, the overall condition of facility instrumentation and the plant control system was found to be in excellent condition. Facility control panels are in good condition except for the alum sludge control panel located in the northeast corner of the chemical room. This panel has been modified extensively in the past and includes an old Ronan system annunciator.

Field instrumentation at the facility range in type from a Hach SC200 controller, which has a platform that can be configured to operate either 2 Digital Sensor Inputs, or 1 or 2 Analog Sensor Inputs, or a combination of digital and analog sensor inputs with communication options from a variety of offerings ranging from MODBUS RTU to Profibus DPV1, to a Fisher-Porter flow transmitter at the intake structure, which is a pure analog instrument. Field bus communication protocol is superior to analog transmissions and hybrid communications in information accuracy, transmission speed, and transmission volume. It also offers superiority to those transmissions and communications in functionality, including the ability to communicate between connected devices and to communicate bi-directionally.

Analog transmission is a topology, which is a one-to-one system and allows only one field device to be connected to a single cable. The transmission direction is one-way. Therefore, two different cables must be provided; one to acquire information from the field device, and the other to transmit control signals to the field device. A hybrid communication is a communication technique in which field device information is superimposed as digital signals on the conventional 4 mA to 20 mA analog signal. In addition to analog transmission capabilities, it is possible to remotely set up the field device range and perform zero-point adjustment.

The field bus communication protocol, which is different from analog transmissions or hybrid communications, supports a perfect digital signal communication system. In addition, the field bus communication supports bidirectional communication, thus allowing more types and a larger amount of data to be transmitted in comparison to analog transmission and hybrid communication.

The main control panel has been recently upgraded and presently includes six Eurotherm/ Chessel video recorders that provide graphical recording and PID control of various process data points. These recorders are enhanced with a dual-channel set point programmer and digital communications options. The instruments have been programmed to allow each recorder to display data for any of the six points, which provides considerable redundancy in the control system.

It has been traditionally costly to connect multiple field devices. Using a field bus communication system, it is possible to connect a large number of field devices to the field bus because of low wiring cost by multi-drop connections. This expands the scale of process control systems and promotes a higher level of plant automation.

Plant control presently uses an Allen Bradley SLC 505 platform. A remote RTU at the raw water pump station and main PLC at the main control panel provide system monitoring and programmed on-site control. The system acquires facility data and remote station data via VHF radio modems, including instrument data and equipment status, and performs local control where programmed. However, the plant is manually brought back online after an outage.

Recommendations

As process system upgrades occur, field instrumentation using a digital field bus topology should be considered. Several instrument manufacturers provide a multivariable technology, where a single instrument can measure more than one process variable. These intelligent transmitters allow the replacement of three separate transmitters with one, meaning fewer transmitters, less wiring, fewer shutoff valves, and fewer process penetrations.

As newer style VFDs are installed, consideration to utilizing a modbus Ethernet input into the plant PLC should be considered. Chemical control panels should be specified with Allen-Bradley PLCs for direct Ethernet connection into the main plant control system.

The alum sludge control panel should be replaced with a new panel with a PLC and HMI and connected to the plant control system. No specific upgrade to the plant control system and process instrumentation was identified as being necessary. However, the installation of local RTU panels at various locations through the facility for local control should be explored.

4.9.6 Recommendation Summary

Recommendations are prioritized on a numerical scale from 1 to 4, where 1 indicates the need to repair or replace immediately, 2 indicates that repair or replacement should occur soon, 3 indicates good condition, and 4 describes excellent condition. Each of the recommendations described in the previous sections are assigned a number and summarized in Table 17.

Table 17: Summary of Electrical and Control Systems Recommendations

No.	Item	Description	Condition
E1	Main Switchboard	Provide new structure, perform ATS upgrades, arc flash analysis, add surge protection	1
E2	Electrical Distribution System	Add new surge protection devices to MCC	1
E3		Investigate and modify VFD cabling where required	2
E4		Large motors are premium efficient and reported to be operating acceptably	3
E5		Panel board P1 should be designated for interior inspection and possible replacement	2
E6		Evaluate existing PAC system installation for potential hazards	1
E7	Standby Generator System	Replace with a larger system in a walk-in style enclosure	1
E8	Fire Alarm System	Upgrade system & review existing detector coverage	2
E9	CCTV and Security System	No immediate specific upgrades are identified	3
E10	Instrumentation and Control	Replace panels	2
E11		No immediate specific upgrades are identified	4

<u>Condition Grading Scale</u>

1 – Repair and Replace Immediately

2 – Repair and Replace Soon

3 – Good Condition

4 – Excellent Condition

5 RECOMMENDATIONS

The TWTP consistently produces high quality water, is operated well, and is in reasonably good condition. Recommendations developed based on an evaluation of the current facility capacity and demands, an assessment of potential future demands, a review of the TWTP chemical processes and alternatives to those processes, and a general overview of the facility have been outlined in the preceding sections. These recommendations are summarized in Table 18.

After completion of the evaluation, a number of other items were brought forward by plant staff. These are detailed as supplemental recommendations in Table 19.

Table 18: Recommendation Summary

No.	Item	Description	Condition
Civil			
C1	Site Drainage	Install interceptor swale to direct runoff away from building	2
Structural			
S1	Raw Water Pump Station	Replace missing or worn grating and install grating clips	2
S2		Continue to maintain monorail hoist and crane beam	4
S3		Repair concrete spalls and pockets at interior wall surfaces	3
S4		Repair foundation concrete at downspouts	2
S5		Maintain concrete floor surface	4
S6	Administration & Process Building	Upgrade pipe and equipment supports to reduce potential for damage due to seismic loading (if required by code review)	3
S7		During repair of coating within chemical containment areas, perform condition assessment and repair concrete if required	2
S8		Repair concrete walls in filter tanks at water surface and outfall area	2
S9		Repair foundation concrete at downspouts	2
S10		Continue to maintain stair concrete, similar to repairs that have been performed in the past	3
S11	PAC Tank	Perform confined space entry inspection of tank to assess condition	1
S12		Perform general repair of entire tank top	2
S13		Continue to maintain the stair concrete	3
S14	Pretreatment Basins	Perform confined space entry inspection of tank to assess condition	1
S15		Perform general repair of entire tank top surface	2
S16		Continue to maintain the stair concrete	3
S17	Clearwell	Perform confined space entry inspection of tank to assess condition	1
S18		Perform general repair of entire tank top surface	2

No.	Item	Description	Condition
Architectural			
A1	Raw Water Pump House	Repair and recoat interior walls and floor	2
A2		Repair roof gutter and broken light fixture cover	2
A3		Remove graffiti and paint splatters on exterior walls and entrance door	2
A4		Install snow guards	2
A5		Precast sealant replacement of exterior walls	2
A6	Pretreatment	Replace domed hatches on Pretreatment Basins No. 1 & 2 with flush style hatches	2
A7	Treatment Plant Interior	Maintain/re-coat process area interiors	2
A8		Retrofit generator room for chemical day tanks	2
A9		Overall upgrade of administration area interiors	2
A10		Tint windows in filter room to reduce algae growth in filters	3
A11		Install missing filter guardrails and retrofit existing guardrails	1
A12		Miscellaneous repair/replacement of doors and windows	2
A13	Treatment Plant Exterior	Precast sealant replacement of exterior walls	2
A14		Repair for missing weep joints in masonry	2
A15		Repair issues at copper downspout locations	2
A16		Repair roof gutter and snow guards	2
A17		Repair or replace west façade lovers	2
A18		Repair cored holes in brick wall	2
A19		Clean exterior wall surface	2
A20		Replace exterior windows	2

No.	Item	Description	Condition
Laboratory			
L1	Existing Condition	Replace ceiling grid and tiles	2
L2		Replace flooring and cabinets	2
L3		Insulate pipes in ceiling	2
L4		Replace cup sinks with larger lab sinks	2
L5		Remove fume hood and replace with tabletop unit	2
L6		Install floor drains	2
L7		Move online analyzers to common location	2
L8		Replace lab equipment as necessary	2
L9	Expansion	Expand laboratory and break room	2
Unit Processes and General Treatment Items			
M1	Flow Measurement	Replace flow tubes with magnetic flow meters	2
M2		Install magnetic flow meter for Basin No. 1 and 2	2
M3	Pretreatment	Replace mixers in Basin No. 1 and 2	2
M4		Install enclosure to prevent sludge valves from freezing	2
M5		Add floating decanter and return pump for recycle	3
M6		Replace 50 HP sludge mixer with smaller unit	3
M7		Ultrasonic level measurement in sludge tanks	3
M8	Filters	Inspect and replace filter bottom plates, cell dividers, and divider rods as necessary	2
M9		Refurbish travelling bridges as necessary	3
M10		Continue filter media replacement	3
M11		Add filter to waste capability	4
M12		Explore lengthening filter run times	3
M13	Clearwell Operation	Install actuators on clearwell gate valves	2
M14	Equalization	Explore the feasibility and cost of equalization	2

No.	Item	Description	Condition
Large Water Pumps			
P1	Raw Water Pumps	Replace Pump No. 2 and 3 with new larger pump and associated fittings	2
P2		Add VFD for new pump	2
P3		Control air burst system through SCADA	3
P4	Distribution Pumps	Replace Pump No. 2 and 3 with new larger pump and associated fittings	2
P5		Add VFDs to all pumps	2
Chemical			
Ch1	Zinc Orthophosphate	Bulk Storage Tank Inspection	3
Ch2		Metering Pumps	3
Ch3		Accessibility	2
Ch4	Sodium Chlorite	System in Separate Room	2
Ch5		Increase Capacity of Tank and Fill Station	2
Ch6		Day Tank and Transfer Pump	2
Ch7		Metering Pumps	3
Ch8	Sodium Hydroxide	Bulk Storage Tank Inspection	2
Ch9		Fill Station	3
Ch10		Day Tank and Transfer Pump	2
Ch11		Metering Pumps	3
Ch12		Accessibility	2
Ch13	Sodium Hypochlorite	Bulk Storage Tank	2
Ch14		Fill Station	3
Ch15		Day Tank and Transfer Pump	2
Ch16		Metering Pumps	3
Ch17		Accessibility	2

No.	Item	Description	Condition
Ch18	Alum	Bulk Storage Tank Inspection	2
Ch19		Fill Station	3
Ch20		Day Tank and Transfer Pump	2
Ch21		Metering Pumps	3
Ch22		Accessibility	2
Ch23	Fluoride	Bulk Storage Tank	2
Ch24		Day Tank and Transfer Pump	2
Ch25		Metering Pumps	3
Ch26	Hydrochloric Acid	Bulk Storage Tank	2
Ch27		Fill Station	3
Ch28		Provide Day Tank and Transfer Pump	2
Ch29		Metering Pumps	3
Ch30	Chlorine Dioxide	Provide New Generation Unit and Gas Detector	2
Ch31	PAC	Dust Collection Improvements	3
Heating, Ventilation, and Air Conditioning			
HV1	Raw Water Pump Station	Install drain pan to collect moisture above VFD	3
HV2	Administration Area	Add split ductless units to offices and break room	1
HV3		Replace air handling unit	2
HV4		Install air to air heat exchanger on intake	2
HV5		Replace toilet exhaust fans	2
HV6	Laboratory	Add split ductless unit for cooling	2
HV7		Install dedicated exhaust fan	2
HV8		Fume hood removal and replacement	2
HV9	Chemical Area	Replace ventilation system	2
HV10	Electrical Room	Remove transfer grille and exhaust directly outside	2

No.	Item	Description	Condition
HV11	Generator Room	Replace ventilation system	2
HV12	Boiler Room	Replace boiler	2
HV13		Replace unit heater	2
HV14		Replace ventilation system	2
HV15	Filter Area	Add split ductless unit and heating coals to AHUs	2
HV16	Dewatering Building	Install new exhaust fan	2
Electrical			
E1	Main Switchboard	Provide new structure, perform ATS upgrades, arc flash analysis, add surge protection	1
E2	Electrical Distribution System	Add new surge protection devices to MCC	1
E3		Investigate and modify VFD cabling where required	2
E4		Large motors are premium efficient and reported to be operating acceptably	3
E5		Panel board P1 should be designated for interior inspection and possible replacement	2
E6		Evaluate existing PAC system installation for potential hazards	1
E7	Standby Generator System	Replace with a larger system in a walk-in style enclosure	1
E8	Fire Alarm System	Upgrade system & review existing detector coverage	2
E9	CCTV and Security System	No immediate specific upgrades are identified	3
E10	Instrumentation and Control	Replace panels	2
E11		No immediate specific upgrades are identified	4

Condition Grading Scale

1 – Repair and Replace Immediately

2 – Repair and Replace Soon

3 – Good Condition

4 – Excellent Condition

Table 19: Supplemental Recommendation Summary

No.	Item	Description	Condition
Civil			
s.C1	Bar Gate	Install access gate on road to Raw Water Pump Station	3
s.C2	Sprinkler System	Install lawn irrigation	4
HVAC			
s.HV1	Backflow Preventers	Replace existing backflow preventers on hot water system	2
Electrical			
s.E1	Exterior Lighting	Install interior lighting on pretreatment retaining wall	2
s.E2	CCTV upgrades	Add CCTV IP cameras and move CCTV camera at Raw Water Pump Station	2
s.E3	Instrumentation Upgrades	Migrate controls to local RTUs	3

6 OPINION OF COST

It was initially anticipated that recommended capital improvements would be made in phases over a five year period. However, during the review of the Draft Water Treatment Plant Engineering Evaluation, the Town indicated that the upgrades would occur in one phase. Our planning level opinion of estimated capital costs associated with the recommendations summarized in Section 5 is approximately **$7.5 million**. Costs of major elements are detailed in Table 20. Additional cost information is included in Appendix F.

Table 20: TWTP Opinion of Costs for Recommended Upgrades

Item	Area	Cost
1.0	Site Work	$ 40,000
2.0	Structural	280,000
3.0	Architectural	255,000
4.0	Laboratory and Break room Expansion	275,000
5.0	Process and Mechanical	1,365,000
6.0	Equalization Tank	375,000
7.0	Chemical System	295,000
8.0	Heating, Ventilation, and Air Conditioning	250,000
9.0	Electrical and SCADA	960,000
Sub-Total		**$ 4,095,000**
Allowance for Final Design Elements (30%)		1,229,000
Estimated Construction Cost		**$ 5,324,000**
Engineering and Contingency (40%)		2,130,000
PROJECT TOTAL (2012)		**$ 7,454,000**
		Use $7.5 million

Costs reflect the current ENR construction cost index as of November 2012. An average wage rate of $85.45 was calculated from 2012 RS Means Labor rates (ENR of 9398) based on costs in the Boston area. The estimate includes contractor overhead and profit, a 30% allowance for final design elements, and an additional 40% for engineering and contingency.

Although the purpose of this evaluation is to recommend capital improvements, it is also important to consider maintenance costs. Regular maintenance, including preventative maintenance, is important to day to day operations and will extend the life of the facility.

Operating budgets should account for regular maintenance expenditures that will protect the investment made as part of the capital improvements plan.

A separate opinion of cost was developed for the recommended chlorine dioxide byproduct sampling and air stripping pilot testing. As detailed in Table 21, these total approximately **$200 thousand**. Similar to the capital cost estimate, a more detailed breakdown is included in Appendix F. Costs for other recommended testing, including the PAC and coagulant bench testing were not assessed.

Table 21: TWTP Opinion of Cost for Chlorine Dioxide Sampling and Pilot Testing

Item	Description	Cost
10.0	Chlorine Dioxide Byproduct Sampling	$ 17,600
11.0	Air Stripping Pilot Testing	175,000
TOTAL (2012)		**$ 192,600**

Use $200 thousand

7 REFERENCES

MA WRC, 2009. Policy for Developing Water Needs Forecasts for Public Water Suppliers and Communities and Methodology for Implementation. Massachusetts Water Resources Commission.

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MassDEP, 2011. Chapter 5: Treatment. Guidelines for Public Water Systems. Bureau of Resource Protection, Drinking Water Program, Massachusetts Department of Environmental Protection.

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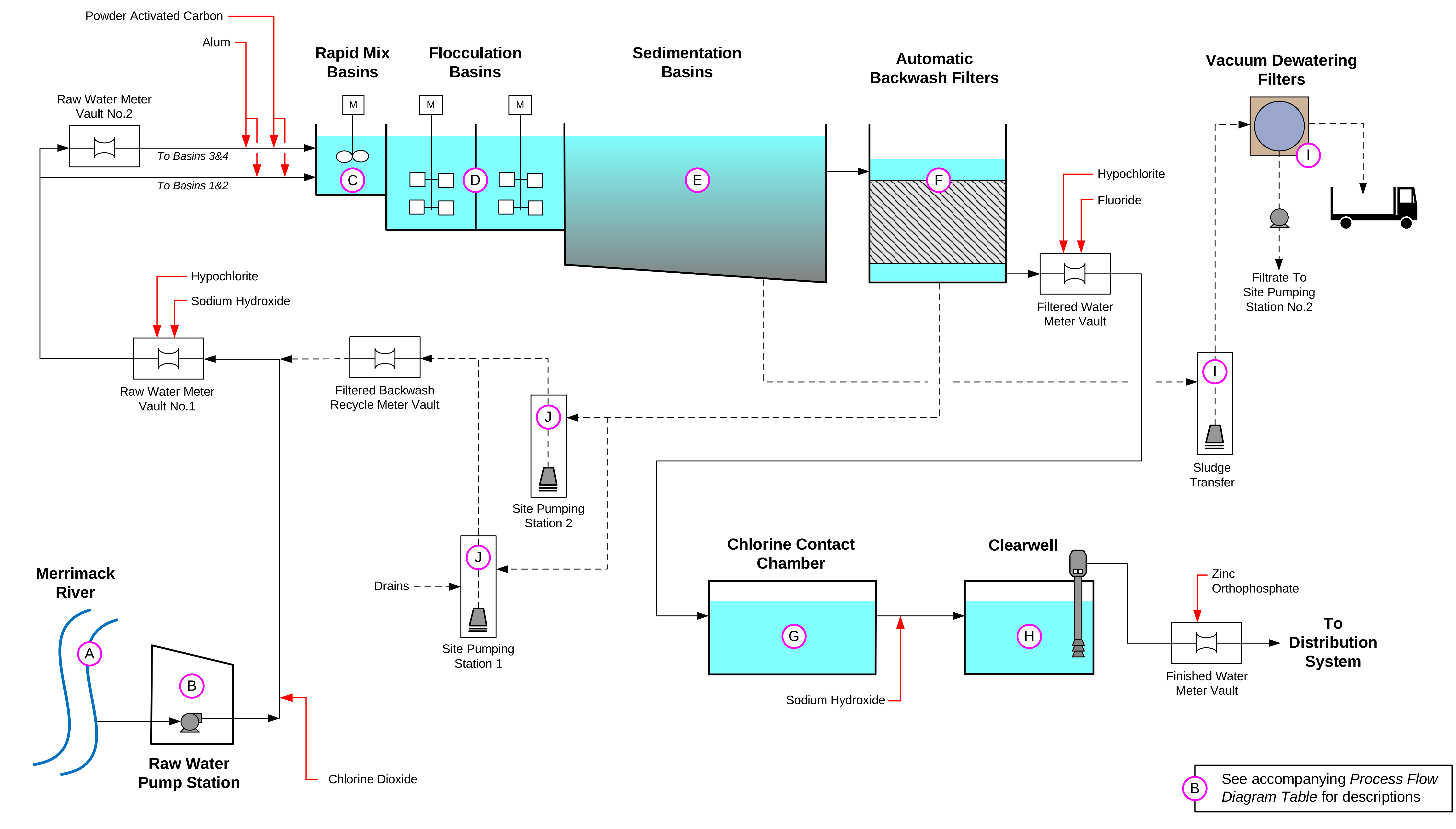
MassDEP, 2000. 314 CMR 4.00: Massachusetts Surface Water Quality Standards. Bureau of Waste Prevention, Massachusetts Department of Environmental Protection.

Tewksbury Planning Board, 2003. Town of Tewksbury Master Plan.

