


**COHASSET,
MASSACHUSETTS**

DISINFECTION
BYPRODUCT
COMPLIANCE
EVALUATION

MARCH 2004



Weston & Sampson
ENGINEERS, INC.

Report

Weston & Sampson Engineers, Inc.
Five Centennial Drive
Peabody, MA 01960-7985
www.westonandsampson.com
Tel: 978-532-1900 Fax: 978-977-0100

**Cohasset, Massachusetts
WSE Job No. 203151.A**

March 5, 2004

Mr. John McNabb
Chairman
Board of Water Commissioners
339 King Street
Cohasset, Massachusetts 02025

Re: Final Report

Dear Mr. McNabb:

We are pleased to submit the attached Disinfection Byproduct Compliance Evaluation report. We want to thank the members of the Board of Water Commissioners and the operating staff of American Water Services, Inc. for their assistance in providing data for the report, and reviewing and commenting on the draft report. Alison Perry, P.E. was the project engineer for the project.

Very truly yours,

WESTON & SAMPSON ENGINEERS, INC.

Barbara K. Cook, P.E.
Associate

Attachment

G:\WATER\COHASSET\203151 DBPREPORT\FINAL_COVERLTR.DOC

TABLE OF CONTENTS

TABLE OF CONTENTS.....	i
LIST OF TABLES.....	iii
LIST OF FIGURES.....	iii
EXECUTIVE SUMMARY.....	iv
1.0 BACKGROUND.....	1-1
1.1 General.....	1-1
2.0 REGULATIONS.....	2-1
2.1 Introduction.....	2-1
2.2 Stage 1 D/DBPR.....	2-3
2.3 Proposed Stage 2 D/DBPR.....	2-5
2.3.1 Initial Distribution System Evaluations (IDSE).....	2-6
2.3.2 IDSE – Standard Monitoring Program (SMP).....	2-6
2.3.3 Minimum Requirements for an SMP IDSE Report.....	2-9
2.3.4 IDSE System-Specific Study (SSS).....	2-9
2.3.5 Methods to Conduct an SSS.....	2-9
2.4 Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR).....	2-10
2.5 Proposed Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) ...	2-12
3.0 SUMMARY OF COHASSET’S DBP’S.....	3-1
3.1 Total Trihalomethanes (TTHMs).....	3-1
3.2 Haloacetic Acids (HAA5s).....	3-4
3.3 Total Organic Carbon (TOC).....	3-5
4.0 TREATMENT OPTIONS.....	4-1
4.1 General.....	4-1
4.2 Relocation of the Pre-Chlorination Injection Point.....	4-1
4.3 Groundwater Supply.....	4-3
4.4 Source Water Quality.....	4-3
4.5 Enhanced Coagulation.....	4-4
4.6 Powdered Activated Carbon.....	4-6
4.7 Filter Media Replacement.....	4-6
4.8 Clearwell Modification/Expansion.....	4-7
4.9 Disinfectants and Oxidants.....	4-9
4.9.1 General.....	4-9
4.9.2 Chlorine.....	4-9
4.9.3 Chloramine.....	4-11
4.9.4 Potassium Permanganate.....	4-12
4.9.5 Ozone.....	4-12
4.9.6 Chlorine Dioxide.....	4-14

4.9.7	Mixed Oxidants	4-14
5.0	RECOMMENDATIONS AND ESTIMATED COSTS.....	5-1
5.1	General	5-1
5.2	Phase 1.....	5-1
5.2.1	General	5-1
5.2.2	Enhanced Coagulation/Polyaluminum Chloride	5-2
5.2.3	Filter Media Replacement	5-2
5.2.4	Clearwell Modification.....	5-3
5.2.5	Potassium Permanganate	5-3
5.3	Phase 2.....	5-3
5.3.1	Chloramines.....	5-4
5.3.2	Ozone.....	5-4
5.3.3	Chlorine Dioxide	5-4
5.3.4	Mixed Oxidant Process	5-5
5.4	Cost Summary	5-5

LIST OF TABLES

TABLE 2-1:	SUMMARY OF STAGE 1 D/DBPR REQUIREMENTS.....	2-4
TABLE 2-2:	REQUIRED PERCENT REMOVAL OF TOC	2-4
TABLE 2-3:	SUMMARY OF SMP SAMPLE SITE REQUIREMENTS	2-7
TABLE 2-4:	SMP SAMPLING REQUIREMENTS	2-8
TABLE 2-5:	SUMMARY OF LT1ESWTR REQUIREMENTS	2-10
TABLE 2-6:	BIN CLASSIFICATION SUMMARY	2-13
TABLE 2-7:	POTENTIAL TREATMENT OPTIONS UNDER LT2ESWTR	2-14
TABLE 3-1:	BATES LANE TTHM SUMMARY	3-1
TABLE 3-2:	TTHM SUMMARY	3-2
TABLE 3-3:	BATES LANE HAA5 SUMMARY	3-4
TABLE 3-4:	RAW WATER TOC SUMMARY	3-5
TABLE 3-5:	TOC SUMMARY.....	3-5
TABLE 3-6:	SUVA SUMMARY	3-6
TABLE 4-1:	IMPACT OF MOVING THE POINT OF CHLORINATION ON DBP FORMATION	4-2
TABLE 4-2:	CT CALCULATIONS FOR A PH OF 6.5, 0.5 LOG INACTIVATION	4-8
TABLE 4-3:	ADVANTAGES AND DISADVANTAGES OF DISINFECTANTS AND OXIDANTS	4-10
TABLE 5-1:	SUMMARY OF ESTIMATED COSTS.....	5-6

LIST OF FIGURES

FIGURE 3-1:	HISTORICAL TRIHALOMETHANE RESULTS.....	3-3
-------------	--	-----

EXECUTIVE SUMMARY

Weston & Sampson Engineers, Inc. (WSE) was hired by the Town of Cohasset to evaluate disinfection byproducts. The evaluation included a review of current and future drinking water regulations including the Stage 1 and 2 Disinfectants/Disinfection Byproduct Rules, the Long Term 1 Enhanced Surface Water Treatment Rule and the Long Term 2 Enhanced Surface Water Treatment Rule. A regulatory compliance determination was made based on available water quality data and recommended improvements were developed to reduce total organic carbon (TOC) and disinfectant byproducts to meet current and future regulatory requirements.

The following tables summarize the major aspects of the aforementioned drinking water regulations and compliance dates for the Town of Cohasset. The contaminants summarized in these tables are those that are applicable to the Town of Cohasset at this point in time. A full summary of these rules is included in Chapter 2.0 of this report. Any items that Cohasset are not in compliance with or are close to the regulatory limit that could be determined at the time of this report are listed in the tables in *bold italicized* text.

MAJOR REQUIREMENTS FOR COHASSET STAGE 1 DISINFECTANTS/DISINFECTION BYPRODUCT RULE (D/DBPR)

Contaminant	Regulatory Limit	Monitoring Frequency	Compliance	Compliance Date
Maximum Contaminant Levels				
<i>Total Trihalomethanes (TTHM)</i>	<i>80 µg/L</i>	<i>1 sample per WTP per quarter</i>	<i>RAA</i>	<i>January 2004</i>
<i>Five Haloacetic Acids (HAA5)</i>	<i>60 µg/L</i>			
Maximum Residual Disinfectant Levels				
Chlorine	4 mg/L	Same as TCR	RAA	January 2004
DBP Precursors	35-50% TOC Removal	Monthly for TOC and Alkalinity	RAA	

RAA – Running Annual Average

**MAJOR REQUIREMENTS FOR COHASSET
STAGE 2 DISINFECTANTS/DISINFECTION BYPRODUCT RULE (D/DBPR)**

Contaminant	Regulatory Limit	Monitoring Frequency	Compliance Date ¹
Stage 2A			
TTHM	120 µg/L	LRAA	January 2008
HAA5	100 µg/L		
Stage 2B			
TTHM	80 µg/L	LRAA	<ul style="list-style-type: none"> • January 2011 (if water is sold to Hingham) • June 2012 (if no <i>Cryptosporidium</i> sampling required) • June 2013 (if <i>Cryptosporidium</i> sampling is required)
HAA5	60 µg/l		
Recommended Standard Monitoring Program (SMP) Start Date		<ul style="list-style-type: none"> • June 2005 (if water is sold to Hingham) • June 2007 (if water is not sold to Hingham) 	
Submit Initial Distribution System Evaluation (IDSE) Report		<ul style="list-style-type: none"> • January 2007 (if water is sold to Hingham) • January 2009 (if water is not sold to Hingham) 	

LRAA – Locational Running Annual Average

¹Compliance dates are based on January 2005 promulgation

**MAJOR REQUIREMENTS FOR COHASSET
LONG TERM 1 ENHANCED SURFACE WATER TREATMENT RULE (LT1ESWTR)**

Contaminant	Regulatory Limit	Monitoring Frequency	Compliance Date
<i>Cryptosporidium</i>	0 oocysts/L MCLG	N/A	January 2005
	99% removal (2-log)		
Turbidity Combined Filter Effluent	≤0.3 NTU in at least 95% of monthly samples; Maximum of 1 NTU	Samples collected every 4 hours	
Turbidity Individual Filter Effluent	<0.5NTU for the first four hours or a filter profile is required	Samples collected every 15 minutes	
	<1 NTU in 3 months; or a self-assessment of the filter is required	Samples collected every 15 minutes	
Disinfection Profiling TTHM HAA5	64 µg/L TTHM	Running Annual Average	Start: July 2003 Finish: June 2004
	48 µg/L HAA5		
Conduct Sanitary Survey every three years			January 2005

**MAJOR REQUIREMENTS FOR COHASSET
LONG TERM 2 ENHANCED SURFACE WATER TREATMENT RULE (LT2ESWTR)**

Contaminant	Regulatory Limit	Compliance Criteria	Compliance Date ¹
<i>E. Coli</i>	10 <i>E. Coli</i> /100 mL for lake/reservoirs 50 <i>E. Coli</i> /100 mL for flowing streams	Annual mean concentration; if limit is exceeded, <i>Cryptosporidium</i> sampling is required.	Compliance dates are summarized below
<i>Cryptosporidium</i> (required if <i>E. Coli</i> exceeded)	Bin 1: <0.075 <i>Crypto</i> oocysts/L	No treatment required	Compliance dates are summarized below
	Bin 2: 0.075 < <i>Crypto</i> <1.0 oocysts/L	1 log removal	
	Bin 3: 1.0 < <i>Crypto</i> <3.0 oocysts/L	2 log removal	
	Bin 4: <i>Crypto</i> >3.0 oocysts/L	2.5 log removal	
<i>E. Coli</i> Sampling			
Sampling schedule submittal for <i>E. coli</i> monitoring			April 2007
Start 12-month sampling of <i>E.coli</i> .			June 2007
Begin disinfection profiling (if not already required under LT1ESWTR)			June 2008
Disinfection profile completed and on file			June 2009
<i>Cryptosporidium</i> Sampling (sampling required if <i>E.coli</i> trigger is exceeded)			
If <i>E.coli</i> trigger exceeded, sampling schedule submittal for <i>Cryptosporidium</i> monitoring.			September 2008
Start 12-month sampling for <i>Cryptosporidium</i> .			January 2009
Begin disinfection profiling (if not already required under LT1ESWTR).			June 2009
Submit initial Bin classification			June 2010
Disinfection profile completed and on file			June 2013
Install treatment technique			June 2013

¹Compliance dates are based on January 2005 promulgation

SUMMARY OF THE RECOMMENDED IMPROVEMENTS

The capital and operations and maintenance cost for each recommended improvement is summarized below. The improvements are summarized into two phases. Not all improvements are required to reduce DBPs to below 80 percent of regulatory limits. The estimated costs for each improvement includes construction costs, engineering costs and contingencies. These costs were updated to an Engineering News Record (ENR) Boston index 7976 for December 2003. Other sources include the 1998 Means “Building Construction Cost Data” and manufacturers’ quotations.

These costs are preliminary and will need to be further evaluated and /or pilot tested prior to the implementation of an improvement. *As previously mentioned, it may not be necessary to institute all the recommended improvements to achieve compliance with the DBP rules.*

SUMMARY OF ESTIMATED COSTS

Phase	Improvement	Estimated Construction Costs	Estimated O&M Costs	20-year Present Worth Cost
Phase 1				
A	Enhanced Coagulation or use of Polyaluminum Chloride	NA	\$11,000	\$310,000
	Construction of baffles in the clearwell.	\$85,000	NA	\$85,000
B	Reactivate potassium permanganate chemical feed system.	\$0	\$39,000	\$1,101,000
C	Source water quality improvements	Costs being developed or included in other reports		
	Re-activation of the groundwater sources	Costs already incurred		
D	Install granular activated carbon in existing filter beds OR	\$230,000	NA	\$1,073,000 ¹
	Replacement of the filter media	\$151,000	NA	\$353,000 ¹
Phase 2				
A	Convert final disinfection from chlorine to chloramines	\$196,000	\$8,000	\$422,000
B	Convert pre-chlorination to ozone OR	\$1,500,000	\$17,000	\$1,980,000
	Convert pre-chlorination to chlorine dioxide OR	\$196,000	\$41,000	\$1,353,000
	Convert pre-chlorination to a mixed oxidant system	\$412,000	\$5,000	\$553,000

¹Assumes GAC filter media replacement is required every 4 years and sand/anthracite filter media replacement is required every 10 years.

1.0 BACKGROUND

1.1 General

The town of Cohasset water system delivers an average flow rate of about 0.75 million gallons per day (MGD) of potable water to its estimated 7,100 customers. Surface water is drawn from Lily Pond and Aaron River and is treated by the Lily Pond water treatment plant (WTP) prior to distribution. Additional water sources for the Town of Cohasset include the Elms Meadow and Sohier well fields. These groundwater sources have been inactive since or before 1979 when the Lily Pond WTP went on-line. The wellfields are currently being rehabilitated. Water from these groundwater sources does not require filtration and upon activation, will pump directly into the distribution system.

The Lily Pond WTP is a conventional surface water treatment plant which operates eight to twelve hours per day, seven days per week on average. The treatment process sequence consists of four unit operations: coagulation, flocculation, sedimentation and filtration. The WTP utilizes aluminum sulfate (alum) as a primary coagulant, polymer as a filtration aid, chlorine gas for chlorination and disinfection, lime for corrosion control and sodium fluoride as a source of fluoride to prevent tooth decay. As with most surface water supplies, the raw water quality fluctuates with the seasons. During the summer months, June through August, the raw water quality has higher levels of turbidity and color. To compensate for these water quality changes, Cohasset adjusts the alum dosage from 40 parts per million (ppm) to 50 ppm when higher levels of turbidity and color are detected in the raw water.

The Town of Cohasset's water system consists of the Lily Pond WTP, the Lily Pond and Aaron River reservoirs, over 40 miles of 6- to 14-inch piping, two inactive well fields and two water storage tanks. The two water storage tanks, the Bear Hill and Scituate Hill tanks, set the hydraulic gradeline for the single pressure zone distribution system. Both tanks are typically operated with a 10-foot fluctuation in water level within each tank.

G:\WATER\COHASSET\203151 DBP\REPORT\REPORT_FINAL.DOC

2.0 REGULATIONS

2.1 Introduction

Chlorination has made public water supplies safe from illness-producing bacteria, viruses, and parasites and has almost completely eliminated the risk of waterborne diseases such as typhoid fever, cholera, and dysentery. However, using chlorine as a disinfectant introduces its own health risks because of the by-products produced during the disinfection process.

Disinfection byproducts (DBPs) from chlorine disinfection form when chlorine reacts with naturally occurring organic matter (NOM) and naturally occurring inorganic compounds in water. It has been found that the resulting DBPs pose significant health threats to humans when consumed over long periods of time. DBPs are currently summarized into two groups: total trihalomethanes (TTHMs) and haloacetic acids (HAA5s). TTHMs are a group of chemicals consisting of chloroform, bromodichloromethane, dibromodichloromethane, and bromoform. HAA5s are a group of haloacetic acids including monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid

TTHMs and HAA5s have been associated with an increased risk of cancer and liver, kidney, and central nervous system problems. Epidemiological studies strongly suggest that DBPs are likely to be reproductive toxins under appropriate exposure conditions and can cause such reproductive health effects as miscarriage, stillbirth, birth defects, and low birth weight. This is further supported by toxicology studies that show that, in addition to adverse reproductive effects, DBPs may also be hazardous to developmental health.

In 1983, the Environmental Protection Agency (EPA) identified the best technologies and treatment techniques that would enable public water systems to comply with the regulated levels of DBPs. These include

- Moving the point of chlorination downstream in the water treatment plant
- Optimizing the coagulation process to enhance the removal of DBP precursors (also referred to as enhanced coagulation)

- The use of chloramines to supplement or replace the use of free chlorine as a post-disinfectant, and
- The replacement of pre-chlorination by pre-oxidation with an alternate disinfectant that produces less DBPs.

Each of these available technologies, as they apply to Cohasset, will be further discussed later in this report.

To address DBPs, EPA promulgated the Stage 1 Disinfectants/Disinfection Byproducts Rule (D/DBPR) to minimize the health concerns associated with disinfection byproducts (DBPs). The D/DBPR specifically targets TTHM and HAA5 levels because of their known health effects and further limits the amount of allowable byproducts created when drinking water is disinfected. The Stage 2 D/DBPR, which was proposed on August 18, 2003, will further reduce DBPs.