Appendix A

TREATMENT PROCESS SCHEMATIC



December 2012	AECOM	Not to Scale	Town of Tewksbury, MA Tewksbury Water Treatment Plant Engineering Evaluation	Tewksbury Water Treatment Plant **Process Flow Diagram**

Table A-1: TWTP Treatment Schematic Definitions from Process Flow Diagram

No.	Location	Description
A	Merrimack River	The Merrimack River is a Class B river, originating at the confluence of the Winnipesaukee and Pemigewasset rivers. It provides the source water for the Tewksbury Water Treatment Plant.
B	Raw Water Pump Station	Raw water is withdrawn through a pump station located on the southern bank of the Merrimack River. The intake system consists of two cylindrical mesh screens located approximately 5 ft above the river bottom. Raw water pumps transfer water from the river to the pretreatment trains.
C	Rapid Mixing	A coagulant, alum, is introduced in the rapid mixing basins. Through high energy mixing, the coagulant reacts with the constituents in the raw water to form particles that will aggregate and settle during flocculation and sedimentation.
D	Flocculation	Low speed mixers gently agitate the small floc formed in coagulation so that larger settleable floc are formed.
E	Sedimentation	The large floc formed in the coagulation and flocculation settle out before clarified water is conveyed to the filters.
F	Filtration	Remaining unsettled particles are removed with four Automatic Backwash Filters through a bed containing 3 ft of granular activated carbon (GAC) over 1 ft of sand.
G	Chlorine Contact Chamber	Chlorine dioxide and sodium hypochlorite are used for disinfection at the Tewksbury Water Treatment Plant. Primary disinfection is achieved through contact time obtained through pretreatment and the Chlorine Contact Chamber.
H	Clearwell	Provides additional contact time for disinfection and is where the distribution pumps draw treated water.
I	Dewatering	Sludge is drawn out from the sedimentation basins through sludge collection hoppers. The sludge is then discharged to the sludge storage tanks. Sludge pumps lift the sludge to a vacuum filter dewatering system. This system greatly reduces the volume of sludge and dries it to about 30% solids.
J	Site Pump Stations	Spent washwater, dewatering sludge filtrate, and other minor flows are collected in the site pump stations and pumped through the Filtered Backwash Recycle Meter Vault back to pretreatment.

Appendix B

REGULATORY REVIEW

Regulatory Review

1 Introduction

A discussion of water quality relative to current and future regulatory requirements is a necessary part of any water treatment plant evaluation. Regulatory requirements are established by the United States Environmental Protection Agency (EPA) and are enforced by the Massachusetts Department of Environmental Protection (MassDEP).

All of the various drinking water regulations are under the purview of the Safe Drinking Water Act (SDWA), although within the SDWA are various rules which individually govern regulated parameters. Regulations of primary concern include:

- Surface Water Treatment Rule (SWTR) promulgated in 1989
- Enhanced Surface Water Treatment Rule Long Term 1 and 2 (ESWTR)
- Disinfectants and Disinfection Byproducts Rule Stage 1 and 2 (DBPR)
- Filter Backwash Recycling Rule (FBRR)
- Lead and Copper Rule (LCR)
- Total Coliform Rule (TCR)

The SDWA was enacted in 1974 and has been amended in 1986 and again in 1996. The 1996 amendments govern current drinking water compliance. As part of the SDWA, the SWTR has a major bearing on the compliance activities for the Tewksbury Water Treatment Plant (TWTP). The SWTR was superseded by the Interim Enhanced Surface Water Treatment Rule (IESWTR) in 1998, which was subsequently strengthened by the Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) in 2002 and most recently, the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) in 2006.

The Stage 1 Disinfectants and Disinfection Byproducts Rule (DBPR) was promulgated in 1998 and was the first regulation to address DBPs. The Stage 1 DBPR is still in effect for the TWTP, but will be superseded by the more stringent Stage 2 DBPR as of October of 2013. The Lead and Copper Rule (LCR) and Filter Backwash Recycling Rule (FBRR) were promulgated in 1991 and 2001, respectively. Minor revisions were made to the LCR in 2000.

Finished water produced at the Tewksbury Water Treatment Plant is of high quality. There are no current compliance issues based on discussions with plant staff, and a review of finished water quality data and Consumer Compliance Reports (CCR) over the last decade.

2 Existing Regulations

2.1 Primary Drinking Water Regulations

EPA drinking water standards fall into four broad categories: microbiological, disinfectants and disinfection byproducts (DBPs), inorganic compounds, and organic compounds. Microbiological, DBP, and inorganic contaminant primary standards pertinent to the TWTP are listed in Table B-1.

Table B-7, which is included at the end of this appendix, summarizes the drinking water regulations as included in the SDWA. Table B-7 also shows future regulations that are currently anticipated, and lists some of the major emerging contaminants that may be regulated in the future. Although not federally regulated, perchlorate limits have been set by MassDEP and are included.

Table B-1 Key Primary Drinking Water Regulations Applicable to the TWTP

Category	MCL[a]	Applicable Treatment/Sampling Requirements
Microbiological		
Filtered Water Turbidity	N/A	≤0.3 NTU in 95% of samples, not to exceed 1.0 NTU
Giardia	N/A	3-log (99.9%) Removal/Inactivation
Cryptosporidium	N/A	2-log (99%) Removal [b]
Viruses	N/A	4-log (99.99%) removal/inactivation
Coliform bacteria	N/A	No more than 5% positive samples
Disinfectants and Disinfection Byproducts		
Total Trihalomethanes (TTHM)	0.080 mg/L	
Total of 5 Haloacetic Acids (HAA5)	0.060 mg/L	
Total Organic Carbon (TOC)	N/A	15%-50% removal based on source TOC & Alkalinity
Bromate	0.01 mg/L	
Chlorite	1.0 mg/L	
Chlorine Dioxide	0.8 mg/L	
Chlorine	4 mg/L	
Inorganic Compounds		
Fluoride	4 mg/L	
Copper	1.3 mg/L[c]	Samples from residential kitchen or bathroom sinks must be below Action Limit in 90% of samples.
Lead	0.015 mg/L[c]	
Perchlorate	0.002 mg/L[d]	

a: Maximum Contaminant Level
b: Based on source water sampling, TWTP is not required to obtain additional *Cryptosporidium* log removal credits.
c: Represents Action Limit
d: State Regulation (MA)

2.2 Surface Water Treatment Rule and Enhanced Surface Water Treatment Rules

The SWTR requires certain amount of removal/inactivation of pathogens such as *Giardia* and viruses. The amount of removal required is expressed in base 10 logarithms, as shown in the following example:

$$Log\ Removal = Log_{10}(Influent) - Log_{10}(Effluent)$$

As an example, assuming the influent value is 1000 cysts (or viruses), and the effluent is 10 cysts, the log removal achieved is:

$$Log\ Removal = Log_{10}(1000) - Log_{10}(10) = 2$$

Alternatively, a 2-log removal also can be expressed as 99% removal. Similarly, a 2.5-log removal is 99.68%, a 3-log removal is 99.9%, and a 4-log removal is 99.99%

The SWTR requires that a 3-log removal of *Giardia* and a 4-log removal of viruses be achieved, using a double barrier approach of removal and disinfection. No actual sampling of *Giardia* and viruses are required as removal is assumed to be provided by conventional treatment (flocculation, sedimentation followed by filtration). Conventional water treatment facilities are assigned a 2.5 log removal credit for *Giardia* and a 2-log removal credit for viruses if the turbidity standard is met. Disinfection is relied on to provide the remaining log removal values, of 0.5-log for *Giardia* and 2-log for viruses.

The SWTR filtered water turbidity standard limits combined filtered effluent turbidity to 0.5 NTU in 95 percent of the samples for any month and no greater than 5 NTU at any time (this was changed to 0.3 NTU in 95 percent of samples with a maximum of 1 NTU with the 2002 promulgation of the IESWTR).

Disinfection provides the second barrier in the double barrier approach of the SWTR. As part of the SWTR and the *Filtration and Disinfection Requirements for Public Water Sources* (AWWA, 1991), the EPA developed a method for evaluating the effectiveness of disinfection in a water treatment system. Under this method, actual disinfection conditions at a water treatment plant are converted to a theoretical level of inactivation known as the CT product, where C is the residual disinfectant concentration (mg/L) multiplied by T_{10} which is the time at which 90% of the water is exposed to chlorine (in minutes). The CT is calculated as follows:

$$CT(mg/min \cdot L) = Residual\ Disinfectant\ Concentration(mg/L) \times T_{10}$$

The SWTR stipulates that the concentration of disinfectant residual cannot drop below 0.2 mg/l for more than 4 hours as measured at the entry point to the distribution system (measured either as free chlorine, chloramines, or chlorine dioxide). As viruses are much more readily inactivated with chlorine than *Giardia*, *Giardia* normally governs disinfection requirements.

The IESWTR superseded the SWTR for water treatment systems serving more than 10,000 people. It required a minimum of 2-log removal of *Cryptosporidium*, made filter effluent turbidity standards more stringent and added the requirement for individual filter monitoring. Plant filtered water turbidity and individual filter turbidity must be 0.3 NTU or less at least 95 percent of the time and at must be below 1 NTU at all times. If these criteria are met, then a 2-log removal of *Cryptosporidium* is assumed and is granted.

The LT1ESWTR extended the IESWTR requirements to systems serving less than 10,000 people. Log removal requirements for *Giardia* and viruses from the SWTR are carried over to the ESWTR.

The LT2ESWTR adds to the LT1ESWTR by strengthening *Cryptosporidium* safeguards. This includes a requirement for surface water and groundwater under the influence of surface water (GWUDI) treatment systems to conduct source water monitoring to determine the level of *Cryptosporidium* present in the source water. Depending on the type of treatment used and the level of *Cryptosporidium* in the source water, systems then have to provide between zero and 3-log of additional removal. Tewksbury has completed their source water monitoring (referred to as "LT2 monitoring") and found no *Cryptosporidium*. Therefore, no additional treatment is required.

Tewksbury Water Treatment Plant Compliance with LT2ESWTR

The TWTP had no compliance issues with the SWTR and the LT2ESWTR. Over the period of time investigated (July 2009 through June 2010), combined effluent turbidity easily met the 0.3 NTU standard in greater than 95 percent of measurements and at no time exceeded 1 NTU. Consumer Confidence Reports (CCRs) reviewed between 2000 and 2011 (excluding 2001 and 2003) demonstrated continuous compliance with the turbidity standard applicable at the time.

The TWTP has also had no difficulty with maintaining sufficient CT and the residual chlorine concentration was maintained above 0.2 mg/L at all times. As a conventional facility that meets the turbidity standard, it is granted 2-log removal for viruses, 2.5-log removal for *Giardia*, and 2-log removal for *Cryptosporidum.* Disinfection is required for an additional 0.5 log removal of *Giardia* and 2 log removal of viruses. Because viruses are much more easily inactivated by chlorine, *Giardia* governs the required CT. In other words, a 0.5-log removal of *Giardia* will provide in excess of 2-log removal of viruses. CT requirements for 0.5-log *Giardia* removal at varying chlorine residuals and pH values are summarized in Table B-2 and Table B-3.

Table B-2: CT Requirements for 0.5 log Removal of *Giardia* at 0.5°C and 5°C

Chlorine Residual (mg/L Cl2)	CT at 0.5°C			CT at 5°C		
	pH <=6	pH = 6.5	pH=7	pH <=6	pH = 6.5	pH = 7
<=0.4	23	27	33	16	20	23
0.6	24	28	33	17	20	24
0.8	24	29	34	17	20	24
1.0	25	29	35	18	21	25
1.2	25	30	36	18	21	25
1.4	26	31	37	18	22	26
1.6	26	32	38	19	22	26
1.8	27	32	39	19	23	27
2.0	28	33	39	19	23	28

Table B-3: CT Requirements for 0.5 log Removal of *Giardia* at 10°C and 15°C

Chlorine Residual (mg/L Cl2)	Temperature at 10°C			Temperature at 15°C		
	pH <=6	pH = 6.5	pH=7	pH <=6	pH = 6.5	pH = 7
<=0.4	12	15	17	8	10	12
0.6	13	15	18	8	10	12
0.8	13	15	18	9	10	12
1.0	13	16	19	9	11	13
1.2	13	16	19	9	11	13
1.4	14	16	19	9	11	13
1.6	14	17	20	9	11	13
1.8	14	17	20	10	11	14
2.0	15	17	21	10	12	14

As the temperature of the water goes up, free chlorine becomes more effective and the required CT is reduced. The Merrimack River experiences wide temperature swings, resulting in the CT requirement changing throughout the year. Average filtered water temperatures for each month between July 2009 and June 2010 are shown in Table B-4 along with the associated CT temperature table in the right hand column (this defaults to the next lower discrete temperature bracket for which to base calculation of CT on, as opposed to extrapolating between discrete temperature brackets).

Table B-4: Filtered Water Temperature Range and Associated CT Table Temperature

Year	Month	Filtered Water Temperature (°C)		CT Table Temperature (°C)
		Average	Minimum	
2009	July	21.4	19.0	15
	August	23.7	21.1	20
	September	20.2	18.3	15
	October	14.4	10.6	10
	November	11.0	8.9	5
	December	6.26	2.7	0.5
2010	January	4.2	2.4	0.5
	February	4.2	2.3	0.5
	March	7.3	3.6	0.5
	April	12.6	8.8	5
	May	17.8	12.9	10
	June	22.5	19.8	10

A review of the 2010 CT compliance monitoring by the TWTP indicated that CT is easily achieved through the combination of pre-chlorination and post-chlorination. An average CT ratio (achieved CT/required CT) of 19.4 was calculated, with a minimum of 3.9. Compliance would still be possible with reduced or eliminated pre-chlorination doses, or with seasonal dosing. Further, credit for chlorine dioxide disinfection through pretreatment could be obtained if pre-chlorination was not in practice.

2.3 Disinfectants/Disinfection Byproducts Rule

Under the Stage 1 DBPR, utilities serving more than 10,000 but less than 50,000 people are required to maintain running annual averages (RAAs) below 80 ppb for TTHMs and below 60 ppb for HAAs based on quarterly distribution system sampling. It also requires bromate and chlorite concentrations to be below 0.01 mg/L and 1.0 mg/L, respectively.

In addition to the DBP MCLs, the Stage I DBPR also mandates the level of total organic carbon (TOC) removal for surface water treatment facilities. The TOC of a water source greatly influences the formation of DBPs. Natural organic matter (NOM) as measured by TOC is a known precursor to the formation of DBPs, and the USEPA recognizes that requiring TOC removal compliments the requirement for controlling DBPs. Required TOC removal per the Stage 1 DBPR as a function of source water TOC and alkalinity is shown in Table B-5.

Table B-5: Required TOC Removal per the Stage 1 DBPR

Source Water TOC (mg/L)	Source Water Alkalinity (mg/L as $CaCO_3$)		
	0 – 60	60 – 120	> 120
> 2.0 to 4.0	35%	25%	15%
> 4.0 to 8.0	45%	35%	25%
> 8.0	50%	40%	30%

Compliance with the TOC removal requirements shown in Table B-5 is based on a running annual average, reported quarterly, and calculated as shown below:

$$\%TOC\ Removal = [1 - (Finished\ Water\ TOC / Source\ Water\ TOC)] \times 100$$

For each month, the TOC removal achieved is divided by the required percent removal and the ratio is then recorded. A ratio equal to or greater than 1.0 indicates that the water treatment facility was successful in achieving the required percent removal for that quarter. Each quarter, the ratios from the preceding 12 months are averaged together. If the average is greater than 1.0, the system is in compliance with the Stage 1 DBPR.

As an alternative to Table B-5, six compliance criteria were developed by the USEPA in recognition of the fact that certain source waters are less amenable to successful TOC removal by coagulation. A water treatment facility can establish alternative minimum compliance goals, by meeting one of the following compliance criteria:

- Source water TOC < 4.0 mg/L, alkalinity > 60 mg/L, TTHM < 0.040 mg/L, and HAA5 < 0.030 mg/L (running annual average)
- Treated water TOC < 2.0 mg/L (can be used on a monthly basis)

- Source water specific ultraviolet absorbance (SUVA) ≤ 2.0 L/mg-m (can be used on a monthly basis)
- Treated water SUVA ≤ 2.0 L/mg-m (can be used on a monthly basis)
- TTHM < 0.040 mg/L, and HAA5 < 0.030 mg/L with only free chlorine for disinfection
- Source water TOC < 2.0 mg/L (can be used on a monthly basis)

The Stage 2 DBPR requires compliance with the same DBP concentrations for each sampling location, with the sampling locations representing areas of high DBP concentrations within the distribution system. Because compliance is required at each sampling location, locational running annual averages (LRAAs) replace the RAAs of the Stage 1 DBPR. The TWTP must comply with the Stage 2 DBPR by October of 2013.

The sites that will require sampling include one site near where high TTHMs are found, one site where high HAA5s are historically found, the entry point into the system, and a fourth site that represents the average water age. The locations of the new sites are based on the Initial Distribution System Evaluation (IDSE) program. Under the new requirements, utilities will not be able to balance historically high DBP sites with lower sites to ultimately meet compliance. In addition, the new sampling sites may be further out in the distribution system, which would increase detention time and in turn increase the formation of disinfection byproducts.

The IDSE program conducted by the Town of Tewksbury in 2008 and 2009 resulted in the replacement of one out of the four Stage 1 DBPR monitoring locations. This was to address the higher locational running annual average (LRAA) HAA5 found at the location (although well below the MCL). See the discussion of future regulations in Section 3 for more information.

Tewksbury Water Treatment Plant Compliance with Stage 1 DBPR

Influent TOC between 2005 and 2009 averaged approximately 4.6 mg/L. Average TOC in the finished water was 1.9 mg/L over the same period, providing an average removal of 59%. This allowed the TWTP to consistently meet the Stage 1 DBPR TOC removal requirements, averaging a removal ratio (% TOC removed/% TOC removal required) of approximately 1.4. Raw and finished water TOC levels are shown in Figure B-1. Removal requirements in relation to the raw water alkalinity as outlined in Table B-5 is shown in Figure B-2.

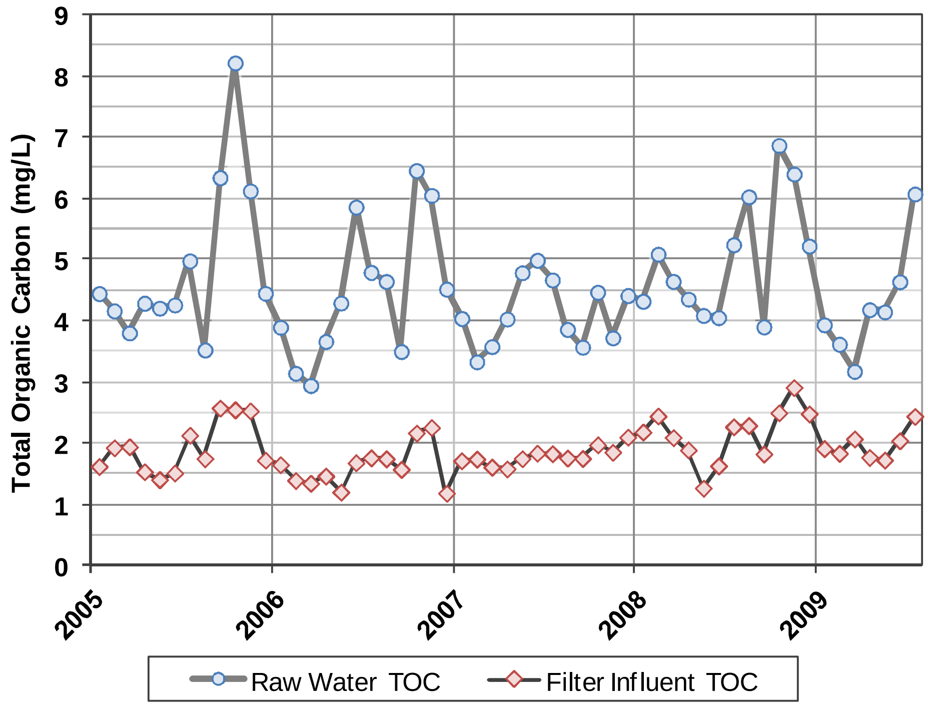


Figure B-1: TWTP TOC Removal (2005-2009)

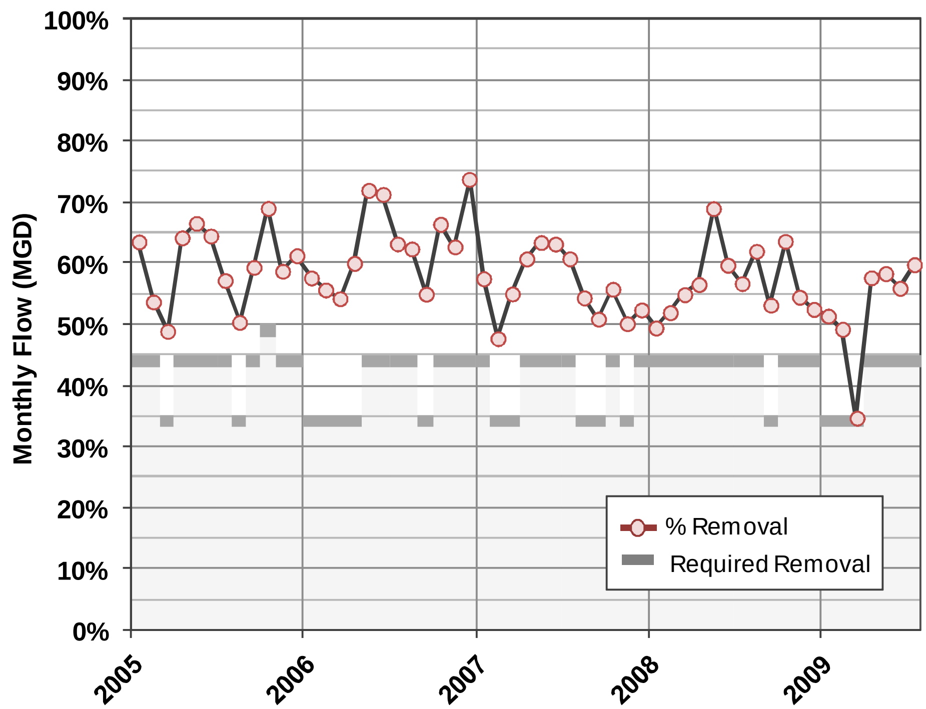


Figure B-2: TWTP TOC Removal (2005-2009)

Effective TOC removal reduces DBP formation. For this reason, monitoring of distribution system DBPs are required. While HAAs have been in compliance, TTHMs have been tested above the maximum contaminant limit (MCL) of 80 ppb in the past, resulting in a short period of non-compliance in the fourth quarter of 2008 and the first quarter of 2009. Distribution system TTHM and HAA running annual averages (RAAs) from June 2002 to 2012 are shown in Figure B-3 and Figure B-4, respectively. In order to address high TTHMs measured in 2009, TWTP staff lowered the free chlorine dosing while raising the chlorine dioxide dose. This has been effective and should remain as a tool for controlling DBP formation.

Chlorine dioxide is regulated as a disinfectant to an MCL of 0.8 mg/L. Chlorine dioxide use leads to both a chlorite and chlorate residual, and chlorite is regulated as a DBP to an MCL of 1.0 mg/L and a maximum contaminant level goal (MCLG) of 0.8 mg/L. Chlorite is formed as a product from the reduction of chlorine dioxide in oxidation reactions with constituents in the source water. EPA recommends that the sum of chlorine dioxide, chlorite, and chlorate be kept below 1.0 mg/L, and there have been studies that show that chlorine dioxide doses in excess of 0.5 mg/L have correlated with odor problems.

As the TWTP generates chlorine dioxide using sodium chlorite, a chlorite residual exists in the clarified water. However, chlorite is adsorbed by the granular activated carbon (GAC) media in the filters. The capacity for adsorption is a function of the age of the media. Chlorite concentrations observed at the TWTP effluent have been in compliance with the MCL and are consistently below 0.5 mg/L.

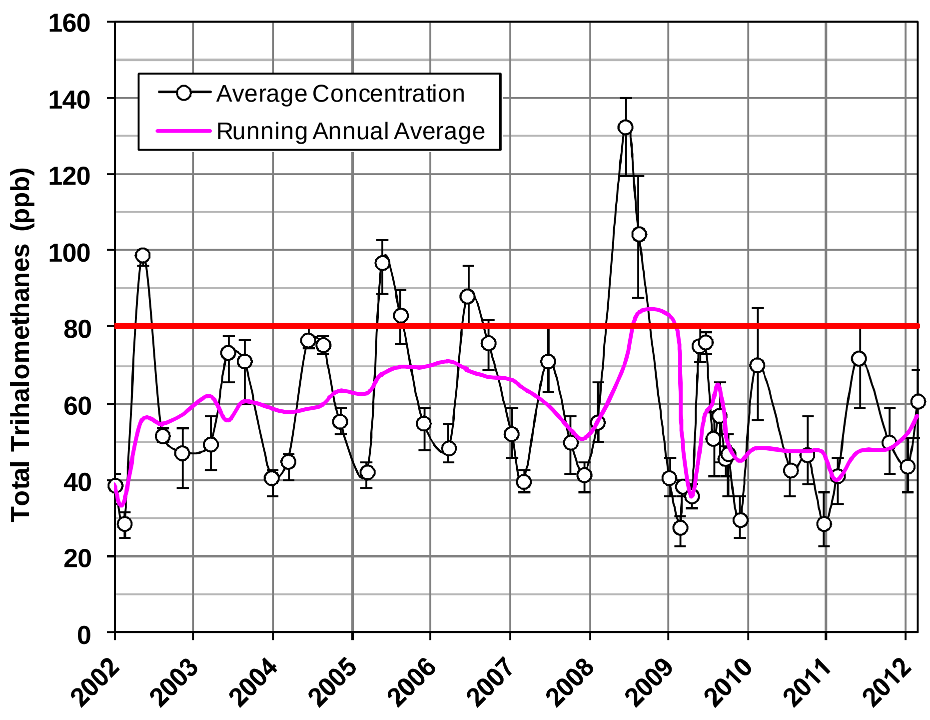


Figure B-3: TTHM Compliance (2002-2012)

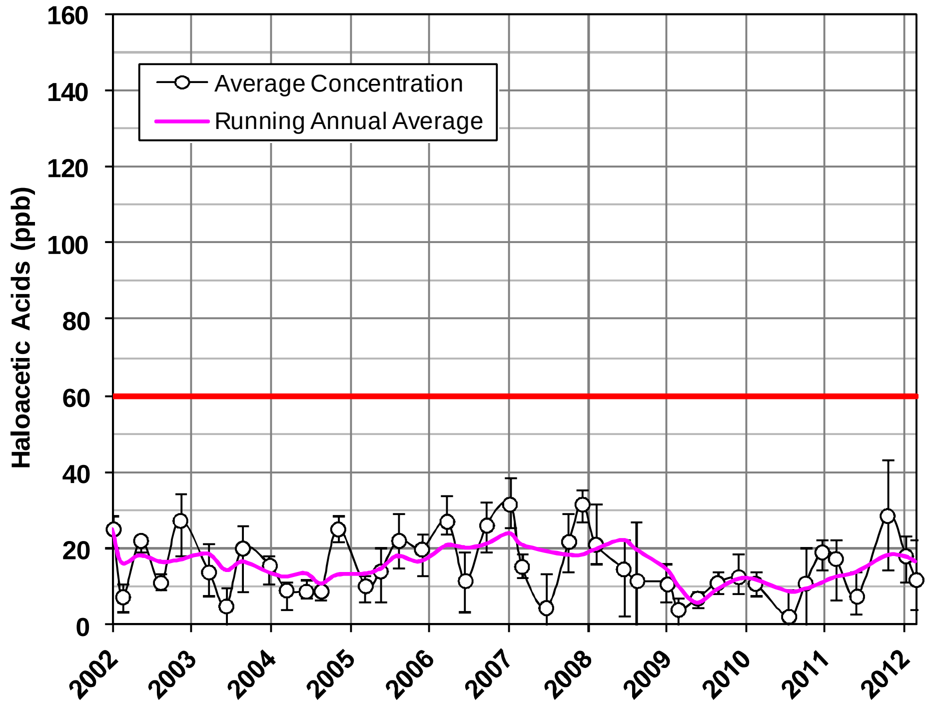


Figure B-4: HAA Compliance (2002-2012)

2.4 Filter Backwash Recycling Rule

Recycling of spent filter wash water (SWW) is governed under the Filter Backwash and Recycling Rule (FBRR). The FBRR was enacted in response to the concern that recycling excessive amounts of waste filter wash water, or recycling to the wrong location, can increase the TOC, pathogen concentration, and inorganic load to the facility. The basic requirements of the FBRR are that the return of SWW is ahead of coagulation, that recycle flows be monitored, and that utilities notify the state agencies if they are in fact recycling SWW. Utilities must also collect data on filter operations for review by the agency, if required.

States may implement their own recycle provisions in addition to those as required by the FBRR. Some states limit the amount of flow as a percentage of the total that may be returned. Ten States Standards requires that the recycled water should be returned at a rate of less than 10 percent of the instantaneous raw water flow entering the plant.

MassDEP does not specify a percentage, but does state that a five percent rate is preferable so as to not impair treatment. Further, MassDEP requires that the SWW recycle be achieved using a variable pumping rate so as to better balance the SWW recycle flows with the current raw water flows. Presently, the TWTP recycles SWW.

Based on communication with the MassDEP, the following systems under the jurisdiction of the MassDEP - Northeast Regional Office also recycle their spent filter backwash water:

- Billerica
- Salem-Beverly
- Danvers
- Haverhill
- Ipswich
- Lynn
- Manchester
- Methuen
- Newburyport
- North Andover
- Rockport
- Tewksbury

Of these communities, two (Ipswich and Manchester) recycle from their clarification waste lagoons. The recycle rates, based on reported flows, run between approximately 2 percent to over 50 percent. The average recycle rate is approximately 13 percent. Half of these communities recycle at a rate of 10 percent or less. There were no reported violations associated with any of the above systems related to turbidity problems or inability to provide adequate disinfection.

As listed in Ten States Standards and as advised by MassDEP, another requirement is the practice of equalization. Ten States Standards states that an equalization tank shall be provided and sized to contain the anticipated volume of spent filter wash water generated when the plant is operating at design capacity.

Tewksbury Water Treatment Plant Compliance with the FBRR

The TWTP complies with the FBRR because all recycle flow passes through the entire pre-treatment process. Although the need for an equalization tank is not crucial because the TWTP uses ABW filters, equalization storage would help balance recycle flow rates. Backwashing is essentially continuous, and therefore the high periodic hydraulic and contaminant loading that would be typical during the backwash of a conventional filter, is not experienced.

2.5 Lead and Copper Rule

The LCR establishes action levels for lead and copper in drinking water. The major source of lead and copper in drinking water is from corrosion of copper pipe, old lead services (if any) and plumbing fixtures. Therefore, the LCR requires that systems that exceed the action levels install a corrosion control system at the water treatment facility.

The action levels are 0.015 mg/L for lead and 1.3 mg/L for copper based on 90th percentile. The 90th percentile value is the highest concentration of lead or copper in tap water that is exceeded by 10 percent of the sites sampled during a monitoring period. This value is then compared to the action level to determine compliance. Initially, systems were required to sample annually. If samples are found to be below the action level for 3 consecutive years, then the utility may sample every 3 years.

Tewksbury Water Treatment Plant Compliance

Based on a review of the CCR reports between 2000 and 2012 (excluding 2001 and 2003), the TWTP has been compliant with the LCR. As a result of monitoring showing levels for both copper and lead to be below the action level for three consecutive years, the Town is on a schedule where monitoring occurs every three years. The most recent sampling took place in 2011.

3 Future Regulations

There are a number of future regulations or modifications to existing regulations that may have an impact on the TWTP if enacted. These include the following:

- Radon Rule,
- Revisions to the Total Coliform Rule,
- Perchlorate,
- Unregulated Contaminant Monitoring Rule 3,
- Atrazine,
- New VOC Rule,
- Long term revisions to the Lead and Copper Rule,
- Fluoride, and
- Stage 2 DBPR.

Each of these items are described in the following sections. Although the Stage 2 DPBR has already been enacted and has been previously discussed, it has not come into effect for the TWTP and is therefore included. Table B-7 lists the future regulations that are on the horizon along with a summary of all existing regulations.

3.1 Radon Rule

A Radon Rule has been anticipated for several years, but has yet to be finalized. In fact, the original rule was proposed in 1991 only to be withdrawn in 1997. The proposed rule is expected to recognize the fact that radon in air can be more of a concern than radon in water. A standard for radon in water of 300 picocuries per liter (pCi/L) is proposed. As it will apply to groundwater systems and systems that use a mix of groundwater and surface water, the TWTP will not be affected.

3.2 Revisions to the Total Coliform Rule

Changes to the Total Coliform Rule (TCR) were proposed in 2010. As currently written, the proposed changes would eliminate the MCL and MCLG for Total Coliform and replace it with an MCL and MCLG of zero for *E. Coli*. Essentially *E. Coli* is more indicative of fecal contamination and therefore a better indicator of harmful pathogens.

Although the MCL and MCLG for total coliforms would no longer determine compliance, monitoring would still be required. A Treatment Technique (TT) would be instituted that would require corrective action should total coliforms be found in a certain number of samples. As the TWTP has not had compliance issues with the existing TCR, there is no concern over the impacts of the revised TCR.

3.3 Perchlorate

Although Massachusetts has instituted a perchlorate rule, a national rule through the EPA is anticipated but is not yet in place. This will not be a concern for the TWTP which has been compliant with the existing MassDEP rule. It should be noted that a common source of perchlorate is from bulk storage of sodium hypochlorite, and particularly where the hypochlorite has been in storage for long periods of time. It is suggested that the TWTP continue to make provisions to minimize the aging of the stored hypochlorite. According to an article published in the Journal AWWA (November 2008), storage times of less than 45-60 days are recommended.

3.4 Unregulated Contaminant Monitoring Rule 3

Utilities serving > 10,000 persons will be required to sample for 28 contaminants including nine VOC's, 1,4-dioxane, four metals, chlorate, five pfluorinated compounds, and seven hormones. The list may also include Chromium-6 and two viruses. Chromium-6 (Cr-6) may be regulated in a separate, stand-alone rule. However, at this time EPA is encouraging utilities to conduct self-monitoring of Cr-6. USEPA is currently completing an evaluation of the health effects and proposed MCL of Cr-6. The UCMR process, in general, is designed to allow EPA to gauge the occurrence of previously unregulated contaminants in full-scale systems. Monitoring is expected to be conducted in 2013-2015.

3.5 Atrazine

EPA has considered lowering the standard for atrazine, a by-product from the use of pesticide. The removal of atrazine can be achieved through PAC and GAC, both of which are available at the TWTP. Therefore, a potentially lower atrazine standard it is not considered a compliance issue for the TWTP. There is no timeline for a revised standard.

3.6 New VOC Rule

Carcinogenic VOC's may be regulated under a new grouping, as part of USEPA's new strategy to regulate contaminants as groups as opposed to one at a time. As part of this reorganization, a lower MCL for trichloroethylene (TCE) and tetrachloroethylene (PCE) from 5 ug/l to 1 ug/l and 0.5 ug/L, respectively, may be included, The new regulation is expected in the fall of 2013. This will have more of an impact on groundwater systems exposed to these pollutants.

3.7 Long-term Revisions to the Lead and Copper Rule

EPA is working towards a new LCR to include the following issues: partial lead service line replacement, sample site selection, tap sampling, measures for corrosion control, and public education. There are no plans to lower the 90^{th} percentile MCL's, so the new rule should not impact the treatment process at the TWTP. The new rule is likely to be published in 2103.

3.8 Fluoride

The Department of Health and Human Services (HHS) has lobbied for a single numerical optimized value for fluoride set at 0.7 mg/L (as opposed to the current accepted range from 0.7-1.2 mg/L).

Although the HHS recommendation is non-regulatory, it is related to an EPA dose-response study also looking at the non-carcinogenic effects of long term excessive fluoride exposure. It is expected that a lower fluoride MCL will be proposed by EPA within the next few years. Where this has little bearing on systems that add fluoride (including the TWTP), it will impact groundwater systems where fluoride is naturally occurring, potentially in concentrations that could exceed the revised MCL.

3.9 Stage 2 DBP Rule

This rule is final, and carried a compliance deadline based on system size. For utilities serving 10,000 to 50,000 customers, compliance will be required by October 1, 2013. Compliance with this rule dovetails with the IDSE report, which looked at new distribution system DBP sample sites and DBP sample results in an attempt to identify if there are more problematic sites where DBP's should be measured. The concern is that utilities may be sampling at locations where DBP's are inherently low and not representative of worse case locations. According to Tewksbury's IDSE report, of the four DBP sampling sites currently used in Stage 1 monitoring, three sites will be retained, namely; American Garage Door, Bianca's Restaurant, and Tewksbury DPW, The Stage 1 Kindercare site will be replaced with a new site, Andover Hess gas station. Starting in October of 2013, each of these four sites will be treated as an independent compliance point, using a "locational" running annual average as the compliance metric.

According to the IDSE sampling results, and as described in Section 2.3 above, HAA's are not an issue but TTHM's can be problematic. The TWTP has instituted the practice of lowering the pre-chlorination dosing which has worked well to minimize TTHM formation. However, as the IDSE results indicated, during the peak TTHM month of August, TTHM locational discrete values (but not the running averages) can be in excess of the 80 ug/L standard. The IDSE sampling was conducted prior to the lowering of the pre-chlorination dosing in 2009, and the impact of this lower dose on the Stage 1 DBP results was significant (see Figure B-3). It can be expected that controlling pre-chlorination will continue to be an important tool for compliance with Stage 2.

4 Emerging Contaminants

Emerging contaminants is a term used to describe a wide array of chemicals and water borne microorganisms that are suspected of posing a risk to public health through drinking water. Emerging contaminants have the common characteristic of not being presently regulated, partly because of difficulty with analytical techniques and detection limits, and also due to lack of baseline information on occurrence and ambient concentrations. The USEPA acknowledges and tracks emerging contaminants through its Contaminant Candidate List (CCL). This list is populated in large part through the efforts of the USEPA Unregulated Contaminant Monitoring Rule (UCMR) as described above in Section 3.

The 1996 amendments to the Safe Drinking Water Act required that EPA establish a program to monitor unregulated contaminants, and to identify no more than 30 contaminants to be monitored every five years. EPA identified and published unregulated contaminants for the first direct-implementation of UCMR (referred to as UCMR 1), and a revised approach for monitoring. UCMR 1 established a tiered monitoring approach, and required all public water systems serving more than 10,000 people and a representative sample of systems serving less than 10,001 people to monitor for unregulated contaminants from 2001-2005. The next UCMR implementation is UCMR 3 scheduled for implementation in 2013.

Many of the contaminants listed on the CCL are not new, but are instead persistent compounds of interest such as pesticides, algal toxins and fuel oxygenates including *methyl-t-butyl ether* (MTBE). More recently, improvements in monitoring and analytical techniques have helped to identify other "emerging" compounds in source waters, including endocrine disrupting compounds (EDC's) and nitrogenous and iodinated disinfection by-products. A summary of the emerging and unregulated contaminants of primary concern is presented in Table B-6. For more information on the CCL, readers are encouraged to visit the following site: http://www.epa.gov/safewater/ccl/index.html.

A review of Table B-6 shows the available water treatment technologies for these emerging contaminants. As shown, three techniques predominantly feature sophisticated processes, such as GAC, ultraviolet (UV) disinfection, nanofiltration (NF) or reverse osmosis (RO) membranes. Often, combinations of techniques are most effective, for example, advanced oxidation processes configured as follows:

- UV Photolysis and UV Advanced Oxidative Processes (UV + H202)
- Ozone and Ozone Advanced Oxidative Processes (Ozone + H2O2)

Strictly speaking, MTBE and algal toxins may not be considered emerging contaminants because both have been acknowledged, for some time, as source water concerns. Also, removal of these compounds can generally be handled through traditional techniques (depending on concentration). For example, MTBE is a volatile organic compound which is amenable to air stripping for removal. Although advanced processes are also effective, concentrations of MTBE encountered in drinking water sources are generally low enough so as to not require advanced methods.

Finally, the EPA has expressed its intention to set allowable limits for chlorate (ClO_3^-) in the future. This is in response to a cancer study by the National Toxicology Program (NIH, 2005[1]) that pointed to chlorate as a potential health problem in drinking water. The California Department of Public Health has set a notification level of 0.8 mg/L for chlorate.