Additional regulations that will effect the Town of Cohasset include the Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) and the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). The LT2ESWTR was proposed on August 11, 2003. These rules aim to improve the control of microbial pathogens, specifically the protozoan *Cryptosporidium* in drinking water by requiring water systems to meet strengthened filtration requirements. These rules also require systems to calculate levels of microbial inactivation to ensure that microbial protection is not jeopardized by systems making changes to comply with requirements of the Stage 1 D/DBPR.

The Stage 2 D/DBPR and the LT2ESWTR are being promulgated at the same time to try to address some technological conflicts that may arise when a water system is trying to comply with both rules at the same time. The conflict arises in that the D/DBPR decreases disinfectant levels to minimize the formation of DBP and the LT2ESWTR increases protection against microbial contaminants. The requirements of the Stage 1 D/DBPR, Stage 2 D/DBPR, LT1ESWTR and LT2ESWTR are summarized below.

In December 1998, the Environmental Protection Agency (EPA) promulgated the Stage 1 D/DBPR to minimize the health concerns associated with DBPs. This rule further limits the amount of allowable byproducts created when drinking water is disinfected. The Stage 2 D/DBPR was proposed on August 18, 2003; a final rule is expected in early 2005.

2.2 Stage 1 D/DBPR

The Stage 1 D/DBPR lowers the previous TTHM maximum contaminant level (MCL) allowed for a drinking water supply from 100 micrograms per liter ($\mu\text{g/L}$) to 80 $\mu\text{g/L}$ and establishes a new DBP level for HAA5 with a MCL of 60 $\mu\text{g/L}$. Compliance for both TTHM and HAA5 is determined by a running annual average (RAA) of samples taken quarterly.

Under the Stage 1 D/DBPR for the Cohasset water system, one sample is required per water treatment plant per quarter. The sample location should represent the maximum residence time of water within the distribution system. If a water system elects to sample more frequently than the minimum required, at least 25 percent of all samples collected each quarter (including those taken in excess of the required frequency) must be taken at locations that represent the maximum residence time of the water in the distribution system. The remaining samples must be taken at locations representative of at least average residence time in the distribution system.

The rule also establishes DBP maximum contaminant level goals (MCLG) and maximum residual disinfection levels (MRDLS). The new regulatory limits, compliance dates, and monitoring requirements for the Stage 1 rule are listed below in Table 2-1. Small water systems (serving <10,000 population), such as Cohasset, must comply with the Stage 1 rule by January 1, 2004.

Naturally occurring organic matter (NOM) is considered to be the precursor to the formation of DBPs. Total organic carbon (TOC) has been determined to be a good indicator for NOM in water. As a result, the Stage 1 D/DBPR has also established a minimum total organic carbon (TOC) removal treatment technique for surface water systems that use conventional filtration.

TABLE 2-1
SUMMARY OF STAGE 1 D/DBPR REQUIREMENTS
FOR SURFACE WATER SUPPLIES SERVING <10,000

Substance	MCL	MCLG	Compliance	Sampling Frequency
Regulated Contaminants				
TTHM	80 µg/L	N/A	Running Annual Average	One sample per quarter
HAA5	60 µg/L	N/A		
Chlorite	1 mg/L	0.8 mg/L	Daily (At Chlorine Dioxide Plants)	Daily at WTP; Monthly in system
Bromate	10 µg/L	0 µg/L	Running Annual Average (At Ozone Plants)	Monthly
Chloroform	N/A	0 µg/L	Running Annual Average	One sample per quarter
Dibromochloromethane	N/A	60 µg/L		
Bromodichloromethane	N/A	0 µg/L		
Bromoform	N/A	0 µg/L		
Dichloroacetic Acid	N/A	0 µg/L		
Trichloroacetic Acid	N/A	0 µg/L		
Regulated Disinfectant Residuals				
Chlorine Dioxide (as ClO ₂)	0.8 mg/L	0.8 mg/L	Daily (At Chlorine Dioxide Plants)	Daily at WTP; Monthly in system
Chloramines (as Cl ₂)	4 mg/L	4 mg/L	Running Annual Average	Same location and frequency as TCR sampling
Chlorine (as Cl ₂)	4 mg/L	4 mg/L		

The specific percentage of TOC removal required is dependent on the source water TOC and alkalinity levels, as are summarized in Table 2-2. Compliance is based on the RAA of monthly raw water alkalinity and percent removals. The required percent removal can change per quarter based on raw water alkalinity and TOC concentration. The percent TOC removal is measured between the raw water sampling point and the combined filter effluent turbidity monitoring location.

TABLE 2-2
REQUIRED PERCENT REMOVAL OF TOC

Source Water TOC (mg/L)	Source Water Alkalinity (mg/L as CaCO ₃)		
	0-60	> 60-120	>120
> 2 to 4	35%	25%	15%
> 4 to 8	45%	35%	25%
> 8	50%	40%	30%

As an alternative to sampling for TOC, a water system can also monitor for specific ultraviolet absorption (SUVA). SUVA is the ratio of ultraviolet (UV) absorption at a wavelength of 254 nanometers (nm) to the dissolved organic carbon (DOC) content of the water. SUVA is an indicator of the humic content of water. Waters with low SUVA values contain primarily non-humic organic matter and are not amenable to removal by enhanced coagulation. Waters with high SUVA values are generally amenable to removal of TOC by enhanced coagulation. Enhanced coagulation is a treatment technique designed to optimize the coagulant dose to increase the removal of TOC by conventional treatment.

Alternative compliance criteria have also been developed to allow WTPs flexibility for establishing compliance with the TOC removal requirements. The alternative criteria were developed to address the difference in source waters and the fact that certain waters are less amenable to effective removal of TOC by coagulation. A WTP can therefore establish compliance with the coagulation TOC removal if any one of the following alternative compliance criteria is met. These criteria are met if the required concentration is met and the calculated quarterly RAA. These criteria can also be used on a monthly basis (i.e. for individual months in which the criteria is met).

- Source water TOC < 2.0 mg/L
- Treated water TOC < 2.0 mg/L
- Raw water SUVA \leq 2.0 L/mg-m
- Treated water SUVA \leq 2.0 L/mg-m
- Raw water TOC < 4.0 mg/L, Raw water alkalinity > 60 mg/L as CaCO₃, TTHM < 40 μ g/L and HAA5 < 30 μ g/L
- TTHM < 40 μ g/L and HAA5 < 30 μ g/L with chlorine as the only disinfectant

2.3 Proposed Stage 2 D/DBPR

The Stage 2 Rule proposes a two-phased approach for DBPs. Stage 2A requires that all water supply systems meet “locational” running annual averages (LRAA) of 120 μ g/L and 100 μ g/L for TTHM and HAA5, respectively, within three (3) years of the rule promulgation. Rule promulgation is expected to occur in early 2005 making compliance required in early 2008. In addition, water systems must continue to maintain Stage 1 D/DBPR RAA of 80 μ g/L and 60 μ g/L for TTHM and HAA5, respectively.

Stage 2B further lowers the LRAA to 80 µg/L and 60 µg/L for TTHM and HAA5, respectively. Small systems must comply within 7.5 years after rule promulgation. Rule promulgation is expected to occur in early 2005 making compliance required in mid-2012. Stage 2 also requires that water system suppliers conduct Initial Distribution System Evaluations (IDSEs) to select new Stage 1 compliance monitoring locations that more accurately represent peak disinfection byproduct concentrations in the distribution system.

2.3.1 Initial Distribution System Evaluations (IDSE)

IDSE requirements apply to all surface water and groundwater systems that use a primary disinfectant other than UV, or that add a residual to their water. Any system whose historical individual TTHM/HAA5 Stage 1 D/DBPR compliance data are $\leq 40/30$ µg/L for TTHM/HAA5 respectively for a specified period may be exempt from performing an IDSE.

An IDSE can be conducted by a Standard Monitoring Program (SMP) or by a System-Specific Study (SSS). Under an SMP, a supplier's distribution system is monitored for one year, collecting sampling data from select sites. The SSS does not require sampling, but relies on historical data and system modeling to obtain representative system data.

2.3.2 IDSE – Standard Monitoring Program (SMP)

The SMP is a one-year monitoring program designed to generate data that is subsequently used to select Stage 2B D/DBPR compliance monitoring sites. These new monitoring sites should better capture representative high TTHM and HAA5 concentrations. Each water supplier's program will be based on a schedule and plan determined by system size, source water type, number of plants, and disinfection method (chlorine or chloramine).

Because so many system factors influence the formation of TTHMs and HAA5s, the locations of the TTHM and HAA5 sites are system-specific. All high TTHM and HAA5 SMP sampling results should represent the maximum DBP concentrations in the finished water that is ***delivered to customers***.

High TTHM sites are typically characterized by long residence times, low or no disinfectant residual, high heterotrophic plate count or positive coliform, areas with historical data showing high TTHM levels, and are located in remote areas with few customers and after storage facilities. Large, dead-end water mains with only a few customers, especially if they are located in remote areas of the distribution system, are likely to have high TTHM concentrations. Dead-end mains with no service, however, should not be used for a sampling site because a customer never consumes this water. Although there is limited data for HAA5s, high HAA5 sites are typically characterized by varying residence times and a low, but positive, disinfectant residual.