[1] NIH, 2005. *NTP Technical Report on the Toxicology and Carcinogenesis Studies of Sodium Chlorate in F344/N Rats and B6C3F Mice (Drinking Water Studies)*. NIH Publication TR 517. National Toxicology Program, National Institutes of Health Public Health Service.

Table B-6: Emerging Contaminants

Compound	Common Source	Public Health Concerns	Available Treatment Technologies	Comments
EDC's	Mostly man-made. From pharmaceuticals, cosmetics, detergents, plasticizers, pesticides, Many of these compounds are discharged from wastewater treatment plants and into receiving waters.	Have been shown to cause hormonal abnormalities and effects growth, development, and reproduction.	• Ozone & peroxide • Peroxide & UV • NF/RO membranes • Granular activated carbon and powdered activated carbon	EPA has developed a screening program. For more information, see: www.epa.gov/scipoly/oscpendo/
MTBE	Underground fuel tanks, boating activities in surface waters, fuel spills, gasoline additive (air deposition)	Toxic gasoline additive now classified as a potential human carcinogen.	• Air stripping • Granular activated carbon • Advanced oxidation (peroxide & ozone) • Advanced Phase Separation	By-product (Tertiary butyl alcohol – TBA) more difficult to remove than MTBE itself
Algal toxins	Certain species of cyanobacteria; microcystis is most prevalent source	In low levels, source of taste & odor problems. Toxins can attack the liver and the nervous system or irritate skin.	• Control of algal blooms in reservoirs through aeration, mixing, or copper sulfate dosing • Coagulation and filtration • Dissolved air flotation • Adsorption (partial) • Ozone & biofiltration	Pre-chlorination of algae can induce toxicity through cell lysis
Nitrosamines	NDMA from disinfection with chloramines. Can also be found in surface waters under the influence of waste water discharges. Also used in agriculture as a soil additive.	Classified by EPA as probable human carcinogen	• UV radiation • UV & hydrogen peroxide • Carbonaceous resins (partial)	Wastewater effluent-dominated surface waters much more prone to NDMA formation during chloramination
Nitrogenous and Iodinated DBPs	Result from chlorination of waters containing nitrogenous precursors or in chloraminated water (iodinated DBP's)	May be carcinogenic and are considered much more toxic than chlorinated DBP's (TTHM's and HAA's)	Formed in distribution systems. Removal of precursors in water treatment process currently the only know means of control.	New DBP categories. Much more research is needed to develop effective control strategies.

Similarly, algal toxins can be controlled through several techniques, including in-situ reservoir aeration and mixing. Of the emerging contaminants listed in Table B-6, endocrine disrupting compounds (EDC's), nitrosamines, and nitrogenous/iodinated DBP's have garnished the most attention, recently. These are relatively new discoveries, made possible by improved analytical techniques enabling detection to very low concentrations. Another unique characteristic of these "microconstituents" is the relative sophistication of the removal technologies. Nitrogenous and iodinated disinfection by-products (DBP's) have been recently identified as possibly more harmful than total trihalomethanes and haloacetic acids (the currently regulated DBP's). A discussion of these three categories of emerging contaminants is provided below.

4.1 EDC's

These compounds, identified in some water sources, are of concern because their chemical structure is similar to compounds with certain health effects such as decreased metabolism or hormonal abnormalities. Endocrine disrupting compounds (EDCs) can be natural or man-made, but much of the attention is focused on man-made EDCs from pharmaceuticals (Pharmaceuticals and Personal Care Products or PPCPs; -e.g. prescription drugs, antibiotics, steroids), soaps, industrial and commercial products (e.g. detergents, plasticizers, cosmetics, and skin lotions). Female estrogen compounds are also EDCs and are interest because they've been linked to feminization of fish in some water sources. Three major classes of endocrine disruptors are:

- Compounds that mimic or block natural estrogen
- Compounds that mimic or block natural testosterone
- Compounds that impact the thyroid gland

EDC's are a current topic in wastewater treatment because wastewater treatment facilities are a major source of EDC's, through discharge to receiving waters. It should be noted that in wastewater treatment facilities, other processes are available that would not normally be included in water treatment plants, such as membrane bioreactors or activated sludge treatment. In the water treatment arena, the most current research has been conducted by the American Water Works Research Foundation (AwwaRF). The report entitled *Removal of EDCs and Pharmaceuticals in Drinking and Reuse Treatment Processes* (AwwaRF Project 2758) is publicly available. This report characterizes the occurrence of EDC's in US drinking water systems and their removal by drinking and reuse treatment processes. AwwaRF had sponsored this study by first selecting a cross-section of representative EDC's, including steroid hormones, antibiotics, analgesics, psychoactive compounds, pesticides, fragrances, poly-aromatic hydrocarbons, heart medications, flame retardant, sunscreens and X-ray contrast medium. Occurrence of these compounds was tested in raw and finished waters at 20 full-scale drinking water plants that intake water from sewage-impacted sources (which would be expected to contain EDCs).

It was determined that bench and pilot scale testing were good predictors of full-scale removal capabilities. Conventional processes were found to be less effective than advanced processes, and disinfection with free chlorine and chloramines were effective for removal of only some compounds. UV at normal disinfection doses was not effective against most tested compounds but high energy UV (oxidative doses) was generally effective. Ozone was also generally effective, and advanced oxidation processes (ozone/peroxide or UV/peroxide combinations) were highly effective at removing most tested compounds. For filtration technologies, granular activated carbon (GAC) was found to be effective for removal of most compounds but only if the carbon was not exhausted. Ultrafiltration, microfiltration and magnetic ion exchange resin were ineffective, while reverse osmosis and nanofiltration were highly effective.

By-products resulting from the ozone-EDC reaction are not well understood. Similarly, the use of UV and hydrogen peroxide has been shown to be very effective against most EDC's, although again, formation of by-products such as nitrite and assimable organic carbon are concerns.

In summary, if the TWTP is interested in assessing EDC control strategies, bench-scale and pilot scale testing of EDC removal unit processes would be recommended. As part of the testing, it would be prudent to also check the EDC removal capability of the existing facility, which uses both powdered and activated carbon, which are proven technologies for certain EDC removal.

4.2 NDMA

N-nitrosodimethylamine (NDMA) is a semivolatile organic that has been manufactured and used commercially for decades as a soil additive for preventing nitrification, a plasticizer for rubber and polymers, and a fiber and plastics industry solvent. NDMA has been shown to cause cancer in laboratory animals and is therefore a suspected carcinogen. Other similar compounds have been discovered, now categorized as nitrosamines.

Although ambient concentrations of NDMA can occur in surface or groundwaters, this contaminant is of primary concern to facilities that practice chloramination. This is because ammonia used in the chloramination process can provide a nitrogen source for nitrifying bacteria, which can then cause increased nitrate levels in the distribution system. Nitrates, in turn, can react with monochloramine residual to form nitrosamines. The most common forms of nitrosamines found in water supplies are NDMA and *N* -nitrodimethylamine (DMN). Currently, NDMA is included in the UCMR program, although there is no maximum contaminant limits yet established. California has set a drinking water action level at 10 parts per trillion (ppt), or nanograms per liter. There is concern that NDMA will soon become regulated along with other DBP's.

NDMA precursors can also be present in source waters, particularly (again) those that receive waste water discharges. A review of the literature indicates the following:

- Wastewater effluent-dominated surface waters are much more prone to NDMA formation during chloramination
- Tertiary amines are the primary precursors, in particular ranitidine. Interestingly, ranitidine is a pharmaceutical used to treat gastritis, so there is a link between EDC's and NDMA formation
- Boron concentration strongly correlates with NDMA formation potential
- Metals such as iron, copper, and nickel have been shown to accelerate nitrosamine formation
- Cationic polymers have been linked to NDMA formation

Basically, source waters under the influence of upstream wastewater discharges are most likely to contain NDMA precursors. In fact, these source waters would likely contain ambient concentrations of NDMA because of the ammonia present in wastewater. Removal of NDMA, once formed, can be best removed through UV or advanced oxidation using UV and hydrogen peroxide. Most water utilities are more concerned with preventing formation of NDMA in the distribution systems, if chloramination is practiced. This can be achieved through careful control of the chlorine to ammonia ratio, and also minimization of nitrate concentrations of finished water.

4.3 Nitrogenous and Iodinated DBPs

Nitrogenous disinfection by-products (NDBP's) are formed after chlorination of water with nitrogenous precursors. These organic contaminants contain halogens, such as chlorine or bromide, and nitrogen. Examples of nitrogenous DBPs include dichloroacetonitrile (DCAN), trichloroacetonitrile, bromochloroacetonitrile (BCAN), dibromoacetonitrile (DBAN), cyanogen chloride (CNCl), cyanogen bromide (CNBr), tribromonitromethane (bromopicrin), and 2,3,5-tribromopyrrole (TBPy). Laboratory studies have shown many nitrogenous DBPs to be carcinogenic or mutagenic. The World Health Organization has set a qualitative target level of 90 ug/L for DCAN and 100 ug/L for DBAN in drinking water. CNCl and TBPy are highly toxic. Researchers are only beginning to understand how they are formed in drinking water treatment.

Common trihalomethanes that contain chlorine or bromide are currently regulated by USEPA. Other trihalomethanes, however, contain iodide and are considered emerging contaminants. Dichloroiodomethane is the most common iodo-trihalomethane observed in drinking water. Some iodo-acids-iodoacetic acid, bromoiodoacetic acid, (E)-3-bromo-3-iodopropenoic acid, and (E)-2-iodo-3-methylbutenedioc acid were recently discovered in chloraminated water. Research is revealing that iodinated DBPs are more toxic than many of the currently regulated species of trihalomethanes and haloacetic acids.

Table B-7: Summary of Drinking Water Regulations

	CONTAMINANTS AND REGULATIONS	MAXIMUM CONTAMINANT LEVEL	SUMMARY OF MONITORING REQUIREMENTS	TEWKSBURY WTP COMPLIANCE STATUS
EXISTING SAFE DRINKING WATER ACT REGULATIONS	**Inorganic Chemicals (IOC's)** Radionuclides: Radium 228 and 226 Gross alpha Beta particles Uranium Arsenic Rule Lead & Copper Rule	Varies by contaminant………………….. …………………………………………….. 5 pCi/L (combined) 15 pCi/L (not incl radon and uranium) 4 mrem/yr 0.03 mg/L 0.01 mg/L…………………………....... Lead action level = 0.015 mg/L………… Copper action level = 1.3 mg/L	1/yr for surface waters, once every 3 years for groundwaters with exceptions………………… Running annual average of 4 quarterly samples…………………………………………………… Annually ……………………………………………………………………………………… Action levels must be met in 90% of samples, collected at building taps. May require corrosion control systems if action levels exceeded.	• In compliance • In compliance • In compliance • Latest LCR sampling shows compliance
	Volatile and synthetic organic chemicals (VOC's & SOC's)	Varies by contaminant…………………..	Two quarterly samples for systems serving > 3,300 people. One sample every 3 years for smaller systems	• In compliance
	Disinfectants & Disinfection By-products (D/DBP) Rules Stage 1 D/DBP Rule: Chlorine Chloramines Chlorine dioxide (ClO_2) Total trihalomethanes (TTHM's) Total haloacetic acids (HAA's) Chlorite Bromate Total organic carbon (TOC) Stage 2 D/DBP Rule: Total trihalomethanes (TTHM's) *Chloroform* *Bromodichloromethane* *Bromoform* Total haloacetic acids (HAA's) *Monochloroacetic acid* *Dichloroacetic acid* *Trichloroacetic acid*	 4.0 mg/L as Cl_2……………..……………. 4.0 mg/L as Cl_2.................................... 0.8 mg/L as ClO_2…………….. 0.08 mg/L…………………….. 0.06 mg/L…………….. 1.0 mg/L…………………… 0.01 mg/L………………….. % removal requirements only. Varies by source TOC and alkalinity 0.08 mg/L………………… 0.07 mg/L 0 mg/L 0 mg/L 0.06 mg/L………………….. 0.07 mg/L 0 mg/L 0.02 mg/L	 Monthly arithmetic average. Monitor along with total coliform monitoring Daily sample at distribution system entry point. Daily at distribution system entry, plus quarterly at 4 sites within distribution system. Running annual average (RAA) of 4 sites within distribution system. Running annual average of 4 sites within distribution system. Daily sample at distribution system entry point. Ozone systems only. One sample per month. Source and treated TOC once per month, Compliance based on running annual average of TOC removal ratios. Will supersede Stage 1 D/DBPR by requiring TTHMA and HAA compliance with running annual average at <u>each</u> sampling site. Sampling sites to be determined based on Initial Distribution System Evaluation (IDSE) results. Compliance with Stage 2 by Oct 2013. Same as TTHM's above.	 • In compliance. RAA's currently at 0.060 mg/L and 0.017 mg/L for TTHM's and HAA's respectively. • IDSE sampling is complete. TWTP to use same monitoring sites as Stage 1.
	Microbiological Contaminants Total Coliform Rule Long Term 2 Enhanced Surface Water Treatment Rule Filtered water turbidity *Giardia* Enteric viruses *Cryptosporidium*	 Specific to system size………………….. 0.3 ntu………………………………….... 3-log removal & inactivation…………… 4-log removal & inactivation…………… If turbidity < 0.3, 2-log granted…………	 If > 40 samples per month, no more than 5 % positive of total, fecal, or E.coli. If less than 40 samples per month, no more than 1 positive for total coliforms. Max turbidity limit is 1.0 ntu, and combined filtered water turbidity must be </= 0.3 ntu in 95 % of samples taken each month, at interval no less than every 4 hours. 2.5 log credit granted via conventional treatment (2-log for direct filtration); additional credits achieved via physical disinfection. Conventional treatment for 2-log removal; additional 2-log through disinfection. LT2 requires 2 years of source water *Cryptosporidium* monitoring. If levels are high, additional treatment required. Otherwise, 2-log removal of *Cryptosporidium* granted and no treatment necessary providing that turbidity standard is achieved.	 • In compliance • In compliance. Filtered water turbidity typically less than 0.1 ntu. • Plant disinfection provides adequate Giardia and virus C(t). • Sampling complete. No need for additional Cryptosporidium removal.

	CONTAMINANTS AND REGULATIONS	MAXIMUM CONTAMINANT LEVEL	SUMMARY OF MONITORING REQUIREMENTS	TEWKSBURY WTP COMPLIANCE STATUS
EXISTING SAFE DRINKING WATER ACT REGULATIONS	**Microbiological Contaminants**			
	Filter Backwash Recycle Rule	Treatment technique……………………………	Intended to prevent recycling of microbiological contaminants to source water. No monitoring, but must return spent filter washwater and other recycle streams to head of plant for full treatment with chemicals. Must collect and record flow values.	• SWW returned to recycle vault in compliance with FBRR.
	Groundwater Rule	Treatment technique……………………………	Intended to control viruses in groundwater systems. Every 3 years, sanitary survey conducted. If a distribution system total coliform sample is positive, source water monitoring is required for systems that do not achieve 4-log virus inactivation.	• GWR does not apply to TWTP.
	Secondary Standards			
	Aluminum	0.05 – 2.0 mg/L	These are finished water standards that are generally non-enforceable. They cause aesthetic and taste issues but are not health risks at normal levels found in drinking water.	• In compliance with all secondary standards. Iron, manganese, and color typically non-detectable in finished water. However, some seasonal variations in finished water manganese has been noted.
	Chloride	250 mg/L		
	Color	15 color units		
	Copper	1.0 mg/L		
	Corrosivity	Noncorrosive		
	Flouride	2.0 mg/L		
	Foaming Agents	0.5 mg/L		
	Iron	0.3 mg/L		
	Manganese	0.05 mg/L		
	Odor	3 threshold odor number		
	pH	6.5-8.5 s.u.		
	Silver	0.10 mg/L		
	Sulfate	250 mg/L		
	Total Dissolved Solids	500 mg/L		
	Zinc	5 mg/L		
	Consumer Confidence Report	Data reporting only………………………………	PWS to prepare and distribute Consume Confidence Report (CCR) by July 1.	• In compliance
FUTURE REGULATIONS	Radon Rule	300 pCi/l…………………………………...........	Final rule proposed for 2013 (subject to change). At each entry point into system, four consecutive quarters of monitoring.	• It is anticipated that compliance with Radon Rule and TCR will be achieved.
	Revisions to Total Coliform Rule	E.coli monitoring to be included ………………	Final rule for 2012 and compliance by 2015. Few changes for systems serving > 4100 people. Monitoring results will now trigger corrective action.	
	Perchlorate (possible)	National standard to be determined…………… Massachusetts standard set at 0.02 mg/L	EPA has determined that food may be higher source of perchlorate than water. Research also shows perchlorate formation from bulk storage of NaOCl.	• Tewksbury already required to comply. No compliance issues.
	Unregulated Contaminant Monitoring Rule (UCMR3)	N/A………………………………………………..	Starting Jan 2013, requires monitoring for 30 previously unregulated contaminants	• Mandatory monitoring for systems serving > 10,000 (includes TWTP)
	Atrazine	0.003 mg/L……………………………………	EPA considering lowering standard of 0.03 mg/L	• GAC can be effective for atrazine adsorption as well as VOC's
	New Carcinogenic VOC Rule	Adds to existing rule……………………………	Proposed by late 2013 with possible inclusion of up to 8 additional compounds	
EMERGING CONTAMINANTS	EDC's……………………………	Endocrine disrupting compounds (EDC's) are mostly man-made. From pharmaceuticals, cosmetics, detergents, plasticizers, pesticides. Many of these compounds are discharged from wastewater treatment plants and into receiving waters.		• Wastewater discharges upstream of the TWTP can be expected to expose the system to EDC's. No current regulations in place. However, to mandate removal of EDC's or other emerging contaminants.
	MTBE……………………………	Methyl tertiary butyl ether (MTBE) is a toxic gasoline additive now classified as a potential human carcinogen. Sources are failed underground fuel tanks, boating activities in surface waters, fuel spills, gasoline additive (air deposition).		
	Algal toxins………………………	In low levels, source of taste & odor problems. At higher levels, toxins can attack the liver and the nervous system or irritate skin. Certain species of cyanobacteria; microcystis is most prevalent source.		
	NDMA……………………………	Classified by EPA as probable human carcinogen, Nitrosodimethylamine (NDMA) is associated with production of rocket fuels. NDMA may be formed when nitrates in the distribution system react with chloramines, or can be pre-formed in waste water discharges.		
	Nitrogenous & iodinated DBP's.	Result from chlorination of waters containing nitrogenous precursors or in chloraminated water (iodinated DBP's). May be carcinogenic and are considered much more toxic than chlorinated DBP's (TTHM's and HAA's)		

Appendix C

POPULATION AND FLOW INFORMATION

Tewksbury Water Treatment Plant Flow Data (2010 - 2011)
Adjusted Data

Month	Year	Finished Water					
		Average MGD	**Min Day** MGD	**Max Day** MGD	**Total** MG	**Annual** ADD	**Peaking Factor**
Jan	2010	1.99	1.83	2.11	61.70	2.40	0.88
Feb	2010	1.86	1.25	2.04	52.00	2.40	0.85
Mar	2010	1.86	1.19	2.13	57.70	2.40	0.89
Apr	2010	1.92	1.80	2.19	57.70	2.40	0.91
May	2010	2.51	1.96	3.64	77.90	2.40	1.51
Jun	2010	2.96	2.13	3.77	88.90	2.40	1.57
Jul	2010	3.77	2.64	4.83	117.0	2.40	2.01
Aug	2010	3.20	2.12	4.05	99.10	2.40	1.68
Sep	2010	2.77	2.12	3.35	83.10	2.40	1.39
Oct	2010	2.23	1.97	3.12	69.00	2.40	1.30
Nov	2010	1.90	1.68	3.74	57.10	2.40	1.56
Dec	2010	1.88	1.75	2.58	58.30	2.40	1.07
Jan	2011	1.92	1.17	2.72	59.39	2.23	1.22
Feb	2011	1.95	1.85	2.02	54.47	2.23	0.91
Mar	2011	1.91	1.77	2.27	59.08	2.23	1.02
Apr	2011	1.84	1.54	2.09	55.23	2.23	0.94
May	2011	2.15	1.79	3.87	66.55	2.23	1.74
Jun	2011	2.70	2.09	3.43	81.04	2.23	1.54
Jul	2011	3.15	2.64	4.29	97.76	2.23	1.93
Aug	2011	2.67	2.33	4.76	82.62	2.23	2.14
Sep	2011	2.41	2.12	2.74	72.22	2.23	1.23
Oct	2011	2.09	1.77	2.34	64.80	2.23	1.05
Nov	2011	1.94	1.76	2.15	58.11	2.23	0.97
Dec	2011	2.00	1.76	2.16	61.87	2.23	0.97