An IDSE for systems serving <10,000 people requires two types of quarterly sampling locations (Note that the SMP sampling locations are *in addition to* Stage 1 D/DBPR compliance monitoring sites). Table 2-3 summarizes the number and type of sample sites required for a small system. Large systems (serving >10,000 people) are required to sample at the same sites as small systems as well as at the entry point to the distribution system and at locations with the system that are representative of average residence times.

TABLE 2-3
SUMMARY OF SMP SAMPLE SITE REQUIREMENTS

System Characteristics	SMP Sample Sites per Plant		
Surface Water Systems (<10,000)	High TTHM	High HAA5	Total Sites
	1	1	2

It is important to note that the samples taken at each site are “dual samples”, meaning two samples must be collected at the same time at each site. One sample is analyzed for TTHM and the other for HAA5. For this example, where Cohasset is required to collect samples from 2 sites per plant, a total of 4 samples (2 per site) will be required for each quarter.

The monitoring schedule is determined from historical DBP data and is system specific. The month with the highest TTHM/HAA5 level or maximum water temperature is referred to as the *controlling month*. At least one set of “dual” samples must be collected during the controlling month. The other rounds of sampling must be scheduled at three month intervals based on the date selected for sample collection in the controlling month. The sampling dates for the entire

year must be scheduled in advance. If the highest TTHM and HAA5 levels do not occur in the same month, the controlling month should be based on the month with the highest TTHM concentrations. If there is no historical DBP data, the controlling month shall be determined based on the month having the maximum annual water temperature.

Table 2-4 summarizes SMP sampling requirements for Cohasset for both small and large systems. The sampling requirements described herein do not consider special circumstances such as wholesaling water systems and systems with temporary sources (less than 90 days). If Cohasset were to sell water to Hingham, a large system (serving >10,000), Cohasset would need to meet the deadline requirements for a large system. Otherwise, the deadline for a small system would need to be met. For either case, the sampling frequency would not change. Water suppliers should refer to the proposed Stage 2 D/DBPR for complete explanations of all special conditions.

TABLE 2-4
SMP SAMPLING REQUIREMENTS

System Type (Population Served)	IDSE Report Due Date	Recommended SMP Sampling Start Date	Sampling Frequency	Sampling Control Month
Surface water systems ($\leq 10,000$)	4 years after final Stage 2 rule promulgation	2 years and 9 months after final Stage 2 rule promulgation	Every 90 days (3 months) for one year	1. Month with highest TTHM/HAA5 level OR 2. Month with maximum temperature
Surface water systems ($> 10,000$)	2 years after final Stage 2 rule promulgation	9 months after final Stage 2 rule promulgation	Every 90 days (3 months) for one year	1. Month with highest TTHM/HAA5 level OR 2. Month with maximum temperature

The success of an SMP, and ultimately an IDSE, depends upon the selection of accurate, representative sample sites. Many water suppliers possess various types of information helpful in identifying preliminary SMP sites. The following list contains several data sources and tools for identifying preliminary SMP sites:

- Maps
- Distribution system water quality data
- Simulated distribution system laboratory tests
- Distribution system hydraulic model
- Tracer studies
- System operating data
- Geographic Information System (GIS)

2.3.3 Minimum Requirements for an SMP IDSE Report

Once an SMP is completed, systems must report the results, along with recommended Stage 2 D/DBPR sampling sites, within the appropriate timeframe. At a minimum, reports must contain the following items:

- Original SMP monitoring plan and an explanation of any deviations from that plan.
- All SMP TTHM and HAA5 analytical results.
- All TTHM and HAA5 analytical results from Stage 1 D/DBPR compliance monitoring collected during the period of the IDSE.
- A schematic of the system's distribution system with results, locations, and dates of all IDSE SMP. All compliance samples should be noted.
- Recommendations for locating Stage 2B compliance monitoring sites. The typical recommendation for monitoring sites is the two sites having the highest TTHM and HAA5 LRAAs from analytical results from the SMP monitoring plan.
- Justification for selection of Stage 2B compliance monitoring sites.

2.3.4 IDSE System-Specific Study (SSS)

An SSS allows systems with extensive data, previous pertinent studies, or detailed knowledge of their operations to use these resources to choose new monitoring sites, thus avoiding the expense of an SMP. However, the Stage 2 D/DBPR requires that an SSS provide *equivalent* or *superior selection* of new Stage 2 D/DBPR compliance monitoring sites targeting high DBP levels as compared to the sites selected from an SMP.

2.3.5 Methods to Conduct an SSS

Although historical monitoring data, new monitoring data, water distribution modeling, tracer study results, and other distribution system analyses can be used as part of an SSS, there are two “pre-defined” methods that are expected to provide equivalent or superior selection of compliance sites as compared to an SMP.

1. The use of historical DBP data that equals or exceeds the IDSE monitoring requirements.
2. The use of a calibrated water distribution system hydraulic model and one new round of sampling during the month of peak DBP levels (or peak water temperature if DBP data is not available).

Water suppliers should refer to the proposed Stage 2 D/DBPR for complete explanations of all requirements of these two methods.

2.4 Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR)

The Interim Enhanced Surface Water Treatment Rule (IESWTR) is an amendment to the SWTR and applies to surface water systems and systems having groundwater under the influence of surface water (GWUDI) that serve at least 10,000 people. The Long Term 1 Enhanced Surface Water Treatment Rule applies similar requirements to surface water systems that serve less than 10,000 people. The LT1ESWTR was designed to optimize treatment reliability and to enhance physical removal efficiencies to minimize *Cryptosporidium* levels in finished water. The rule also includes disinfection benchmark provisions to assure continued levels of microbial protection while facilities take the necessary steps to comply with new DBP standards. Table 2-5 summarizes the LT1ESWTR requirements for small systems.

**TABLE 2-5
SUMMARY OF LT1ESWTR REQUIREMENTS**

Contaminant	Regulatory Limit	Monitoring Frequency
<i>Cryptosporidium</i>	0 oocysts/L MCLG	N/A
	99% removal (2-log)	
Turbidity Combined Filter Effluent	≤0.3 NTU in at least 95% of monthly samples; Maximum of 1 NTU	Samples collected every 4 hours
Turbidity Individual Filter Effluent	<0.5 NTU for the first four hours of operation or a filter profile is required	Samples collected every 15 minutes
	<1 NTU in 3 months; or a self-assessment of the filter is required	Samples collected every 15 minutes
	<2 NTU in 2 months; or a comprehensive performance evaluation is required	Samples collected every 15 minutes

The LT1ESWTR also requires that disinfection profiling be conducted by any system whose TTHM or HAA5 RAA are greater than or equal to 80 percent of the MCLs. The 80 percent thresholds are 64 µg/L and 48 µg/L for TTHMs and HAA5s, respectively. Disinfection profiling

is designed to evaluate impacts on microbial risk before a significant change in disinfection practices is made to ensure that adequate microbial protection is maintained. Given the historical TTHM and HAA5 RAAs for Cohasset, disinfection profiling is required. Systems required to develop a disinfection profile must consult the state prior to making a significant change in their disinfection practices. Significant changes may include moving the point of disinfection application, changing the type of disinfectant used and changing the disinfection process (i.e. changing the contact basin geometry).

Disinfection profiling for *Giardia* inactivation (3-log removal) is required for all systems that exceed the 80 percent trigger TTHM and HAA5 concentrations, such as Cohasset. A disinfection profile is a graphical representation of a system's level of *Giardia* or virus inactivation measured during the course of a year. The EPA website (<http://www.epa.gov/ogwdw000/mdbp/lt1eswtr.html>) contains an excel spreadsheet that can be used to develop a disinfection profile. Disinfection profiling for virus inactivation (4-log removal) is *required* for any system that proposes to add or switch to ozone or chloramines; it is *recommended* for any system that proposes to add or switch to chlorine dioxide. The inactivation calculation is a function of the peak hourly flow, chlorine residual concentration, contact time, temperature and pH over each disinfection segment within the WTP. A disinfection segment is defined as the section of the treatment system beginning at one disinfectant injection or monitoring point and ending at the next disinfectant injection or monitoring point.

If there is less than one year of data available, the disinfection benchmark is calculated as the average of the monthly average inactivations. If there is one year of data available, the disinfection benchmark is the lowest monthly average of inactivation. The disinfection benchmark will be used as a monitor to assess microbial protection when significant disinfection modifications are made to the plant such that microbial protection is not compromised for lower DBPs.

The LT1ESWTR was promulgated in January 2002. By June 30, 2003, systems serving less than 10,000 people, such as Cohasset, must indicate that their system has started their disinfection

profiling. The disinfection profile must be completed by June 30, 2004. Compliance with the rule (i.e. turbidity standards, individual filter monitoring) is required by January 14, 2005. Under the rule, sanitary surveys must be conducted every three years by the state for all surface waters and GWUDI systems regardless of size.