Note: 2010 flow data has been modified to reflect incorrect flow measurement

Tewksbury Water Treatment Plant Flow Data (2010 - 2011)
Unadjusted Data

Month	Year	Finished Water					
		Average MGD	**Min Day** MGD	**Max Day** MGD	**Total** MG	**Annual** ADD	**Peaking Factor**
Jan	2010	2.24	2.06	2.38	69.54	2.80	0.85
Feb	2010	2.12	1.42	2.32	59.25	2.80	0.83
Mar	2010	2.12	1.35	2.43	65.78	2.80	0.87
Apr	2010	2.21	2.07	2.52	66.32	2.80	0.90
May	2010	3.00	2.35	4.35	93.11	2.80	1.56
Jun	2010	3.53	2.54	4.49	105.8	2.80	1.60
Jul	2010	4.36	3.05	5.57	135.1	2.80	1.99
Aug	2010	3.73	2.48	4.72	115.6	2.80	1.69
Sep	2010	3.20	2.45	3.87	96.05	2.80	1.38
Oct	2010	2.62	2.31	3.66	81.09	2.80	1.31
Nov	2010	2.23	1.97	4.38	66.82	2.80	1.57
Dec	2010	2.20	2.05	3.02	68.23	2.80	1.08
Jan	2011	1.92	1.17	2.72	59.39	2.23	1.22
Feb	2011	1.95	1.85	2.02	54.47	2.23	0.91
Mar	2011	1.91	1.77	2.27	59.08	2.23	1.02
Apr	2011	1.84	1.54	2.09	55.23	2.23	0.94
May	2011	2.15	1.79	3.87	66.55	2.23	1.74
Jun	2011	2.70	2.09	3.43	81.04	2.23	1.54
Jul	2011	3.15	2.64	4.29	97.76	2.23	1.93
Aug	2011	2.67	2.33	4.76	82.62	2.23	2.14
Sep	2011	2.41	2.12	2.74	72.22	2.23	1.23
Oct	2011	2.09	1.77	2.34	64.80	2.23	1.05
Nov	2011	1.94	1.76	2.15	58.11	2.23	0.97
Dec	2011	2.00	1.76	2.16	61.87	2.23	0.97

Town of Tewksbury ASR Information

Public Water Supply Annual Statistical Report Data

Critieria	Units	Year		
		2009	2010	2011
System Information				
Population Served		32,774	32,516	30,309
No. of Service Connections		10,516	9,916	10,065
Percent Metered		100	100	100
Finished Water Storage Capacity	MGD	7	7	7
Pumping Capacity	gpm	4,860	4,860	4,860
Water Production and Consumption				
Max Finished Water Production	MGD	4.22	4.43	4.29
Date		19-Jul	24-Aug	22-Jul
% Commercial				18%
% Industrial/Agricultural		18%	22%	
% Residential		60%	76%	68%
Distribution				
Miles of Mains	mile	165	160	160
Estimated Lost Volume	MG	0	0	31.1
Residential Use	MG	526	567	554
Commercial/Business	MG	152		146
Municipal/Institutional	MG	5	17	9
Industrial			160	
Total	MG	684	743	708
Unaccounted for Water (Flushing)	MG	14	16	17
Total Finished Water	MG	907	879	813
*ADD**	*MGD*	*2.48*	*2.41*	*2.23*
*Peaking Factor**		*1.70*	*1.84*	*1.93*
Metered Use	MG	684	743	708
Municipal Use	MG	14	16	17
Unaccounted for Water	MG	210	120	88
Unaccounted for Water			13.6%	10.8%
Residential Water Use	MG	526	567	554
Per Capital Water Use	gpcd	44.0	47.8	50.1
Basin Withdrawal				
Total Raw Water	MG	907	879	813
*% Non-Residential Total Used**		*17.4%*	*20.1%*	*19.0%*
*% Unaccounted of Total**		*23.1%*	*13.6%*	*10.8%*
Average Withdrawal	MGD	2.14	2.41	2.23
Permitted Withdrawal	MGD	3.17	3.17	3.17
Difference	MGD	0.69	0.76	0.94

Data from MassDEP Bureau of Resource Protection - Drinking Water Program
** Calculated Values*

Town of Tewksbury ASR Information

Public Water Supply Annual Statistical Report Data

Demand	Year				Notes
	2009	2010	2011	2032	
Residential					Used Town Clerk 2011 population,
Population	32,774	32,516	30,309	33,997	increase based on 2003 Master Plan.
Per Capita Water Use (gpcd)	44.0	47.8	50.1	50.1	
ADD (MGD)	1.44	1.55	1.52	1.70	
Total Water Use (MG)	526	567	554	622	
% of Total	58.0%	64.5%	68.2%	68.7%	
Non-Residential					Non-residential includes commercial,
ADD (MGD)	0.43	0.48	0.42	0.46	industrial, and municipal. Predicted to
Total Water Use (MG)	157	177	154	169.6	increase by 10%.
% of Total	17.4%	20.1%	19.0%	18.8%	
Unaccounted for Water					Predicted to increase by 10%.
ADD (MGD)	0.57	0.33	0.24	0.26	
Total Water Use (MG)	210	120	88	96.7	
% of Total	23.1%	13.6%	10.8%	10.7%	
Flushing					Projected to remain the same as in 2011.
ADD (MGD)	0.04	0.04	0.05	0.05	
Total Water Use (MG)	14	16	17	17	
% of Total	1.5%	1.8%	2.1%	1.8%	
Total ADD	2.48	2.41	2.23	2.48	
Total Water Use	907	879	813	905	

Town of Tewksbury Population Information

Year	Population	
	Town Clerk	U.S. Census
1950	7,505	7,505
1960	15,902	15,902
1965	18,079	
1970	22,755	22,755
1975	24,048	
1980	24,478	24,635
1985	24,442	
1990	28,304	27,266
1991	28,262	
1992	28,537	
1993	27,060	
1994	27,451	
1995	27,629	
1996	28,009	
1997	28,320	
1998	28,135	
1999	29,074	
2000	30,315	28,851
2001	29,770	
2002	29,960	
2003	29,979	
2004	30,859	
2005	30,730	
2006	30,762	
2007	32,382	
2008	32,774	
2009	33,067	
2010		28,961
2011	30,309	
2012	30,077	

Appendix D

MONTHLY RAW WATER QUALITY (2009-2010)

Tewksbury Water Treatment Plant - Daily Lab Sheet Information

May, 2009

Parameter	Flow MGD	pH	Turbidity NTU	Color TCU	Free Cl_2 mg/L	Total Cl_2 mg/L
Raw Water						
Average	2.82	6.92	2.47	29.53		
Maximum	4.50	7.22	4.95	46.90		
Minimum	1.60	6.72	1.06	17.70		
Std Dev	0.63	0.09	0.65	5.32		
Flocculator Influent	**pH** Floc 1		**pH** Floc 2			
Average	6.32		6.21		0.62	1.53
Maximum	6.65		6.50		1.50	2.60
Minimum	5.98		5.88		0.10	0.85
Std Dev	0.09		0.10		0.25	0.33
Filter Influent	**Temp** degC		**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	17.15	6.25	0.75	2.83	0.21	0.57
Maximum	21.30	6.44	1.20	5.80	0.80	1.40
Minimum	14.40	6.10	0.41	0.00	0.05	0.15
Std Dev	1.40	0.07	0.13	1.15	0.14	0.23
Filter Effluent	**Turbidity** Filter 1	**Turbidity** Filter 2	**Turbidity** Filter 3	**Turbidity** Filter 4	**Turbidity** Comb	**Color** Comb
Average	0.55	0.03	0.03	0.03	0.03	0.00
Maximum	17.20	0.10	0.06	0.07	0.06	0.10
Minimum	0.02	0.01	0.01	0.01	0.02	0.00
Std Dev	2.89	0.01	0.01	0.01	0.01	0.01
Contact Chamber	**Flow** MGD	**pH**	**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	2.98	6.02	0.03		0.54	0.63
Maximum	4.40	6.31	0.06		0.85	0.95
Minimum	1.70	5.68	0.02		0.20	0.40
Std Dev	0.65	0.13	0.01		0.10	0.09
Finished Water						
Average	3.12	7.42	0.06	0.00	0.45	0.51
Maximum	5.30	8.03	0.14	0.00	0.70	0.75
Minimum	1.20	7.04	0.03	0.00	0.15	0.30
Std Dev	0.78	0.18	0.01	0.00	0.09	0.09

Location	Flow MGD	pH	Free Cl2 mg/L	Temp degC	Det Time min	CT mg-min/L
Pre-Treatment CT						
Average	2.82	6.25	0.21	17.15	195	42
Maximum	4.50	6.44	0.80	21.30	328	145
Minimum	1.60	6.10	0.05	14.40	117	7
Contact Chamber CT						
Average	2.98	6.02	0.54	17.15	76	41
Maximum	4.40	6.31	0.85	21.30	127	89
Minimum	1.70	5.68	0.20	14.40	49	17

Max Turbidity (NTU)	Filter	Plant
	0.06	0.14

Pumped Flow (MG)	Raw	Finished	Recycle	Plant
Max Day	3.85	4.04	0.21	4.16
Average Flow	2.70	2.75	0.19	2.98
Total Flow	83.84	85.15	5.98	92.37

Other Parameters	Fl mg/L	Hardn mg/L	Alk (raw) mg/L	Alk (fin) mg/L	Pre-Cl_2 mg/L	Post-Cl_2 mg/L
Average	1.1	27.8	12.3	14.8	0.62	0.45
Maximum	1.3	36.0	15.9	18.6	1.28	0.63
Minimum	1.0	22.0	0.2	0.2	0.29	0.32

Chemical	Dose (mg/L)
Zinc Ortho Phosphate	0.6
Sodium Chlorite	2.6
Fluoride (Silly Acid)	1.1
Muriactic Acid (HCl)	1.4
Sodium Hypo (Hypo)	4.6
Sodium Hydr (NaOH)	16.1
Aluminum Sulf (Alum)	31.1

pH	Floc Basin	Fin Water
Average	6.27	7.42
Maximum	6.36	7.71
Minimum	6.16	7.12

Tewksbury Water Treatment Plant - Daily Lab Sheet Information
June, 2009

Parameter	Flow MGD	pH	Turbidity NTU	Color TCU	Free Cl_2 mg/L	Total Cl_2 mg/L
Raw Water						
Average	2.75	6.80	3.36	32.69		
Maximum	4.50	7.07	7.10	48.60		
Minimum	2.10	6.31	1.60	20.90		
Std Dev	0.60	0.11	1.18	8.75		
Flocculator Influent	**pH** Floc 1		**pH** Floc 2			
Average	6.15		6.09		0.74	1.55
Maximum	6.46		35.72		1.60	2.30
Minimum	5.73		5.33		0.10	0.95
Std Dev	0.15		1.11		0.25	0.28
Filter Influent	**Temp** degC		**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	19.44	6.04	0.65	2.60	0.25	0.52
Maximum	22.50	6.34	1.07	5.70	1.00	1.20
Minimum	17.00	5.72	0.40	0.00	0.05	0.25
Std Dev	1.06	0.14	0.14	1.06	0.15	0.17
Filter Effluent	**Turbidity** Filter 1	**Turbidity** Filter 2	**Turbidity** Filter 3	**Turbidity** Filter 4	**Turbidity** Comb	**Color** Comb
Average	0.03	0.03	0.02	0.02	0.03	0.00
Maximum	0.10	0.06	0.06	0.05	0.04	0.10
Minimum	0.01	0.01	0.01	0.01	0.01	0.00
Std Dev	0.01	0.01	0.01	0.01	0.01	0.01
Contact Chamber	**Flow** MGD	**pH**	**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	3.00	5.70	0.03		0.56	0.64
Maximum	5.96	6.12	0.05		0.75	0.90
Minimum	2.30	5.23	0.02		0.35	0.40
Std Dev	0.79	0.22	0.01		0.07	0.08
Finished Water						
Average	3.13	7.30	0.04	0.01	0.47	0.53
Maximum	7.29	8.10	0.10	0.40	0.60	0.70
Minimum	2.30	6.96	0.02	0.00	0.30	0.35
Std Dev	1.05	0.21	0.01	0.03	0.06	0.06

Location	Flow MGD	pH	Free Cl2 mg/L	Temp degC	Det Time min	CT mg-min/L
Pre-Treatment CT						
Average	2.75	6.04	0.25	19.44	199	50
Maximum	4.50	6.34	1.00	22.50	250	210
Minimum	2.10	5.72	0.05	17.00	117	10
Contact Chamber CT						
Average	3.00	5.70	0.56	19.44	76	42
Maximum	5.96	6.12	0.75	22.50	94	68
Minimum	2.30	5.23	0.35	17.00	36	20

Max Turbidity (NTU)	Filter	Plant
	0.04	0.10

Pumped Flow (MG)	Raw	Finished	Recycle	Plant
Max Day	4.02	4.14	0.22	4.30
Average Flow	2.68	2.63	0.19	2.93
Total Flow	77.62	76.40	5.33	85.03

Other Parameters	Fl mg/L	Hardn mg/L	Alk (raw) mg/L	Alk (fin) mg/L	Pre-Cl_2 mg/L	Post-Cl_2 mg/L
Average	1.1	23.7	11.4	13.8	0.74	0.47
Maximum	1.3	32.5	13.5	18.6	1.24	0.56
Minimum	0.9	17.5	9.2	11.0	0.36	0.37

Chemical	Dose (mg/L)
Zinc Ortho Phosphate	0.5
Sodium Chlorite	2.6
Fluoride (Silly Acid)	1.0
Muriactic Acid (HCl)	1.4
Sodium Hypo (Hypo)	4.6
Sodium Hydr (NaOH)	15.3
Aluminum Sulf (Alum)	31.4

pH	Floc Basin	Fin Water
Average	6.12	7.30
Maximum	8.39	7.79
Minimum	5.75	7.05

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Parameter	Flow MGD	pH	Turbidity NTU	Color TCU	Free Cl_2 mg/L	Total Cl_2 mg/L
Raw Water						
Average	2.66	6.78	3.62	44.59		
Maximum	3.80	7.07	9.82	69.40		
Minimum	2.00	6.42	1.32	29.70		
Std Dev	0.38	0.11	1.68	7.67		
Flocculator Influent	**pH** Floc 1		**pH** Floc 2			
Average	5.82		5.72		1.06	1.60
Maximum	6.20		6.07		1.80	2.35
Minimum	5.18		5.23		0.30	1.00
Std Dev	0.22		0.19		0.29	0.26
Filter Influent	**Temp** degC		**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	21.43	5.70	0.61	2.94	0.27	0.50
Maximum	25.00	6.03	1.54	7.70	0.85	1.10
Minimum	19.00	5.05	0.28	0.00	0.05	0.25
Std Dev	1.44	0.19	0.16	1.37	0.14	0.15
Filter Effluent	**Turbidity** Filter 1	**Turbidity** Filter 2	**Turbidity** Filter 3	**Turbidity** Filter 4	**Turbidity** Comb	**Color** Comb
Average	0.04	0.04	0.03	0.03	0.03	0.00
Maximum	0.26	0.32	0.06	0.07	0.08	0.00
Minimum	0.01	0.02	0.00	0.01	0.02	0.00
Std Dev	0.02	0.03	0.01	0.01	0.01	0.00
Contact Chamber	**Flow** MGD	**pH**	**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	2.81	5.38	0.03		0.70	0.77
Maximum	3.70	5.79	0.10		0.90	1.10
Minimum	2.10	5.01	0.02		0.55	0.65
Std Dev	0.40	0.18	0.01		0.08	0.08
Finished Water						
Average	2.85	7.39	0.04	0.00	0.56	0.63
Maximum	4.00	8.05	0.08	0.00	0.70	0.80
Minimum	1.70	7.00	0.02	0.00	0.40	0.45
Std Dev	0.46	0.24	0.01	0.00	0.07	0.07

Location	Flow MGD	pH	Free Cl2 mg/L	Temp degC	Det Time min	CT mg-min/L
Pre-Treatment CT						
Average	2.66	5.70	0.27	21.43	201	53
Maximum	3.80	6.03	0.85	25.00	263	167
Minimum	2.00	5.05	0.05	19.00	138	9
Contact Chamber CT						
Average	2.81	5.38	0.70	21.43	79	55
Maximum	3.70	5.79	0.90	25.00	103	82
Minimum	2.10	5.01	0.55	19.00	58	36

Max Turbidity (NTU)	Filter	Plant
	0.08	0.08

Pumped Flow (MG)	Raw	Finished	Recycle	Plant
Max Day	3.26	3.31	0.25	3.55
Average Flow	2.58	2.54	0.20	2.86
Total Flow	79.89	78.86	6.05	88.52

Other Parameters	Fl mg/L	Hardn mg/L	Alk (raw) mg/L	Alk (fin) mg/L	Pre-Cl_2 mg/L	Post-Cl_2 mg/L
Average	1.0	24.2	12.0	15.2	1.06	0.56
Maximum	1.2	32.5	15.5	19.6	1.58	0.64
Minimum	0.9	15.0	8.0	11.4	0.75	0.43

Chemical	Dose (mg/L)
Zinc Ortho Phosphate	0.5
Sodium Chlorite	2.5
Fluoride (Silly Acid)	1.0
Muriactic Acid (HCl)	1.4
Sodium Hypo (Hypo)	5.4
Sodium Hydr (NaOH)	14.8
Aluminum Sulf (Alum)	30.1

pH	Floc Basin	Fin Water
Average	5.77	7.39
Maximum	6.02	7.83
Minimum	5.39	7.06

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August, 2009

Parameter	Flow	pH	Turbidity	Color	Free Cl_2	Total Cl_2
	MGD		NTU	TCU	mg/L	mg/L
Raw Water						
Average	3.19	6.89	1.85	35.16		
Maximum	5.00	7.29	4.54	61.20		
Minimum	2.20	6.24	0.91	20.40		
Std Dev	0.61	0.15	0.87	10.04		
Flocculator Influent	**pH**		**pH**			
	Floc 1		Floc 2			
Average	5.74		5.66		1.39	1.91
Maximum	6.10		6.41		3.60	4.20
Minimum	5.18		5.09		0.45	1.20
Std Dev	0.18		0.20		0.41	0.40
Filter Influent	**Temp**		**Turbidity**	**Color**	**Free Cl_2**	**Total Cl_2**
	degC		NTU	TCU	mg/L	mg/L
Average	23.98	5.61	0.54	5.87	0.48	0.74
Maximum	27.90	5.90	1.10	11.30	1.25	1.40
Minimum	21.10	5.13	0.30	1.10	0.10	0.25
Std Dev	1.47	0.17	0.13	2.02	0.19	0.22
Filter Effluent	**Turbidity**	**Turbidity**	**Turbidity**	**Turbidity**	**Turbidity**	**Color**
	Filter 1	Filter 2	Filter 3	Filter 4	Comb	Comb
Average	0.04	0.04	0.03	0.03	0.03	0.00
Maximum	0.09	0.08	0.08	0.08	0.06	0.10
Minimum	0.02	0.02	0.02	0.02	0.02	0.00
Std Dev	0.01	0.01	0.01	0.01	0.01	0.00
Contact Chamber	**Flow**	**pH**	**Turbidity**	**Color**	**Free Cl_2**	**Total Cl_2**
	MGD		NTU	TCU	mg/L	mg/L
Average	3.41	5.23	0.03		0.79	0.87
Maximum	5.00	5.55	0.05		1.00	1.10
Minimum	2.50	4.76	0.02		0.60	0.65
Std Dev	0.57	0.17	0.01		0.09	0.09
Finished Water						
Average	3.60	7.43	0.05	0.00	0.67	0.74
Maximum	5.50	8.12	0.35	0.00	1.00	1.10
Minimum	2.20	7.00	0.03	0.00	0.50	0.55
Std Dev	0.74	0.22	0.03	0.00	0.10	0.10