2.5 Proposed Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)

The LT2ESWTR was proposed on August 11, 2003 and is expected to be finalized with the Stage 2 D/DBPR in early 2005. The intent of the rule is to provide additional public health protection, if needed, from *Cryptosporidium* and other pathogenic microorganisms in drinking water.

Under the LT2ESWTR, systems will initially conduct source water monitoring for *Cryptosporidium* to determine their treatment requirements. *Cryptosporidium* monitoring by large systems will begin six months after the LT2ESWTR is finalized and will last for a duration of two years. Small systems, such as Cohasset, are on a delayed schedule and will start monitoring when the large system monitoring period has been completed. To reduce monitoring costs, small filtered systems will initially be required to conduct one year of monitoring for *E. coli*. *Cryptosporidium* monitoring will be required of small systems only if their *E. Coli* results exceed specified trigger concentrations.

It has been proposed that the annual mean source water *E. coli* concentration of 10 and 50 per 100 ml are appropriate values to trigger the requirement for *Cryptosporidium* monitoring in lakes/reservoirs and flowing streams, respectively. Both *E. coli* and *Cryptosporidium* monitoring will include one sample collected twice a month over a one-year period. A second round of monitoring will be required six years after the initial bin classification. It is recommended that Cohasset begin to collect source water samples for *E. coli* twice a month such that the requirements of the LT2ESWTR will be known well in advance of the compliance dates.

The analytical results of the *Cryptosporidium* monitoring, if applicable, will classify systems into different categories or “bins”. Additional treatment will be required based on which bin a system

is assigned. For small systems (<10,000 population) bin classification will be based on the one year mean based on *Cryptosporidium* samples collected twice per month for 12 months. If *Cryptosporidium* monitoring is not required, a system is automatically placed into Bin 1 requiring no additional treatment. A system is exempt from monitoring for the purposes of the bin classification if they can provide 2.5 log treatment for *Cryptosporidium* in addition to conventional treatment requirements.

The bin classification will trigger the water supplier into meeting certain levels of *Cryptosporidium* treatment, ranging from no treatment for Bin 1 classification to 2.5 log removal/inactivation for a Bin 4 classification. The bins are defined below in Table 2-6.

**TABLE 2-6
BIN CLASSIFICATION SUMMARY**

Bin	<i>Cryptosporidium</i> Concentration	Required Additional Treatment
1	<i>Cryptosporidium</i> <0.075/L	No additional treatment requirement for a system using conventional treatment
2	$0.075/L \leq \textit{Cryptosporidium} < 1.0/L$	1-log treatment will be required.
3	$1.0/L \leq \textit{Cryptosporidium} < 3.0/L$	2-log treatment will be required.
4	<i>Cryptosporidium</i> $\geq 3.0/L$	2.5 log treatment will be required.

In preparation for the LT2ESWTR, the EPA has also conducted investigations to determine what bin classification systems would fall into. Based on their studies they estimate that most of the water systems will fall into a bin assignment of Bin 1 or Bin 2.

The rule employs a “microbial toolbox” approach where properly designed and implemented “tools” will receive a corresponding *Cryptosporidium* log credit reduction. Examples of “tools” include watershed controls, the development of alternative sources, the addition of pretreatment and the improvement of existing treatment and disinfection processes

The proposed LT2ESWTR presented various treatment options and the removal/inactivation for *Cryptosporidium* that each will receive. Table 2-7 lists potentially applicable treatment alternatives.

Compliance with the rule will be required three years after initial bin classification. A second round of monitoring will be required six years after the initial bin classification.

TABLE 2-7
POTENTIAL TREATMENT OPTIONS UNDER LT2ESWTR

Treatment Approach	Potential Log Credit
Watershed Control Program	0.5 log removal/inactivation credit
Combined Filter Performance	0.5 log removal/inactivation credit for combined filter effluent turbidity ≤ 0.15 NTU in 95% of samples each month at a monitoring frequency of every four hours.
Individual Filter Performance	1.0 log removal/inactivation credit for individual filter effluent turbidity ≤ 0.15 NTU in 95% of the samples each month and turbidity <0.30 NTU in two consecutive samples taken at 15 minute intervals.
Chlorine dioxide	Up to 1.0 removal/inactivation log credit based on demonstration of compliance with CT tables
Ozone	Up to 2.0 removal/inactivation log credit based on demonstration of compliance with CT tables
UV	Up to 2.5 log credit for <i>Cryptosporidium</i> , <i>Giardia</i> and viruses based on the delivered UV dose provide in relation to the UV dose tables.
Membrane Filtration	Up to 2.5 log credit for <i>Cryptosporidium</i> removal based on demonstration testing and daily membrane integrity testing during operation
Second Stage Filtration	0.5 log credit for <i>Cryptosporidium</i> removal for a second stage filtration stage (i.e. rapid sand, dual media, GAC or other fine grain media).

G:\WATER\COHASSET\203151 DBP\REPORT\REPORT_080603.DOC

3.0 SUMMARY OF COHASSET'S DBP'S

3.1 Total Trihalomethanes (TTHMs)

Based on recent data from February 2002 to the present, the RAA for the Bates Lane TTHMs sample site ranged from 55.0 to 80.0 µg/L indicating that Cohasset is barely in compliance with the new Stage 1 TTHM MCL of 80 µg/L. Table 3-1 summarizes the Bates Lane TTHM sample results from May 2000 to the present.

**TABLE 3-1
BATES LANE TTHM SUMMARY**

Date Sampled	TTHM (µg/L)	RAA (µg/L)
05/03/00	167.5	--
06/07/00	98.8	--
06/21/00	96.1	--
10/18/00	130.5	--
11/27/00	49.7	--
06/26/01	44.6	--
09/19/01	41.4	--
02/20/02	82.7	--
05/21/02	65.6	--
09/25/02	66.1	--
12/18/02	60.4	68.7
01/29/03	44.3	59.1
05/28/03	49.2	55.0
09/17/03	126.5	70.1
11/17/03	100.1	80.0
12/31/03 ¹	74.9	73.7

¹Assumed to be taken in the first quarter for calculation purposes

The Stage 1 D/DBPR requires that the sampling site be located at a point representing the maximum residence time in the distribution system. High TTHMs are typically characterized by long residence times within the distribution system. A hydraulic model of the distribution system was used to identify a sample location having a maximum distribution system residence time. Beginning in December 2003, the TTHM sample location was relocated from Bates Lane to Whitehead Road, at the eastern extent of the distribution system. Samples collected from this location had TTHM concentrations of 78.9 and 81.7 µg/L for samples collected on December 24,

2004 and December 31, 2004, respectively. Based on samples collected on December 31, 2004, the TTHM concentration at Whitehead Road was almost 13 percent higher than the concentration at Bates Lane.

Figure 3-1 and Table 3-2 summarizes historical TTHM sampling data collected from 1994 through 2003 throughout the distribution system. Based on the TTHM summary in Table 3-2, the RAA based on a “mock” quarterly average of all available data from each quarter is 88.5 µg/L, which is greater than the current regulatory level of 80 µg/L. By summarizing the data by quarter, the variation of TTHM concentrations between seasons can be evaluated.

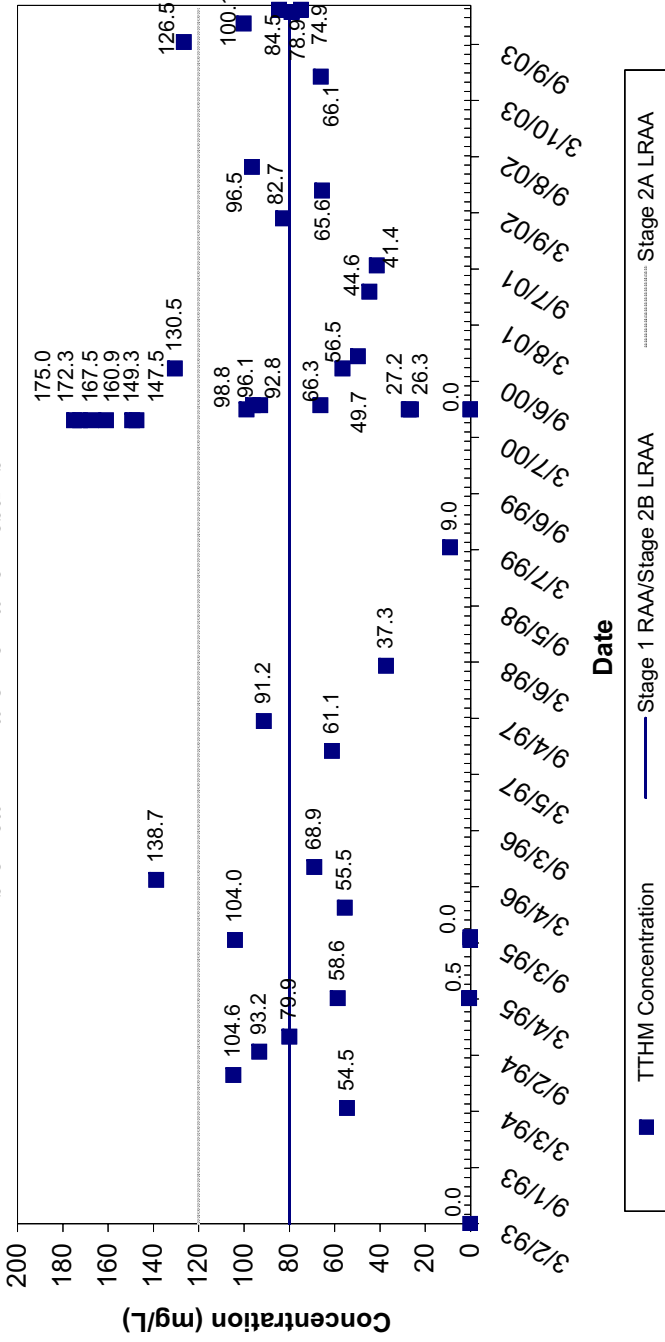
**TABLE 3-2
TTHM SUMMARY**

Quarter	TTHM Concentration (µg/L)				Number of Samples
	Minimum	Maximum	Average	Standard Deviation	
1	44.3	138.7	75.8	37.9	5
2	44.6	175.0	110.3	47.5	15
3	41.4	126.5	88.4	27.4	7
4	49.7	130.5	79.4	24.8	9

The town will need to refine their TOC removal and evaluate current disinfection practices to reduce DBP formation to ensure that the D/DBPR Stage 1 RAA and Stage 2 LRAA TTHM levels are met consistently. As a first step, the pre-chlorination injection point has been relocated from the rapid mix basins to post-sedimentation/pre-filtration.

Between September 1995 and October 2000, seven samples were collected from the WTP effluent and were analyzed for TTHM. TTHM concentrations leaving the plant ranged from non-detect to 66.3 µg/L with an average concentration of 31.8 µg/L TTHM. Because high TTHM sites are typically characterized by long residence times and low or no disinfectant residual, the TTHM concentration leaving the plant will increase as it moves to the extent of the distribution system. Measures should be taken to reduce the amount of DBPs formed within the WTP.

Figure 3-1
Historical Trihalomethane Results



3.2 Haloacetic Acids (HAA5s)

Based on data from September 2002 to the present for Bates Lane, the RAA for HAA5s ranged from 63.0 to 89.6 µg/L. The HAA5 MCL was exceeded in all RAAs calculated for the given timeframe. Between May 2001 and the present, ten samples have been collected from this sample location and analyzed for HAA5s. The results are summarized in Table 3-3. The RAA MCL was exceeded in the last three quarters indicating that treatment modifications are required to meet the requirements of the D/DBPR Stage 1 RAA and Stage 2 LRAA.

**TABLE 3-3
BATES LANE HAA5 SUMMARY**

Date Sampled	Total HAA5 (µg/L)	RAA (µg/L)
05/21/01	60.6	--
09/19/01	63.7	--
02/27/02	60.0	--
09/25/02	37.4	--
12/18/02	35.4	--
03/31/03	108.7	--
05/28/03	70.6	63.0
09/17/03	80.9	73.9
11/17/03	51.4	77.9
12/31/03 ¹	98.0	89.6

¹Assumed to be taken in first quarter for calculation purposes

Beginning in December 2003, the HAA5 sample location was moved from Bates Lane to Whitehead Road, at the eastern extent of the distribution system. Samples collected from this location had an HAA5 concentration of 1.3 µg/L and was not detected in the second sample for samples collected on December 31, 2004 and December 24, 2004, respectively. As has been previously mentioned, high HAA5 concentrations are typically characterized by average residence times within the distribution system. Based on the sampling results from the new sampling location, HAA5 concentrations are greatly reduced from what was previously seen at the Bates Lane sampling location. After the IDSE is completed under the Stage 2 D/DBPR, this sample location may need to be relocated.

3.3 Total Organic Carbon (TOC)

Average raw water alkalinity from samples collected from Lily Pond range from 5.5 to 5.9 mg/L as calcium carbonate, as was reported in ENSR’s Lily Pond Limnology and Water’s Edge Study, dated February 2003. Typical raw water TOC samples collected from the same study ranged from 5.0 to 12.0 mg/L at different locations in the Pond. The TOC sample results are summarized in Table 3-4. The higher TOC concentration in Brass Kettle Brook is attributed to its heavily vegetated wetland system.

**TABLE 3-4
RAW WATER TOC SUMMARY**

Sample Location	TOC Concentration (mg/L)
Shoreline near intake wingwall	5.0
Peppermint Brook	6.2
Along eastern shoreline	9.8
Brass Kettle Brook	12.0

Beginning in August 2003, monthly raw water and finished water samples were collected and analyzed for TOC to provide a preliminary evaluation of compliance with the Stage 1 D/DBPR. Table 3-5 summarizes the TOC analytical results. Based on the results, the WTP was in compliance with the required TOC removal percentage.

**TABLE 3-5
TOC SUMMARY**

Sample Date	TOC (mg/L)		Percent Removal	Percent Removal Required	Compliance Met?
	Raw Water	Finished Water			
8/14/2003	12.0	4.3	64.2	50	YES
9/17/2003	13.0	5.3	59.2	50	YES
10/14/2003	11.0	4.6	58.2	50	YES
11/17/2003	11.0	5.3	51.8	50	YES
12/28/2003	7.8	3.2	59.0	45	YES

On August 14, 2004, raw water and finished water samples were collected and were also analyzed for DOC and SUVA. Table 3-6 summarizes the analytical results. If compliance isn’t met under the TOC removal criteria, compliance can be met by the alternate SUVA compliance criteria where either the raw water or finished water SUVA is less than 2.0 L/mg-m. The alternate SUVA compliance criteria was not met for the raw water and finished water samples,

but because the TOC removal criteria was met, the WTP is in compliance. The finished water SUVA was 2.4 L/mg-m. It is possible that the finished water SUVA may be below 2.0 L/mg-m at other times of the year.

**TABLE 3-6
SUVA SUMMARY**

Sample Type	DOC (mg/L)	UV254 (cm-1)	SUVA (L/mg-m)
Raw Water	12	0.69	5.8
Finished Water	4.2	0.101	2.4

Based on the analytical results of the monthly samples collected between August and December 2003, it appears that the WTP will be in compliance with the Stage 1 D/DBPR. However, since compliance with TOC removals is based on a running annual average of monthly data, there is insufficient TOC and alkalinity data available to make a determination as to whether the WTP will be able to remove the required TOC the remainder of the year. Additional TOC, DOC and SUVA raw water and surface water samples will need to be collected before a final compliance determination can be made.

G:\WATER\COHASSET\203151 DBP\REPORT\REPORT_FINAL.DOC

4.0 TREATMENT OPTIONS

4.1 General

An initial review of best available technologies for removal of TTHMs and HAA5s for the Lily Pond WTP include relocation of the pre-chlorination injection point, enhanced coagulation, powdered activated carbon (PAC) addition, replacement of the filter media with sand/antracite or granular activated carbon (GAC), modifying the clearwell and changing/eliminating oxidants and disinfectants. In addition, the reactivation of the groundwater wellfields and the improvement of source water quality will also contribute to DBP reduction. These technologies are further discussed in the following sections of this chapter.

An additional available treatment technology is membrane filtration. The installation of membranes will result in significantly higher capital costs than previously mentioned technologies. For this reason, this technology was not considered as other more cost-effective technologies for TTHM/HAA5 removal are available.

Any modification to the treatment process will likely require a pilot study to document process reliability and performance to the Massachusetts Department of Environmental Protection (DEP). This requirement is triggered in part by the LT1ESWTR since the running annual average of TTHMs or HAA5 levels in Cohasset are greater than or equal to 80 percent of the MCLs of 64 µg/L and 48 µg/L for TTHMs and HAA5s, respectively.

4.2 Relocation of the Pre-Chlorination Injection Point

As has been described, the key to reducing TTHMs and HAA5s is to remove any organics prior to chlorine addition to avoid creating disinfection byproducts. Until December 1, 2003, chlorine gas was added at the rapid mix basins and post-filtration at concentrations of 3.0 and 2.0 mg/L, respectively. Based on these typical chlorine dosages from April 2002 to April 2003, free chlorine residuals throughout the distribution system ranged from 0.03 to 0.55 mg/L with an average concentration of 0.23 mg/L. Samples collected from the extents of the system (Jerusalem Road, South Main Street) had residual concentrations ranging from 0.03 to 0.10 mg/L with an average concentration of 0.05 mg/L.