Location	Flow	pH	Free Cl2	Temp	Det Time	CT
	MGD		mg/L	degC	min	mg-min/L
Pre-Treatment CT						
Average	3.19	5.61	0.48	23.98	170	81
Maximum	5.00	5.90	1.25	27.90	239	212
Minimum	2.20	5.13	0.10	21.10	105	19
Contact Chamber CT						
Average	3.41	5.23	0.79	23.98	65	52
Maximum	5.00	5.55	1.00	27.90	86	82
Minimum	2.50	4.76	0.60	21.10	43	30

Max Turbidity (NTU)	Filter	Plant
	0.06	0.35

Pumped Flow (MG)	Raw	Finished	Recycle	Plant
Max Day	4.22	4.36	2.71	4.56
Average Flow	3.11	3.23	0.32	3.44
Total Flow	96.45	96.82	9.93	106.62

Other Parameters	Fl	Hardn	Alk (raw)	Alk (fin)	Pre-Cl_2	Post-Cl_2
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Average	1.0	25.2	13.2	15.8	1.39	0.67
Maximum	1.1	33.0	16.1	19.6	2.10	0.82
Minimum	1.0	17.5	0.2	0.3	0.92	0.53

Chemical	Dose
	(mg/L)
Zinc Ortho Phosphate	0.6
Sodium Chlorite	3.0
Fluoride (Silly Acid)	1.0
Muriactic Acid (HCl)	1.6
Sodium Hypo (Hypo)	6.0
Sodium Hydr (NaOH)	13.2
Aluminum Sulf (Alum)	26.6

pH	Floc Basin	Fin Water
Average	5.70	7.43
Maximum	5.92	7.73
Minimum	5.34	7.13

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September, 2009

Parameter	Flow	pH	Turbidity	Color	Free Cl_2	Total Cl_2
	MGD		NTU	TCU	mg/L	mg/L
Raw Water						
Average	2.85	6.86	1.14	24.89		
Maximum	3.90	7.30	2.74	39.60		
Minimum	1.80	6.02	0.73	13.10		
Std Dev	0.40	0.20	0.28	6.13		
Flocculator Influent	**pH**		**pH**			
	Floc 1		Floc 2			
Average	5.97		5.90		1.21	1.85
Maximum	6.34		6.96		2.60	2.90
Minimum	5.00		4.93		0.45	1.15
Std Dev	0.18		0.20		0.28	0.27
Filter Influent	**Temp**		**Turbidity**	**Color**	**Free Cl_2**	**Total Cl_2**
	degC		NTU	TCU	mg/L	mg/L
Average	20.20	5.85	0.51	6.83	0.52	0.83
Maximum	25.00	6.16	0.85	13.20	1.30	1.45
Minimum	18.30	4.99	0.29	0.39	0.15	0.30
Std Dev	1.15	0.16	0.11	2.66	0.16	0.22
Filter Effluent	**Turbidity**	**Turbidity**	**Turbidity**	**Turbidity**	**Turbidity**	**Color**
	Filter 1	Filter 2	Filter 3	Filter 4	Comb	Comb
Average	0.04	0.04	0.04	0.04	0.03	0.00
Maximum	0.14	0.09	0.06	0.07	0.06	0.20
Minimum	0.01	0.02	0.02	0.02	0.02	0.00
Std Dev	0.01	0.01	0.01	0.01	0.01	0.01
Contact Chamber	**Flow**	**pH**	**Turbidity**	**Color**	**Free Cl_2**	**Total Cl_2**
	MGD		NTU	TCU	mg/L	mg/L
Average	3.15	5.67	0.03		0.85	0.93
Maximum	5.95	6.09	0.05		1.10	1.50
Minimum	1.90	4.81	0.02		0.60	0.70
Std Dev	0.65	0.28	0.01		0.07	0.08
Finished Water						
Average	3.39	7.38	0.05	0.01	0.73	0.81
Maximum	7.49	8.02	0.18	0.50	0.90	0.95
Minimum	1.80	6.94	0.03	0.00	0.50	0.60
Std Dev	0.88	0.23	0.02	0.02	0.08	0.07

Location	Flow	pH	Free Cl2	Temp	Det Time	CT
	MGD		mg/L	degC	min	mg-min/L
Pre-Treatment CT						
Average	2.85	5.85	0.52	20.20	188	98
Maximum	3.90	6.16	1.30	25.00	292	253
Minimum	1.80	4.99	0.15	18.30	135	30
Contact Chamber CT						
Average	3.15	5.67	0.85	20.20	71	60
Maximum	5.95	6.09	1.10	25.00	114	114
Minimum	1.90	4.81	0.60	18.30	36	26

Max Turbidity (NTU)	Filter	Plant
	0.06	0.18

Pumped Flow (MG)	Raw	Finished	Recycle	Plant
Max Day	3.50	3.62	2.55	3.81
Average Flow	2.81	2.90	0.31	3.09
Total Flow	84.17	86.87	9.16	92.58

Other Parameters	Fl	Hardn	Alk (raw)	Alk (fin)	Pre-Cl_2	Post-Cl_2
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Average	1.0	28.9	14.4	15.7	1.21	0.73
Maximum	1.1	34.0	17.6	17.7	1.93	0.83
Minimum	1.0	22.5	10.7	13.6	0.86	0.63

Chemical	Dose (mg/L)
Zinc Ortho Phosphate	0.6
Sodium Chlorite	2.9
Fluoride (Silly Acid)	1.0
Muriactic Acid (HCl)	1.6
Sodium Hypo (Hypo)	5.3
Sodium Hydr (NaOH)	13.1
Aluminum Sulf (Alum)	28.0

pH	Floc Basin	Fin Water
Average	5.93	7.38
Maximum	6.20	7.72
Minimum	5.54	7.13

Tewksbury Water Treatment Plant - Daily Lab Sheet Information
October, 2009

Parameter	Flow MGD	pH	Turbidity NTU	Color TCU	Free Cl_2 mg/L	Total Cl_2 mg/L
Raw Water						
Average	2.40	7.36	1.78	28.46		
Maximum	3.30	22.40	6.57	63.20		
Minimum	2.00	6.59	0.84	13.80		
Std Dev	0.27	2.61	1.22	12.19		
Flocculator Influent	**pH** Floc 1		**pH** Floc 2			
Average	12.54		6.00		1.07	1.93
Maximum	636.00		6.34		2.00	2.70
Minimum	5.51		5.54		0.40	1.05
Std Dev	25.39		0.15		0.27	0.26
Filter Influent	**Temp** degC		**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	14.44	5.75	0.50	4.47	0.50	0.84
Maximum	18.30	6.20	0.94	10.60	1.10	1.55
Minimum	10.60	0.38	0.31	0.50	0.15	0.40
Std Dev	2.31	1.00	0.13	2.03	0.19	0.21
Filter Effluent	**Turbidity** Filter 1	**Turbidity** Filter 2	**Turbidity** Filter 3	**Turbidity** Filter 4	**Turbidity** Comb	**Color** Comb
Average	0.02	0.02	0.02	0.02	0.02	0.00
Maximum	0.06	0.06	0.09	0.07	0.06	0.10
Minimum	0.01	0.01	0.01	0.01	0.01	0.00
Std Dev	0.01	0.01	0.01	0.01	0.01	0.00
Contact Chamber	**Flow** MGD	**pH**	**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	2.48	5.80	0.02		0.80	0.87
Maximum	3.00	6.11	0.06		0.90	0.95
Minimum	2.10	5.47	0.01		0.65	0.70
Std Dev	0.24	0.17	0.01		0.05	0.05
Finished Water						
Average	2.64	7.41	0.03	0.00	0.69	0.77
Maximum	3.20	8.38	0.08	0.10	0.80	0.85
Minimum	2.20	6.96	0.01	0.00	0.55	0.65
Std Dev	0.24	0.19	0.01	0.01	0.04	0.04

Location	Flow MGD	pH	Free Cl2 mg/L	Temp degC	Det Time min	CT mg-min/L
Pre-Treatment CT						
Average	2.40	5.92	0.50	14.44	222	110
Maximum	3.30	6.20	1.10	18.30	263	263
Minimum	2.00	5.57	0.15	10.60	159	30
Contact Chamber CT						
Average	2.48	5.80	0.80	14.44	88	70
Maximum	3.00	6.11	0.90	18.30	103	88
Minimum	2.10	5.47	0.65	10.60	72	48

Max Turbidity (NTU)	Filter	Plant
	0.06	0.08

Pumped Flow (MG)	Raw	Finished	Recycle	Plant
Max Day	2.64	2.73	0.27	2.94
Average Flow	2.33	2.42	0.22	2.63
Total Flow	72.23	75.13	6.85	81.41

Other Parameters	Fl mg/L	Hardn mg/L	Alk (raw) mg/L	Alk (fin) mg/L	Pre-Cl_2 mg/L	Post-Cl_2 mg/L
Average	1.0	29.0	13.5	16.0	1.07	0.69
Maximum	1.0	37.0	20.0	19.3	1.59	0.76
Minimum	0.9	20.0	6.9	11.2	0.60	0.63

Chemical	Dose (mg/L)
Zinc Ortho Phosphate	0.6
Sodium Chlorite	2.5
Fluoride (Silly Acid)	1.0
Muriactic Acid (HCl)	1.4
Sodium Hypo (Hypo)	4.7
Sodium Hydr (NaOH)	12.6
Aluminum Sulf (Alum)	26.8

pH	Floc Basin	Fin Water
Average	9.27	7.41
Maximum	58.60	7.63
Minimum	5.69	7.09

Tewksbury Water Treatment Plant - Daily Lab Sheet Information
November, 2009

Parameter	Flow MGD	pH	Turbidity NTU	Color TCU	Free Cl_2 mg/L	Total Cl_2 mg/L
Raw Water						
Average	2.26	6.86	1.97	36.30		
Maximum	3.40	7.25	5.00	48.60		
Minimum	2.00	6.56	1.31	23.60		
Std Dev	0.21	0.14	0.49	6.13		
Flocculator Influent	**pH** Floc 1		**pH** Floc 2			
Average	6.12		6.11		1.31	1.93
Maximum	6.52		6.46		2.30	3.00
Minimum	5.65		5.74		0.10	1.40
Std Dev	0.16		0.14		0.25	0.25
Filter Influent	**Temp** degC		**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	11.05	6.03	0.60	4.98	0.64	0.91
Maximum	13.90	6.33	0.93	8.10	1.35	1.65
Minimum	8.90	5.77	0.42	2.20	0.30	0.60
Std Dev	1.01	0.13	0.11	0.94	0.15	0.16
Filter Effluent	**Turbidity** Filter 1	**Turbidity** Filter 2	**Turbidity** Filter 3	**Turbidity** Filter 4	**Turbidity** Comb	**Color** Comb
Average	0.02	0.02	0.02	0.02	0.02	0.00
Maximum	0.09	0.14	0.08	0.07	0.05	0.00
Minimum	0.01	0.01	0.01	0.01	0.01	0.00
Std Dev	0.01	0.01	0.01	0.01	0.01	0.00
Contact Chamber	**Flow** MGD	**pH**	**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	2.36	5.77	0.02		0.74	0.80
Maximum	2.80	6.13	0.03		0.95	1.00
Minimum	2.00	5.39	0.01		0.60	0.65
Std Dev	0.13	0.16	0.00		0.04	0.04
Finished Water						
Average	2.49	7.35	0.03	0.00	0.64	0.71
Maximum	2.80	7.89	0.05	0.10	0.75	0.80
Minimum	2.30	6.99	0.01	0.00	0.55	0.60
Std Dev	0.12	0.19	0.01	0.00	0.04	0.04

Location	Flow MGD	pH	Free Cl2 mg/L	Temp degC	Det Time min	CT mg-min/L
Pre-Treatment CT						
Average	2.26	6.03	0.64	11.05	235	151
Maximum	3.40	6.33	1.35	13.90	263	289
Minimum	2.00	5.77	0.30	8.90	154	71
Contact Chamber CT						
Average	2.36	5.77	0.74	11.05	92	68
Maximum	2.80	6.13	0.95	13.90	108	93
Minimum	2.00	5.39	0.60	8.90	77	54

Max Turbidity (NTU)	Filter	Plant
	0.05	0.05

Pumped Flow (MG)	Raw	Finished	Recycle	Plant
Max Day	2.54	2.59	0.28	2.84
Average Flow	2.20	2.29	0.22	2.50
Total Flow	65.95	68.76	6.74	74.95

Other Parameters	Fl mg/L	Hardn mg/L	Alk (raw) mg/L	Alk (fin) mg/L	Pre-Cl_2 mg/L	Post-Cl_2 mg/L
Average	1.0	23.6	10.9	13.5	1.31	0.64
Maximum	1.3	27.5	13.3	15.8	1.65	0.71
Minimum	0.9	20.0	9.3	11.1	1.03	0.58

Chemical	Dose (mg/L)
Zinc Ortho Phosphate	0.6
Sodium Chlorite	2.5
Fluoride (Silly Acid)	1.1
Muriactic Acid (HCl)	1.4
Sodium Hypo (Hypo)	4.8
Sodium Hydr (NaOH)	13.2
Aluminum Sulf (Alum)	27.7

pH	Floc Basin	Fin Water
Average	6.11	7.35
Maximum	6.34	7.50
Minimum	5.91	7.08

Tewksbury Water Treatment Plant - Daily Lab Sheet Information
December, 2009

Parameter	Flow MGD	pH	Turbidity NTU	Color TCU	Free Cl_2 mg/L	Total Cl_2 mg/L
Raw Water						
Average	2.31	6.85	1.50	27.93		
Maximum	3.30	7.26	3.10	42.90		
Minimum	2.00	6.38	0.84	19.20		
Std Dev	0.26	0.12	0.58	4.58		
Flocculator Influent	**pH** Floc 1		**pH** Floc 2			
Average	6.22		6.22		1.17	2.01
Maximum	6.67		6.56		2.20	3.10
Minimum	5.75		5.69		0.25	0.90
Std Dev	0.15		0.17		0.31	0.35
Filter Influent	**Temp** degC		**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	6.29	6.15	0.86	7.06	0.69	1.09
Maximum	12.30	6.51	1.28	11.60	1.50	2.05
Minimum	2.70	5.86	0.53	2.20	0.25	0.55
Std Dev	2.29	0.13	0.16	2.02	0.18	0.24
Filter Effluent	**Turbidity** Filter 1	**Turbidity** Filter 2	**Turbidity** Filter 3	**Turbidity** Filter 4	**Turbidity** Comb	**Color** Comb
Average	0.02	0.02	0.02	0.02	0.02	0.00
Maximum	0.10	0.04	0.04	0.06	0.03	0.00
Minimum	0.01	0.01	0.01	0.01	0.01	0.00
Std Dev	0.01	0.01	0.01	0.01	0.00	0.00
Contact Chamber	**Flow** MGD	**pH**	**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	2.34	5.94	0.02		0.68	0.75
Maximum	2.90	6.33	0.04		0.75	0.85
Minimum	2.10	5.39	0.01		0.55	0.60
Std Dev	0.18	0.24	0.01		0.04	0.04
Finished Water						
Average	2.58	7.38	0.02	0.00	0.62	0.69
Maximum	3.70	8.07	0.11	0.00	0.70	0.80
Minimum	2.30	6.99	0.01	0.00	0.50	0.55
Std Dev	0.20	0.19	0.01	0.00	0.04	0.04

Location	Flow MGD	pH	Free Cl2 mg/L	Temp degC	Det Time min	CT mg-min/L
Pre-Treatment CT						
Average	2.31	6.15	0.69	6.29	231	159
Maximum	3.30	6.51	1.50	12.30	263	342
Minimum	2.00	5.86	0.25	2.70	159	60
Contact Chamber CT						
Average	2.34	5.94	0.68	6.29	93	64
Maximum	2.90	6.33	0.75	12.30	103	77
Minimum	2.10	5.39	0.55	2.70	74	48

Max Turbidity (NTU)	Filter	Plant
	0.03	0.11

Pumped Flow (MG)	Raw	Finished	Recycle	Plant
Max Day	2.67	2.74	0.25	2.97
Average Flow	2.26	2.36	0.19	2.53
Total Flow	70.12	73.04	5.91	78.31

Other Parameters	Fl mg/L	Hardn mg/L	Alk (raw) mg/L	Alk (fin) mg/L	Pre-Cl_2 mg/L	Post-Cl_2 mg/L
Average	1.1	25.8	11.3	14.1	1.17	0.62
Maximum	1.2	34.0	14.1	18.0	1.59	0.68
Minimum	1.0	18.0	8.2	10.9	0.53	0.55

Chemical	Dose (mg/L)
Zinc Ortho Phosphate	0.6
Sodium Chlorite	2.5
Fluoride (Silly Acid)	1.1
Muriactic Acid (HCl)	1.5
Sodium Hypo (Hypo)	4.3
Sodium Hydr (NaOH)	13.7
Aluminum Sulf (Alum)	26.1

pH	Floc Basin	Fin Water
Average	6.22	7.38
Maximum	6.40	7.68
Minimum	5.94	7.16

Tewksbury Water Treatment Plant - Daily Lab Sheet Information
January, 2010

Parameter	Flow MGD	pH	Turbidity NTU	Color TCU	Free Cl_2 mg/L	Total Cl_2 mg/L
Raw Water						
Average	2.17	6.78	1.54	22.48		
Maximum	3.30	7.24	8.90	39.80		
Minimum	1.70	6.48	0.76	15.60		
Std Dev	0.14	0.15	1.24	5.69		
Flocculator Influent	**pH** Floc 1		**pH** Floc 2			
Average	6.41		6.31		1.16	2.39
Maximum	6.78		6.65		2.00	3.20
Minimum	6.01		5.91		0.35	1.40
Std Dev	0.12		0.15		0.30	0.31
Filter Influent	**Temp** degC		**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	4.22	6.31	0.86	9.05	0.80	1.24
Maximum	8.40	6.63	1.22	14.20	1.40	1.60
Minimum	2.40	6.02	0.62	4.10	0.20	0.70
Std Dev	1.01	0.09	0.09	1.48	0.21	0.19
Filter Effluent	**Turbidity** Filter 1	**Turbidity** Filter 2	**Turbidity** Filter 3	**Turbidity** Filter 4	**Turbidity** Comb	**Color** Comb
Average	0.02	0.02	0.02	0.02	0.02	0.00
Maximum	0.08	0.05	0.05	0.05	0.03	0.00
Minimum	0.01	0.01	0.01	0.01	0.01	0.00
Std Dev	0.01	0.01	0.01	0.01	0.00	0.00
Contact Chamber	**Flow** MGD	**pH**	**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	2.19	6.17	0.02		0.68	0.75
Maximum	2.70	6.40	0.03		0.80	0.85
Minimum	1.80	5.71	0.01		0.60	0.65
Std Dev	0.10	0.11	0.00		0.04	0.05
Finished Water						
Average	2.47	7.38	0.02	0.00	0.63	0.69
Maximum	2.70	8.30	0.05	0.00	0.75	0.80
Minimum	2.10	6.86	0.01	0.00	0.50	0.60
Std Dev	0.09	0.25	0.01	0.00	0.04	0.04

Location	Flow MGD	pH	Free Cl2 mg/L	Temp degC	Det Time min	CT mg-min/L
Pre-Treatment CT						
Average	2.17	6.31	0.80	4.22	242	192
Maximum	3.30	6.63	1.40	8.40	228	297
Minimum	1.70	6.02	0.20	2.40	263	53
Contact Chamber CT						
Average	2.19	6.17	0.68	4.22	98	67
Maximum	2.70	6.40	0.80	8.40	94	75
Minimum	1.80	5.71	0.60	2.40	103	62

Max Turbidity (NTU)	Filter	Plant
	0.03	0.05

Pumped Flow (MG)	Raw	Finished	Recycle	Plant
Max Day	2.34	2.38	0.50	2.59
Average Flow	2.15	2.24	0.20	2.40
Total Flow	66.69	69.54	6.06	74.50

Other Parameters	Fl mg/L	Hardn mg/L	Alk (raw) mg/L	Alk (fin) mg/L	Pre-Cl_2 mg/L	Post-Cl_2 mg/L
Average	1.1	29.2	12.1	15.5	1.16	0.63
Maximum	1.2	34.5	14.4	18.7	1.83	0.72
Minimum	1.0	20.0	7.3	10.9	0.53	0.56

Chemical	Dose (mg/L)
Zinc Ortho Phosphate	0.5
Sodium Chlorite	2.7
Fluoride (Silly Acid)	1.1
Muriactic Acid (HCl)	1.5
Sodium Hypo (Hypo)	4.6
Sodium Hydr (NaOH)	14.3
Aluminum Sulf (Alum)	24.6

pH	Floc Basin	Fin Water
Average	6.36	7.38
Maximum	6.63	7.96
Minimum	6.11	7.00

Tewksbury Water Treatment Plant - Daily Lab Sheet Information
February, 2010

Parameter	Flow MGD	pH	Turbidity NTU	Color TCU	Free Cl_2 mg/L	Total Cl_2 mg/L
Raw Water						
Average	2.04	6.82	2.46	25.87		
Maximum	2.80	7.27	16.39	180.40		
Minimum	1.70	6.45	0.97	10.60		
Std Dev	0.11	0.16	3.30	17.61		
Flocculator Influent	**pH** Floc 1		**pH** Floc 2			
Average	6.20		6.22		0.96	2.29
Maximum	6.78		6.62		2.15	3.00
Minimum	2.40		5.46		0.15	1.80
Std Dev	0.65		0.25		0.35	0.23
Filter Influent	**Temp** degC		**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	4.20	6.25	0.93	8.45	0.59	1.06
Maximum	7.20	6.55	2.33	17.10	1.10	1.80
Minimum	2.30	5.48	0.64	5.00	0.20	0.65
Std Dev	0.98	0.15	0.21	1.42	0.22	0.20
Filter Effluent	**Turbidity** Filter 1	**Turbidity** Filter 2	**Turbidity** Filter 3	**Turbidity** Filter 4	**Turbidity** Comb	**Color** Comb
Average	0.02	0.02	0.02	0.02	0.02	0.00
Maximum	0.17	0.15	0.04	0.04	0.06	0.10
Minimum	0.01	0.01	0.01	0.00	0.01	0.00
Std Dev	0.02	0.01	0.01	0.01	0.00	0.00
Contact Chamber	**Flow** MGD	**pH**	**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	2.10	6.14	0.02		0.61	0.68
Maximum	2.30	6.45	0.03		0.75	0.80
Minimum	1.80	5.71	0.01		0.50	0.60
Std Dev	0.08	0.16	0.00		0.04	0.04
Finished Water						
Average	2.36	7.35	0.03	0.00	0.56	0.62
Maximum	3.00	8.12	0.14	0.00	0.65	0.70
Minimum	1.50	6.87	0.01	0.00	0.45	0.50
Std Dev	0.10	0.23	0.01	0.00	0.04	0.04

Location	Flow MGD	pH	Free Cl2 mg/L	Temp degC	Det Time min	CT mg-min/L
Pre-Treatment CT						
Average	2.04	6.25	0.59	4.20	258	151
Maximum	2.80	6.55	1.10	7.20	309	304
Minimum	1.70	5.48	0.20	2.30	188	53
Contact Chamber CT						
Average	2.10	6.18	0.61	4.20	103	63
Maximum	2.30	7.64	0.75	7.20	120	77
Minimum	1.80	5.71	0.50	2.30	94	51

Max Turbidity (NTU)	Filter	Plant
	0.06	0.14

Pumped Flow (MG)	Raw	Finished	Recycle	Plant	
Max Day	2.20	2.32	0.22	2.47	
Average Flow	2.01	2.12	0.18	2.26	0.14
Total Flow	56.21	59.29	5.00	63.28	3.99

Other Parameters	Fl mg/L	Hardn mg/L	Alk (raw) mg/L	Alk (fin) mg/L	Pre-Cl_2 mg/L	Post-Cl_2 mg/L
Average	1.1	30.7	13.1	15.8	0.96	0.56
Maximum	1.2	37.5	16.7	20.1	1.73	0.61
Minimum	1.0	17.5	6.1	9.8	0.57	0.48

Chemical	Dose (mg/L)
Zinc Ortho Phosphate	0.6
Sodium Chlorite	2.6
Fluoride (Silly Acid)	1.1
Muriactic Acid (HCl)	1.4
Sodium Hypo (Hypo)	4.7
Sodium Hydr (NaOH)	14.1
Aluminum Sulf (Alum)	25.7

pH	Floc Basin	Fin Water
Average	6.22	7.34
Maximum	6.58	7.83
Minimum	4.69	7.08

Tewksbury Water Treatment Plant - Daily Lab Sheet Information
March, 2010

Parameter	Flow MGD	pH	Turbidity NTU	Color TCU	Free Cl_2 mg/L	Total Cl_2 mg/L
Raw Water						
Average	2.08	6.66	2.93	30.09		
Maximum	3.50	6.95	10.40	60.80		
Minimum	1.90	6.32	1.15	20.10		
Std Dev	0.18	0.13	1.94	8.24		
Flocculator Influent	**pH** Floc 1		**pH** Floc 2			
Average	9.35		6.29		1.44	2.01
Maximum	605.00		6.69		2.85	3.40
Minimum	5.68		5.61		0.75	1.25
Std Dev	18.08		0.21		0.32	0.32
Filter Influent	**Temp** degC		**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	7.32	6.11	0.54	5.25	0.78	1.12
Maximum	10.70	6.36	1.38	10.70	1.60	13.00
Minimum	3.60	5.80	0.31	1.40	0.45	0.70
Std Dev	1.79	0.13	0.10	1.53	0.19	0.54
Filter Effluent	**Turbidity** Filter 1	**Turbidity** Filter 2	**Turbidity** Filter 3	**Turbidity** Filter 4	**Turbidity** Comb	**Color** Comb
Average	0.02	0.02	0.02	0.02	0.02	0.00
Maximum	0.04	0.03	0.06	0.06	0.03	0.00
Minimum	0.01	0.01	0.01	0.00	0.01	0.00
Std Dev	0.00	0.00	0.01	0.01	0.00	0.00
Contact Chamber	**Flow** MGD	**pH**	**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	2.12	5.77	0.02		0.67	0.74
Maximum	2.70	6.31	0.04		0.80	0.90
Minimum	1.90	5.43	0.01		0.60	0.65
Std Dev	0.14	0.17	0.00		0.04	0.05
Finished Water						
Average	2.36	7.40	0.03	0.00	0.61	0.67
Maximum	4.10	7.99	0.22	0.30	0.75	0.80
Minimum	1.80	7.08	0.02	0.00	0.50	0.60
Std Dev	0.19	0.16	0.02	0.02	0.04	0.04

Location	Flow MGD	pH	Free Cl2 mg/L	Temp degC	Det Time min	CT mg-min/L
Pre-Treatment CT						
Average	2.08	6.11	0.78	7.32	255	199
Maximum	3.50	6.36	1.60	10.70	276	420
Minimum	1.90	5.80	0.45	3.60	150	118
Contact Chamber CT						
Average	2.12	5.77	0.67	7.32	102	69
Maximum	2.70	6.31	0.80	10.70	114	82
Minimum	1.90	5.43	0.60	3.60	80	52

Max Turbidity (NTU)	Filter	Plant
	0.03	0.22

Pumped Flow (MG)	Raw	Finished	Recycle	Plant
Max Day	2.28	2.43	0.47	2.53
Average Flow	2.00	2.12	0.20	2.26
Total Flow	61.92	65.78	6.12	70.03

Other Parameters	Fl mg/L	Hardn mg/L	Alk (raw) mg/L	Alk (fin) mg/L	Pre-Cl_2 mg/L	Post-Cl_2 mg/L
Average	1.0	19.3	7.6	11.0	1.45	0.61
Maximum	1.1	27.0	11.4	13.2	2.48	0.67
Minimum	0.9	9.5	4.3	8.8	1.01	0.57

Chemical	Dose (mg/L)
Zinc Ortho Phosphate	0.6
Sodium Chlorite	2.5
Fluoride (Silly Acid)	1.1
Muriactic Acid (HCl)	1.4
Sodium Hypo (Hypo)	4.1
Sodium Hydr (NaOH)	15.6
Aluminum Sulf (Alum)	28.3

pH	Floc Basin	Fin Water
Average	7.82	7.40
Maximum	56.06	7.72
Minimum	5.92	7.16

Tewksbury Water Treatment Plant - Daily Lab Sheet Information
April, 2010

Parameter	Flow MGD	pH	Turbidity NTU	Color TCU	Free Cl_2 mg/L	Total Cl_2 mg/L
Raw Water						
Average	2.12	6.71	1.69	26.16		
Maximum	3.20	6.96	14.83	66.40		
Minimum	1.90	6.42	1.07	20.00		
Std Dev	0.17	0.11	1.02	4.91		
Flocculator Influent	**pH** Floc 1		**pH** Floc 2			
Average	6.07		6.09		1.14	1.69
Maximum	6.42		6.52		1.90	2.50
Minimum	5.52		5.45		0.35	1.00
Std Dev	0.18		0.20		0.23	0.22
Filter Influent	**Temp** degC		**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	12.60	6.02	0.48	4.17	0.53	0.74
Maximum	15.30	6.29	0.89	8.60	0.90	1.20
Minimum	8.80	5.71	0.33	1.40	0.20	0.40
Std Dev	1.34	0.13	0.09	0.96	0.14	0.15
Filter Effluent	**Turbidity** Filter 1	**Turbidity** Filter 2	**Turbidity** Filter 3	**Turbidity** Filter 4	**Turbidity** Comb	**Color** Comb
Average	0.02	0.02	0.02	0.02	0.02	0.00
Maximum	0.05	0.04	0.07	0.07	0.04	0.00
Minimum	0.01	0.01	0.01	0.01	0.01	0.00
Std Dev	0.00	0.00	0.01	0.01	0.00	0.00
Contact Chamber	**Flow** MGD	**pH**	**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	2.21	5.68	0.02		0.66	0.75
Maximum	3.10	6.16	0.03		0.80	5.00
Minimum	2.00	5.12	0.01		0.40	0.50
Std Dev	0.16	0.24	0.00		0.05	0.17
Finished Water						
Average	2.42	7.35	0.03	0.00	0.60	0.66
Maximum	3.10	7.94	0.05	0.00	0.70	0.80
Minimum	2.20	6.94	0.02	0.00	0.50	0.55
Std Dev	0.16	0.14	0.01	0.00	0.05	0.05

Location	Flow MGD	pH	Free Cl2 mg/L	Temp degC	Det Time min	CT mg-min/L
Pre-Treatment CT						
Average	2.12	6.02	0.53	12.60	250	132
Maximum	3.20	6.29	0.90	15.30	276	236
Minimum	1.90	5.71	0.20	8.80	164	33
Contact Chamber CT						
Average	2.21	5.68	0.66	12.60	98	65
Maximum	3.10	6.16	0.80	15.30	108	82
Minimum	2.00	5.12	0.40	8.80	70	38

Max Turbidity (NTU)	Filter	Plant
	0.04	0.05

Pumped Flow (MG)	Raw	Finished	Recycle	Plant
Max Day	2.39	2.52	0.42	2.71
Average Flow	2.08	2.21	0.23	2.37
Total Flow	62.26	66.32	6.90	71.23

Other Parameters	Fl mg/L	Hardn mg/L	Alk (raw) mg/L	Alk (fin) mg/L	Pre-Cl_2 mg/L	Post-Cl_2 mg/L
Average	1.0	21.4	9.7	13.0	1.14	0.60
Maximum	1.2	26.5	11.8	15.0	1.44	0.68
Minimum	0.1	8.9	5.3	9.8	0.86	0.54

Chemical	Dose (mg/L)
Zinc Ortho Phosphate	0.6
Sodium Chlorite	2.4
Fluoride (Silly Acid)	1.4
Muriactic Acid (HCl)	1.3
Sodium Hypo (Hypo)	4.4
Sodium Hydr (NaOH)	18.7
Aluminum Sulf (Alum)	28.0

pH	Floc Basin	Fin Water
Average	6.08	7.35
Maximum	6.31	7.79
Minimum	5.75	7.18

Tewksbury Water Treatment Plant - Daily Lab Sheet Information
May, 2010

Parameter	Flow	pH	Turbidity	Color	Free Cl_2	Total Cl_2
	MGD		NTU	TCU	mg/L	mg/L
Raw Water						
Average	2.77	6.82	1.86	24.99		
Maximum	4.70	7.09	4.67	35.40		
Minimum	2.00	6.67	1.21	19.10		
Std Dev	0.59	0.07	0.69	2.88		
Flocculator Influent	**pH**		**pH**			
	Floc 1		Floc 2			
Average	6.02		5.96		1.12	1.93
Maximum	6.36		6.26		1.95	14.40
Minimum	5.36		5.60		0.50	1.25
Std Dev	0.23		0.15		0.29	0.62
Filter Influent	**Temp**		**Turbidity**	**Color**	**Free Cl_2**	**Total Cl_2**
	degC		NTU	TCU	mg/L	mg/L
Average	17.76	5.94	0.54	4.71	0.49	0.72
Maximum	24.20	6.24	1.06	9.80	1.10	1.40
Minimum	12.90	5.35	0.36	2.10	0.20	0.30
Std Dev	2.79	0.20	0.09	1.10	0.18	0.19
Filter Effluent	**Turbidity**	**Turbidity**	**Turbidity**	**Turbidity**	**Turbidity**	**Color**
	Filter 1	Filter 2	Filter 3	Filter 4	Comb	Comb
Average	0.03	0.02	0.02	0.03	0.03	0.00
Maximum	0.09	0.06	0.05	0.06	0.06	0.00
Minimum	0.01	0.01	0.02	0.02	0.02	0.00
Std Dev	0.01	0.01	0.01	0.01	0.01	0.00
Contact Chamber	**Flow**	**pH**	**Turbidity**	**Color**	**Free Cl_2**	**Total Cl_2**
	MGD		NTU	TCU	mg/L	mg/L
Average	3.00	5.88	0.03		0.69	0.75
Maximum	5.00	6.42	0.05		1.00	1.10
Minimum	2.00	5.31	0.02		0.50	0.60
Std Dev	0.61	0.27	0.01		0.07	0.07
Finished Water						
Average	3.36	7.30	0.04	0.00	0.64	0.70
Maximum	5.70	8.40	0.24	0.20	0.85	0.90
Minimum	2.30	6.97	0.02	0.00	0.45	0.55
Std Dev	0.73	0.22	0.02	0.01	0.07	0.07

Location	Flow	pH	Free Cl2	Temp	Det Time	CT
	MGD		mg/L	degC	min	mg-min/L
Pre-Treatment CT						
Average	2.77	5.94	0.49	17.76	197	99
Maximum	4.70	6.24	1.10	24.20	263	251
Minimum	2.00	5.35	0.20	12.90	112	28
Contact Chamber CT						
Average	3.00	5.88	0.69	17.76	75	52
Maximum	5.00	6.42	1.00	24.20	108	86
Minimum	2.00	5.31	0.50	12.90	43	24

Max Turbidity (NTU)	Filter	Plant
	0.06	0.24

Pumped Flow (MG)	Raw	Finished	Recycle	Plant
Max Day	3.94	4.35	1.00	4.24
Average Flow	2.72	3.00	0.28	3.09
Total Flow	84.23	93.11	8.82	95.76

Other Parameters	Fl	Hardn	Alk (raw)	Alk (fin)	Pre-Cl_2	Post-Cl_2
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Average	1.1	30.5	14.1	16.1	1.12	0.64
Maximum	1.2	39.5	17.7	19.7	1.66	0.74
Minimum	1.0	20.0	11.4	13.2	0.73	0.53

Chemical	Dose
	(mg/L)
Zinc Ortho Phosphate	0.6
Sodium Chlorite	2.5
Fluoride (Silly Acid)	1.1
Muriactic Acid (HCl)	1.2
Sodium Hypo (Hypo)	5.2
Sodium Hydr (NaOH)	12.0
Aluminum Sulf (Alum)	27.8

pH	Floc Basin	Fin Water
Average	5.99	7.30
Maximum	6.22	7.96
Minimum	5.65	7.12

Tewksbury Water Treatment Plant - Daily Lab Sheet Information
June, 2010

Parameter	Flow MGD	pH	Turbidity NTU	Color TCU	Free Cl_2 mg/L	Total Cl_2 mg/L
Raw Water						
Average	3.24	6.88	2.91	29.92		
Maximum	4.40	7.20	5.90	38.90		
Minimum	2.20	6.53	2.00	19.20		
Std Dev	0.59	0.14	0.67	3.77		
Flocculator Influent	**pH** Floc 1		**pH** Floc 2			
Average	5.74		5.49		1.37	1.97
Maximum	6.17		5.99		2.40	3.10
Minimum	5.35		5.03		0.60	1.00
Std Dev	0.14		0.22		0.34	0.36
Filter Influent	**Temp** degC		**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	22.54	5.64	0.48	5.45	0.55	0.83
Maximum	26.30	6.61	0.93	10.60	1.10	1.60
Minimum	19.80	5.29	0.32	0.48	0.15	0.30
Std Dev	1.69	0.14	0.10	1.89	0.19	0.23
Filter Effluent	**Turbidity** Filter 1	**Turbidity** Filter 2	**Turbidity** Filter 3	**Turbidity** Filter 4	**Turbidity** Comb	**Color** Comb
Average	0.03	0.03	0.02	0.03	0.03	0.00
Maximum	0.05	0.05	0.05	0.04	0.04	0.00
Minimum	0.02	0.01	0.02	0.01	0.02	0.00
Std Dev	0.01	0.01	0.01	0.01	0.01	0.00
Contact Chamber	**Flow** MGD	**pH**	**Turbidity** NTU	**Color** TCU	**Free Cl_2** mg/L	**Total Cl_2** mg/L
Average	3.51	5.33	0.03		0.66	0.72
Maximum	4.50	5.90	0.04		0.85	0.90
Minimum	2.50	4.92	0.02		0.50	0.55
Std Dev	0.60	0.22	0.01		0.06	0.06
Finished Water						
Average	4.00	7.34	0.04	0.00	0.58	0.64
Maximum	5.10	8.16	0.10	0.20	0.70	0.80
Minimum	2.40	7.00	0.02	0.00	0.45	0.50
Std Dev	0.72	0.19	0.01	0.01	0.06	0.07

Location	Flow MGD	pH	Free Cl2 mg/L	Temp degC	Det Time min	CT mg-min/L
Pre-Treatment CT						
Average	3.24	5.64	0.55	22.54	168	95
Maximum	4.40	6.61	1.10	26.30	239	263
Minimum	2.20	5.29	0.15	19.80	119	20
Contact Chamber CT						
Average	3.51	5.33	0.66	22.54	64	42
Maximum	4.50	5.90	0.85	26.30	86	65
Minimum	2.50	4.92	0.50	19.80	48	25

Max Turbidity (NTU)	Filter	Plant
	0.04	0.10

Pumped Flow (MG)	Raw	Finished	Recycle	Plant
Max Day	4.14	4.49	0.27	4.43
Average Flow	3.22	3.53	0.20	3.51
Total Flow	96.50	105.75	6.13	105.27

Other Parameters	Fl mg/L	Hardn mg/L	Alk (raw) mg/L	Alk (fin) mg/L	Pre-Cl_2 mg/L	Post-Cl_2 mg/L
Average	1.1	34.3	17.0	18.1	1.37	0.58
Maximum	1.2	42.5	19.9	21.0	1.94	0.68
Minimum	1.0	27.0	14.5	16.0	0.87	0.51