Based on a review of data from April 2002 through April 2003, pre-chlorine dosages were decreased from 3.0 mg/L to 2.4 mg/L during the summer months. This is a good WTP practice as the effectiveness of chlorine increases with higher temperature, thereby requiring a lower dosage in the summer months. The reduction/optimization of the chlorine dose will help to counteract the formation of DBP at the time of year when DBP formation is highest.

At the Lily Pond WTP, one of the easiest and simplest ways to reduce DBPs in the water is to eliminate or relocate the pre-chlorination injection point. The elimination or relocation of the pre-chlorine injection point will decrease the formation of DBPs as the amount of total organic carbon (TOC) available to react with the chlorine at the application point will be reduced through settling and filtration. Chlorination can not be totally eliminated as a required amount of chlorine contact time (CT) and a disinfectant residual in the distribution system is necessary to meet regulatory requirements

Table 4-1 shows the percent reduction of DBPs as the pre-chlorination injection point is moved throughout a conventional WTP. The table also shows the reductions for enhanced coagulation, which is further described below. The Environmental Protection Agency (EPA) has not provided information regarding potential DBP reduction for a pre-chlorine injection point at post-filtration.

TABLE 4-1

IMPACT OF MOVING THE POINT OF CHLORINATION ON DBP FORMATION

Point of Application	Median Reduction in DBP Formation (%)			
	TTHM		HAA5	
	Baseline Coagulation	Enhanced Coagulation	Baseline Coagulation	Enhanced Coagulation
Pre Rapid Mix	--	17	--	4.7
Post Rapid Mix	1.6	21	5.3	21
Mid-Flocculation	8.7	36	14	36
Post-Sedimentation	21	48	35	61

Source: USEPA, Enhanced Coagulation and Enhanced Precipitative Softening Guidance Manual, May 1999

Based on tracer studies conducted at the plant in November 2003, the pre-chlorination injection point was relocated from the rapid mix basins to post-sedimentation/pre-filtration in December 2003. This change should reduce the amount of TOC available to react with the chlorine from pre-chlorination and reduce the formation of DBPs. The relocation of the injection point may reduce required chlorine gas dosages by 10 to 15 percent.

4.3 Groundwater Supply

The Elms Meadow and Sohler groundwater wellfields are currently being renovated and are expected to be placed back on-line within the next year. The wells will pump directly in to the distribution system. Assuming that these wells are consistently operated and have low TOC levels, the addition of this groundwater supply to the distribution system will help to reduce the system DBPs. Groundwater sources are characterized as having lower TOC and therefore a lower potential to form DBPs. DBPs in the distribution system will be reduced proportional to the amount of groundwater that is pumped from these wellfields.

4.4 Source Water Quality

The watershed of Lily Pond is approximately 1,603 acres. The high watershed area to lake area ratio suggests that in-lake water quality is highly dependent on the water quality of the watershed. Based on an evaluation of physical, chemical, and biological characteristics conducted by ENSR in February 2003, Lily Pond was classified as eutrophic (overly productive). The classification was based on nutrient loadings and plant densities in the lake, both of which contribute to a deterioration of water quality. This problem is compounded during the summer months when the bar racks and microscreens on the Lily Pond intake structure become clogged with weeds, causing operating problems.

Lily Pond receives water from seasonal releases from the Aaron River Reservoir, which is located upstream of the Lily Pond. The Bound Brook control structure, located at the intersection of Bound Brook Lane and Beechwood Street, controls water released by the Aaron River Reservoir. Released water from Aaron Reservoir either pools in the wetlands located to the south of Lily Pond or flows to Lily Pond. During drier periods when the surface elevation of

Lily Pond falls below the controlling elevation at the Bound Brook control structure and/or when water is withdrawn from Lily Pond, water is drawn into Lily Pond.

Studies being conducted by Weston and Sampson and by others have suggested alternatives to improve the source water quality of Lily Pond and to minimize clogging of the intake structure. These alternatives include construction of a raw water transmission main from Aaron Pond directly to the Lily Pond WTP and the installation of a floating silt curtain around the Lily Pond intake structure to prevent clogging and improve water quality. For additional details concerning the methodologies to improve source water quality, refer to these reports.

4.5 Enhanced Coagulation

Enhanced coagulation is defined as the process of obtaining improved removal of DBP precursors (TOCs/SUVA) through conventional treatment. The process includes increasing the alum (coagulant) dose to a point where the TOC removal is optimized at a pH of 5.5 to 6.0. The primary goal of enhanced coagulation is to achieve significant TOC reduction without the addition of unreasonable amounts of coagulant. Jar testing using enhanced coagulation is currently being conducted by Tom Sawyer, an independent consultant. The jar testing program also includes testing an alternative coagulant, polyaluminum chloride (PACl). Results of this testing will indicate if TOC removals can be increased. If removals are greater than the current treatment process, Cohasset should consider changing their coagulant. Advantages of PACl include reducing the coagulant dosage, providing better sludge dewatering and better particulate removal for some surface waters.

TOC removal compliance, as it pertains to enhanced coagulation, is a two-step process. The first step involves the collection of monthly source water alkalinity and source water and finished water TOC data to determine compliance. Once a full year of data has been collected, the RAA for the year can be calculated and it can be determined whether a water system is in compliance with the required TOC removals. The percent TOC removal is measured between the raw water sampling point and the combined filter effluent turbidity monitoring location.

If a system is not in compliance with the TOC removals previously listed in Table 2-2, jar testing and/or pilot testing can be conducted to identify an alternative TOC removal requirement that is system specific. The alternate TOC removal requirement was included in the Stage 1 D/DBPR rule to ensure that treatment requirements could be met for all source water types and qualities. Some source waters will be easy to treat, while others will be difficult to treat. This process allows a system to define the TOC removal that is realistic to their water system and source waters.

To determine an alternative TOC removal requirement during jar tests, the alum dose is increased in 10 mg/L increments to determine the TOC removal for each dose. Increased dosages must be added until the target pH (for waters having 0 to 60 mg/L as CaCO₃ of alkalinity) of 5.5 is reached.

The Stage 1 D/DBPR has identified a point of diminishing return (PODR) for determining the optimal alum dose. This point is defined as the point where less than 0.3 mg/L TOC is removed per every additional 10 mg/L alum dose. The intention of the PODR is to limit the dose to a point beyond which the TOC removal is insignificant. The water system is required to submit the results of the jar testing within three months of failure to comply. Once approved by DEP, a strategy for full-scale implementation should be developed.

In addition to establishing a new coagulant dose, the jar tests are intended to determine if there are any secondary effects as a result of the increased coagulant dosage. Secondary effects will vary depending on the source water and may include the following:

- Increased inorganic levels. Enhanced coagulation reduces the pH of the water. The lower pH slows the rate of oxidation and may decrease the oxidation/removal of some manganese. Other potential impacts include increased iron, aluminum, sulfate, chloride and sodium concentrations. Based on current WTP practices and raw water quality, it is unlikely that significant increases in concentrations of these inorganics will be encountered.
- Corrosion control. The increased coagulant dosage results in a lower pH. The alkalinity of the water will also be reduced as each milligram of alum added to the water consumes

approximately 0.5 mg of alkalinity as calcium carbonate. Studies have also shown that the removal of NOM from water increases the potential for lead corrosion. The finished water lime dosage will need to be adjusted to increase the pH and alkalinity prior to distribution. Based on lead and copper sampling rounds conducted between June 1994 and August 1998, it is not expected that Cohasset will have a problem continuing to meet the Lead and Copper Rule, if enhanced coagulation is practiced.

- Particulate and pathogen removal. The lower pH and higher coagulant dosage may result in the restabilization of particles and an increase in the settled water turbidity. This has not been shown to occur in all cases. It is recommended that settling performance be studied with jar tests prior to implementation.
- Increased residuals production. The increased TOC removal as a result of the increased coagulant dosage will increase the volume of residuals that is produced. The sludge characteristics and its dewaterability may also be altered.

4.6 Powdered Activated Carbon

Powdered activated carbon (PAC) has been used in water treatment for taste and odor control and has been shown to remove some TOC. Typically, PAC is added at the rapid mix stage and is settled out in the sedimentation stage. Because PAC is added at the same time that coagulants are added, the growth of floc around PAC particles can block adsorption onto the PAC particles. Many studies have indicated that NOM removal by PAC increases with contact time up to seven days or longer. For this reason, the contact time in conventional settling basins, such as those at the Lily Pony WTP, is not long enough for the effective removal of NOM by PAC. Therefore, PAC is not recommended for DBP reduction.

4.7 Filter Media Replacement

The existing filter media is a dual media filter consisting of anthracite coal and silica sand. Filter media typically requires replacement every 5 to 10 years. The existing media was last replaced in 1995 and is scheduled for replacement within the next several years. The media replacement will improve the efficiency of the treatment process and will decrease the TOC and turbidity

levels leaving the filters. The reduced TOC levels will decrease potential disinfection. It is assumed that filter media replacement will be required every ten years.