Chemical	Dose (mg/L)
Zinc Ortho Phosphate	0.7
Sodium Chlorite	3.0
Fluoride (Silly Acid)	0.9
Muriactic Acid (HCl)	16.2
Sodium Hypo (Hypo)	5.4
Sodium Hydr (NaOH)	14.7
Aluminum Sulf (Alum)	34.3

pH	Floc Basin	Fin Water
Average	5.62	7.34
Maximum	5.94	7.65
Minimum	5.44	7.17

Appendix E

CONCEPTUAL LABORATORY LAYOUTS

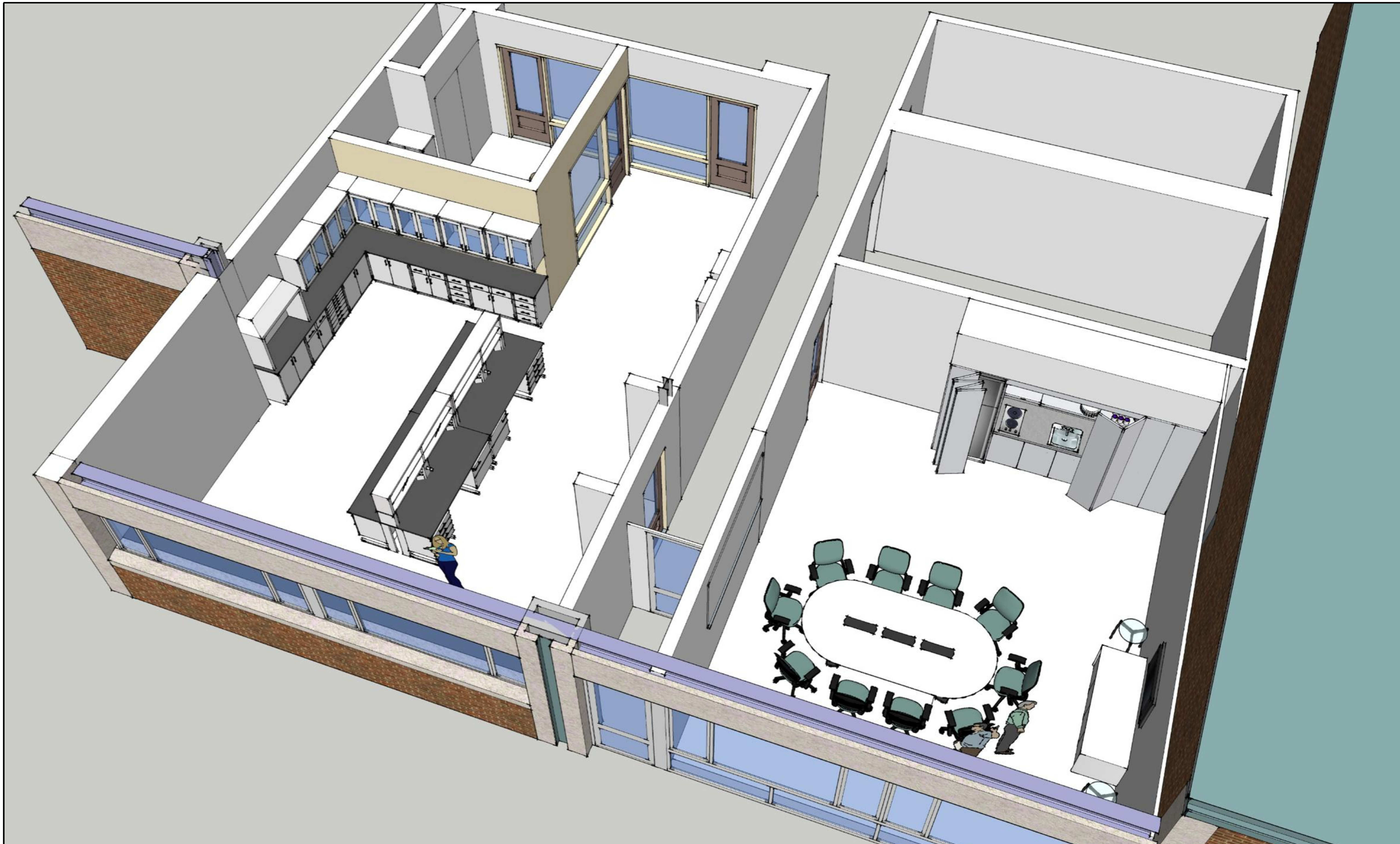
December 2012	AECOM	Town of Tewksbury, MA Tewksbury Water Treatment Plant Engineering Evaluation	Appendix E – Conceptual Laboratory Layouts **Existing Laboratory (Exterior)**	E-1

December 2012	AECOM	Town of Tewksbury, MA Tewksbury Water Treatment Plant Engineering Evaluation	Appendix E – Conceptual Laboratory Layouts **Existing Laboratory (Interior)**	E-2

Town of Tewksbury, MA
Tewksbury Water Treatment Plant Engineering Evaluation

Appendix E – Conceptual Laboratory Layouts
Office and Storage Room (View 2)

December 2012	AECOM	Town of Tewksbury, MA Tewksbury Water Treatment Plant Engineering Evaluation	Appendix E – Conceptual Laboratory Layouts **Office at Inside Corner (View 1)**	E-5



December 2012	AECOM	Town of Tewksbury, MA Tewksbury Water Treatment Plant Engineering Evaluation	Appendix E – Conceptual Laboratory Layouts **Office at Inside Corner (View 2)**	E-6

Office at Outside Corner (View 1)

Office at Outside Corner (View 2)

Proposed Roof Line (Exterior)

Roof Line (Interior)

Appendix F

CAPITAL OPINION OF COST BACK-UP

JOB NO :	60265941	**AECOM**	CLIENT :	Town of Tewksbury
DATE :	December, 2012	**Opinion of Probable Costs**	PROJECT :	WTP Engineering Evaluation
LOCATION :	Tewksbury, MA	**Tewksbury WTP**	ENR CCI :	9398
PREPARED BY :	Pickle/Mastrogiacomo	**S U M M A R Y**	CAPACITY :	7 MGD

Item	Reference No.	Description	Code	Estimated Cost
1.0		**Site Work**		**$ 40,000**
1.1	C1	Rough Grading (Swale)	2	
1.1	s.C1	Bar Gate	4	
1.2	s.C2	Lawn Irrigation	4	
2.0		**Structural**		**$ 280,000**
2.1	S1-S3	Raw Water Pump Station Interior	2	
2.2	S4-S5	Raw Water Pump Station Exterior	2	
2.3	S6-S7	Chemical Area	2	
2.4	S8	Filter Area	2	
2.5	S9-S10/13/16	Water Treatment Plant Exterior	2	
2.6	S12	PAC Tank Top Slab	2	
2.7	S15	Pretreatment Basin Top Slabs	2	
2.8	S18	Clearwell Top Slab	2	
2.9	S11/14/17	Confined Space Inspections	1	
3.0		**Architectural**		**$ 255,000**
3.1	A1	Raw Water Pump Station Interior	2	
3.2	A2-A5	Raw Water Pump Station Exterior	2	
3.3	A6	Hatches	2	
3.4	A7-A8	Chemical Area	2	
3.5	A9	Administration Area and Restrooms	2	
3.6	A7/10	Filter Area General	2	
3.7	A11	Filter Guardrails	1	
3.8	A12	Treatment Building Interior Doors	2	
3.9	A13-A20	Treatment Building Exterior	2	
4.0		**Laboratory and Breakroom Expansion**		**$ 275,000**
4.1	L9	Demolition	2	
4.2	L9	Foundation	2	
4.3	L9	Exterior Walls	2	
4.4	L1-L7,L9	Interior Walls and Flooring	2	
4.5	L1-L7,L9	Doors and Windows	2	
4.6	L1-L7,L9	Roofing System	2	
4.7	L1-L7,L9	Plumbing	2	
4.8	L1-L7,L9	Electrical	2	
4.9	L1-L7,L9	Laboratory Furnishings	2	
4.10	L1-L7,L9	Breakroom Furnishings	2	
4.11	L1-L7,L9	Allowance for Matching Existing	2	
4.12	L1-L7	Staging Allowance	2	
5.0		**Process and Mechanical**		**$ 1,365,000**
5.1	P1-P3	Raw Water Pumps and Pump Station	2	
5.2	P4-P5	Distribution Pumps	2	
5.3	M1-M2	New Flow Meters	2	
5.4	M3-M4	Pretreatment Basins	2	
5.5	M5-M7	Sludge Tank	2	
5.6	M8-M12	Automatic Backwash Filters	3	
5.7	M13	Clearwell Slide Gates	2	

JOB NO :	60265941	**AECOM**	CLIENT :	Town of Tewksbury
DATE :	December, 2012	**Opinion of Probable Costs**	PROJECT :	WTP Engineering Evaluation
LOCATION :	Tewksbury, MA	**Tewksbury WTP**	ENR CCI :	9398
PREPARED BY :	Pickle/Mastrogiacomo	**S U M M A R Y**	CAPACITY :	7 MGD

Item	Reference No.	Description	Code	Estimated Cost
6.0		**Equalization Tank**		**$ 375,000**
6.1	M14	Site Work	2	
6.2	M14	Structural	2	
6.3	M14	Process Equipment	2	
6.4	M14	Electrical, Instrumentation, and Controls	2	
7.0		**Chemical Systems**		**$ 295,000**
7.1	Ch Various	Day Tanks	2	
7.2	Ch Various	Bulk Storage Tank Replacement, Inspection, and Access	2	
7.3	Ch Various	Metering Pumps	3	
7.4	Ch Various	Transfer Pumps	2	
7.5	Ch30	Chlorine Dioxide System	2	
7.6	Ch31	Dust Collection Improvements	2	
7.7	Ch27	Fill Station	2	
8.0		**Heating, Ventilation, and Air Conditioning**		**$ 250,000**
8.1	HV1	Raw Water Pump Station	2	
8.2	HV2-HV5	Administration Areas	2	
8.3	HV6-HV8	Laboratory and Breakroom	2	
8.4	HV9/15,s.HV1	Process Areas	2	
8.5	HV16	Dewatering Building	2	
8.6	HV2-HV16	Controls	2	
8.7	HV2-HV16	Demolition	2	
9.0		**Electrical and SCADA**		**$ 960,000**
9.1	E1	Main Switchgear w/ Enclosure and Surge Protection	1	223,000
9.2	E2-6	Electrical Distribution System	1	
9.3	E7	Standby Generator w/ Walk-in Enclosure	1	383,000
9.4	E7	Removal of Ex. Generator and Fuel Tank	1	19,000
9.5	s.E1	Exterior Lighting	2	
9.6	E8	Fire Alarm System	2	
9.7	E9, s.E2	CCTV System Upgrades	2	
9.8	E10/11, s.E3	Instrumentation and Controls	2	
Sub-Total				**$ 4,095,000**
Allowance for Final Design Elements (30%)				1,229,000
Estimated Construction Cost				**$ 5,324,000**
Engineering Contingency (40%)				2,130,000
PROJECT TOTAL (2012)				**$ 7,454,000**

JOB NO :	60265941	**AECOM**	CLIENT :	Town of Tewksbury
DATE :	December, 2012	**Opinion of Probable Costs**	PROJECT :	WTP Engineering Evaluation
LOCATION :	Tewksbury, MA	**Tewksbury WTP**	ENR CCI :	9398
PREPARED BY :	Pickle/Mastrogiacomo	**Piloting and Sampling**	CAPACITY :	7 MGD

Item	Description	Estimated Cost
10.0	**Chlorine Dioxide Byproduct Sampling**	**$ 17,600**
10.1	Chlorate/Chlorite Sampling	
10.2	Engineering Support	
11.0	**Air Stripping**	**$ 175,000**
11.1	PAX/Solar Bee System Rental (3 Month Pilot)	
11.2	Delivery, Installation, and Start-up	
11.3	Analytical	
11.4	Blower	
11.5	Electrical Service	
11.6	Engineering Support	
PROJECT TOTAL (2012)		**$ 192,600**

Appendix G

PROJECT SCOPE

Appendix A

Tewksbury Water Treatment Plant Evaluation, Scope of Work

The purpose of this project is to perform engineering analysis of the drinking water facility for updating and upgrading in order to provide water in sufficient quantity and quality while meeting all Environmental Protection Agency (EPA) and Massachusetts Department of Environmental Protection (MassDEP) drinking water regulations.

1. Basic Chemistry

Chlorine Dioxide & Sodium Hypochlorite
The water treatment facility uses Chlorine Dioxide at a dose of two and a half (2.5) milligrams per liter (mg/L) (+/-) as the primary disinfectant /oxidant. Although Chlorine Dioxide has worked well over the years, tighter disinfection regulations may make the process antiquated. Total cost to use Chlorine Dioxide at two and a half (2.5) mg/L is approximately: eighty thousand to one hundred thousand dollars ($80,000 - $100,000) per year. Twelve and a half (12.5) percent Sodium Hypochlorite is used as a secondary disinfectant/oxidant and is used to further stabilize and gain CT values for disinfection credit. It has been found, over time, that in order to promote good treatment and produce stable water, both disinfectants are required. The feed system for the muriatic acid system may be improved through installation of a new bulk tank if Chlorine Dioxide remains as the primary disinfectant.

25 % Sodium Hydroxide
Recently, twenty five (25) percent Sodium Hydroxide was employed for pH adjustment and for adding alkalinity. This replaced fifty (50) percent Sodium Hydroxide, which became problematic due to freezing in the winter time despite great efforts to keep it warm. The Town's chemical suppliers do not have fine control on the ultimate concentration and deliveries were made at fifty one point nine (51.9) percent which has a much higher freeze point than the desired fifty (50) percent concentration. Otherwise Sodium Hydroxide chemical has been working well and the Finished Water Sodium values have been reasonable.

50 % Aluminum Sulfate (ALUM)
Aluminum sulfate has been employed at the plant since it opened in 1988. Attempts using polymers and some bench tests using other coagulants proved worthy to study, but alum always remained the best and most cost efficient coagulant in our section of the river. Typical alum concentrations are twenty-five to thirty (25-30) mg/L with excursions up to fifty (50) mg/L, when the Concord River has a greater influence on the raw water quality.

Hydrofluorosilicic Acid
The plant uses Hydrofluorosilicic acid for its source of fluoride. The system works well but the facility still uses fifty-five (55) gallon barrels. Installing a bulk storage system would be most advantageous to reduce deliveries, handling and to also increase safety of operators.

Zinc ortho Phosphate

Zinc-ortho-Phosphate is used for corrosion control. This formulation contains a one to three (1:3) zinc to phosphate ratio formulation. Application is at the end of our treatment trains but the feed system has been very consistent and works well. Lead and Copper analysis cycles has been very good since the incorporation of this chemical.

1. The engineering firm shall investigate the methods of application and type of chemical treatment processes currently used in the plant, including:
   i. Investigating if the chemical feed system equipment is in need of an upgrade;
   ii. Investigating the efficiency of each chemical process and suggest possible improvements to meet present and future MaDEP/EPA regulations; and
   iii. Investigating all storage tanks for aging.

2. Electrical System

The electrical system in the original section of the plant is over twenty-three (23) years old. Some sections have been replaced as of 2000 during an expansion of the hydraulic capacity of the plant to seven (7) million gallons per day (MGD). However some original sections do remain and must be evaluated for replacement or simple upgrades. Several raw and finished water pumping systems have been retrofitted with variable frequency drives (VFD); however four (4) more motor control systems could easily be replaced with VFD's.

The back-up generator electrical capacity was not increased in order to meet the plants expanded electrical needs. In addition, the switch gear, located outside, is problematic due to the effects of the exposure to the weather.

1. The engineering firm shall investigate and evaluate the electrical system of the facility, including:
   i. Determining where and what electrical systems may need updating and/or replacement;
   ii. Evaluating the present emergency back-up generator for sufficient power generating capacity and longevity of the gen-set;
   iii. Investigating and determine alternative means for cooling the generator;
   iv. Evaluating and suggest improvements to the present switchgear system;
   v. Evaluating all large motors and drive systems for replacement with premium efficient motors or addition of VFD's to save electrical costs; and
   vi. Investigating energy credits under the United States Green Building (USGB) Leadership in Energy and Environmental Design (LEED)

3. Heating Ventilation & Air Conditioning (HVAC)

Most of the HVAC system in the plant is over twenty three (23) years old. The newer sections of the plant are now using small ceiling mounted heating units, which are much easier to control and maintain.

All hydronic units should be replaced and new control systems installed due to age. The air conditioning (AC) system is an air to water system and has been very problematic over the years. An entirely new AC system should be installed based on an air to air system. In some areas of the plant dust particles are a nuisance and methods of removal should be investigated.

1. The Engineering firm shall investigate the (HVAC) systems of the facility
   - i. Evaluate the present HVAC system for replacement and/or upgrade;
   - ii. Determine type and method of air conditioning the facility;
   - iii. The chemical room should be considered for a large dehumidifier;
   - iv. Investigate USGB/LEED energy credits; and
   - v. Suggest methods to remove particulates in dusty areas.

4. Large Water Pumps

During the plant expansion in 2000, four (4) new water pumps were installed. These were two (2) raw water horizontal water pumps (3.5 MGD) and two (2) finished water vertical turbine pumps (3.5 MGD). The remaining pumps (two (2) horizontal & two (2) vertical turbines) are all older, set speed pumps from the original installation of 1988. All four (4) pumps are beyond their service life and should be replaced.

1. The engineering firm shall investigate and evaluate the present water pumping system of the facility
   - i. Evaluate for longevity and suggest a schedule for replacement or upgrades;
   - ii. Evaluate various pump sizes to best serve the needs of the water system (winter flows vs. summer flows);
   - iii. Evaluate the issue of hydraulic noise in the raw water pumps;
   - iv. Evaluate the water pumps for use with VFD's in order to save in electrical costs; and
   - v. Investigate USGB/LEED energy credits.

5. Supervisory Control and Data Acquisition (SCADA)

Recently a concerted effort was made to upgrade the SCADA system. The present system employs Eurotherm/Chessel video recorders and an Allen Bradley PLC. A new chemical feed pacing system was also recently installed. While relatively new, the system should be reviewed for improvements and upgrades.

1. The engineering firm shall evaluate and investigate the SCADA system currently in use in the water system
    i. Evaluate for longevity and suggest a schedule for improvements and/or replacement;
    ii. Evaluate the report generation system and suggest improvements and/or replacement; and
    iii. Evaluate the possibility of converting to digital language for the field instrumentation.

6. Laboratory

The laboratory has been in constant use since 1988. As a result, the cabinetry and furniture has become either worn out or rusted from constant use. The flow pattern for the laboratory is inefficient and a new design should be investigated. The entire laboratory should be considered for upgrade and replacement. In addition, an area in the laboratory should be segregated for creating office/storage space for the Chemist.

1. The engineering firm shall evaluate and investigate the laboratory condition in respect to analytical equipment and physical condition
    i. Suggest a schedule for upgrading and or replacing the physical facility;
    ii. Suggest a method for improving the use of the existing space;
    iii. Evaluate and suggest improvements and or upgrades for the analytical equipment; and
    iv. Investigate and evaluate the possibility of installing office space within the laboratory.

7. Piping, basins, storage tanks, valves, other appurtenances.

Some parts of the unit processes shall require an upgrade due to age. Some concrete has started to crumble and flake; certain valves may require replacement or rejuvenation to insure good working order.

1. The engineering firm shall investigate and evaluate the physical treatment structures
    i. Evaluate for longevity and suggest a schedule for improvements and/or replacement;
    ii. Evaluate concrete surfaces for cracking and/or crumbling and suggest methods for improvements and or replacement;

iii. Evaluate all piping and valves for proper working order and physical condition, suggest upgrades and or replacement; and
iv. Investigate the addition of an equalization tank for recycled water to trap Granulated Activated Carbon (GAC) and grit and improve consistent recycled water flows.

8. Physical Plant

The physical plant shall include the building structure which has three sections, which were built in 1988 (main building & intake structure), 2000 (expansion) and 2004 (sludge drying facility). Each section should be investigated for upgrades and /or replacement to correct past problems and to address wear and tear items.

1. The engineering firm shall evaluate all parts of the physical plant
    i. Evaluate the condition of all roofs and suggest upgrades and/or replacement;
    ii. Evaluate interior floors for reconditioning and/or replacement;
    iii. Evaluate and suggest a schedule for reconditioning all interior walls with an appropriate surface for the conditions encountered;
    iv. Evaluate and suggest a schedule for reconditioning the external walls and precast of the building exterior;
    v. Evaluate and investigate caulking lines for replacement;
    vi. Evaluate and determine what and if door replacement may be required; and
    vii. Evaluate and investigate property drainage, suggest methods to eliminate and/or mitigate surface water drainage.

9. Future Water Demands

The engineering firm shall perform an analysis of the Towns water capacity demand in order to predict future needs such as new storage tanks and/or expanded pumping/treatment capacity.

1. The analysis shall be evaluated by
    i. Using historical records of flow;
    ii. Population figures and/or predictions;
    iii. Required changes in the rules and regulations; and
    iv. Information from the Town Planner.
2. The report shall be a simple explanation of the preparation process and how the predictions were made and shall include:
    i. Required updates to unit processes;
    ii. Required expansion of the plant capacity; and
    iii. Hydraulic improvements to the plant's intake.