As an alternative to anthracite and sand as filter media, granular activated carbon (GAC) can also be used for the removal of TOC precursors including humic and fulvic acids that react with disinfectants to produce disinfection byproducts. GAC is also used to remove organic compounds that cause taste and odor problems and can be installed in place of sand and/or anthracite in an open filter or can be installed as a capping layer over other media. If the media in the existing filters at the Lily WTP were replaced with GAC, the required bed expansion during a backwash would increase from 30 to 50 percent based on the DEP Guidelines and Policies for Public Water Systems. Based on the 40 inch depth of media in the existing filters and assuming a similar GAC media depth, there is sufficient space available for the required 50 percent bed expansion required.

The effective life of GAC for this type of application has been shown to range between a few months to 4 years. Therefore, before GAC is installed in a filter, a pilot study should be conducted to determine how long the adsorptive qualities of the GAC will last given the organic loading on the filter.

4.8 Clearwell Modification/Expansion

Pre-chlorination could be totally eliminated if additional chlorine contact time was provided in the clearwell. The existing clearwell size limits the residence time of the water. If additional space is provided in the clearwell, the expanded clearwell would be sized to increase the chlorine contact time through the plant to comply with the Surface Water Treatment Rule (SWTR) such that pre-chlorination is no longer required. To maintain the current gravity feed within the plant, a clearwell expansion should be continuous with the existing clearwell and would need to be constructed with baffles.

Available space adjacent to the existing clearwell is limited to the south side of the WTP between the WTP building and Lily Pond. The costs associated with this improvement would exceed other improvement options included herein and would not offer significant additional

compliance with the regulations. The use of an alternate disinfectant or oxidant will reduce DBP levels and meet future regulatory levels at a lower cost.

Instead of expanding the clearwell, baffles could be constructed within the existing clearwell to increase the contact time. The contact time will be based on a minimum detection time of 90 percent of the measured flow through the clearwell (T_{10}). Based on the tracer study conducted in November 2003, the T_{10} was determined to be 52 minutes between the filters and the clearwell. Assuming that 90 percent of the T_{10} applies to the filters, gullet and manifold before the clearwell, the portion of the T_{10} applicable to the clearwell would be 5.2 minutes.

For a well-baffled clearwell, the T_{10} can be estimated as 60 percent of the theoretical contact time. To be conservative, it was assumed that the estimated T_{10} is 50 percent of the theoretical contact time, resulting in an estimated clearwell T_{10} of 17.3 minutes for a well baffled clearwell. Hypothetically, the construction of baffles in the clearwell would increase the estimated existing contact time from 5.2 minutes to 17.3 minutes, allowing for a lower chlorine dose from the post-sedimentation/pre-filtration injection point.

Based on the estimated T_{10} of 17.3 minutes, the re-location of the pre-chlorination injection point from pre-filtration/post-sedimentation to before the clearwell can be evaluated. Table 4-2 summarizes the required chlorine dosages to meet CT values at a pH of 6.5, 0.5 log activation given an estimated T_{10} of 17.3 minutes.

Table 4-2
CT Calculations for a pH of 6.5, 0.5 log inactivation

Temperature (°C)	CT Required (mg/L-min)	Minimum Residual Chlorine Concentration (mg/L)
5	25	1.44
25	6	0.35

Based on these results, it appears that the construction of baffles in the clearwell would enable the pre-chlorination injection point to be moved further downstream to a point before the clearwell. A tracer study of the clearwell alone should be conducted to verify the assumptions contained herein.

4.9 Disinfectants and Oxidants

4.9.1 General

Raw water oxidants/disinfectants are added to oxidize iron, manganese and other organics, remove tastes and odors, improve coagulation/filtration efficiency and to prevent microbiological growth in a WTP prior to disinfection. There are a variety of disinfectants and oxidants that may be used in water treatment for this purpose. The following sections review the use of chlorine, chloramine, potassium permanganate, ozone, chlorine dioxide and a mixed-oxidant process. Of the disinfectants and oxidants listed, typically all but chloramines are used for pre-treatment. Chloramines and chlorine are typically used for post-treatment, because they can maintain a residual in the distribution system. Table 4-3 summarizes the advantages and disadvantages of the previously listed disinfectants and oxidants.

4.9.2 Chlorine

Chlorine is the most widely used chemical in the water treatment industry. It is primarily used for water disinfection, however its oxidizing power also makes it popular for other purposes in water treatment. Chlorine used for disinfection is typically in the form of chlorine gas, sodium hypochlorite, or calcium hypochlorite.

Because chlorine reacts with so many naturally occurring organic and inorganic compounds in water, it readily produces undesirable DBPs. It is becoming popular to combine chlorine with a second disinfectant to prevent the formation of DBPs while still achieving effective disinfection. Chlorine has many attractive features that contribute to its wide use in the industry. The four key advantages of chlorine are that it 1) effectively inactivates a wide range of pathogens commonly found in water, 2) leaves a residual in the water that is easily measured and controlled, 3) is economical, and 4) has an extensive track record of successful use in improving water treatment operations. Other advantages include control of nuisance organisms, taste and odor control, maintenance of filter media, removal of iron and manganese, destruction of hydrogen sulfide, maintenance of distribution system water quality by controlling slime growth, and bleaching of certain organic colors.

TABLE 4-3

ADVANTAGES AND DISADVANTAGES OF DISINFECTANTS AND OXIDANTS

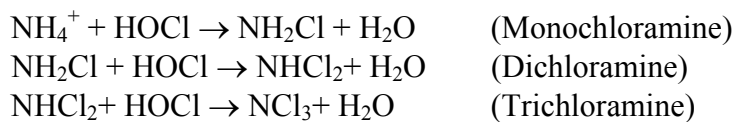
Oxidant	Advantages	Disadvantages
Chlorine	<ul style="list-style-type: none"> • Strong oxidant • Easy to feed • Persistent residual • Long history of use 	<ul style="list-style-type: none"> • Disinfection by-products (DBPs) • Taste and odor problems possible • pH influences effectiveness
Chloramines	<ul style="list-style-type: none"> • No trihalomethane (THM) formation • Reduces taste and odor • Reduces biofilm • Persistent residual • Easy to feed • Long history of use 	<ul style="list-style-type: none"> • Weak oxidant • Some total organic halide formation • pH influences effectiveness • Taste, odor, and growth problems possible • More difficult to operate than chlorine • Increases corrosivity in water • Potential need of break point chlorination if nitrification occurs in system • Hydrant flushing concerns • Ammonia handling concerns
Potassium Permanganate	<ul style="list-style-type: none"> • Moderately strong oxidant • Easy to feed • No THM formation • Reduces taste and odor 	<ul style="list-style-type: none"> • Pink water • By-products are unknown • No disinfectant properties • Limited TOC removal capabilities
Ozone	<ul style="list-style-type: none"> • Strong oxidant • Usually no THM or total organic halide formation • No taste or odor problems • Some by-products are biodegradable • Little pH effect • Coagulant aid 	<ul style="list-style-type: none"> • Short half-life • Onsite generation required • Energy intensive • Complex generation and feeding • Corrosive
Chlorine Dioxide	<ul style="list-style-type: none"> • Strong oxidant • Relatively persistent residual • No THM formation • No pH effect 	<ul style="list-style-type: none"> • Chlorite and chlorate by-products • Chlorite must be monitored daily • Onsite generation required • Hydrocarbon odors possible
Mixed Oxidant Process	<ul style="list-style-type: none"> • Strong oxidants • Multiple oxidants can be more effective over a wider range of conditions • Low THM formation 	<ul style="list-style-type: none"> • Relative amounts of oxidants are difficult to characterize • Effectiveness of disinfectant is difficult to gauge.

The major disadvantage of using chlorine as a disinfectant is the formation of DBPs that result from free chlorine's reaction with naturally occurring matter in the water. Hazards associated with using chlorine, specifically chlorine gas, that require special treatment and response

programs, and taste and odor problems resulting from high chlorine doses are two other significant disadvantages. Other disadvantages of using chlorine include the potential deterioration in the coagulation and filtration of dissolved organic substances, storage issues with sodium and calcium hypochlorites, and the loss of disinfection efficiency at high pH.

4.9.3 Chloramine

When chlorine and ammonia are both present in water, they react to form chloramines. As opposed to free chlorine, the chloramines are referred to as “combined chlorine.” The inorganic chloramines consist of three species: monochloramine (NH₂Cl), dichloramine (NHCl₂) and trichloramine or nitrogen trichloride (NCl₃). The principal reactions, which occur in a stepwise fashion, are:



The disinfection method of chloramination uses ammonia and chlorine to generate chloramines, which maintain a disinfectant residual in the distribution system. Chloramination disinfection usually works best at system pHs between 8.0 and 8.5. The optimum ratio of chlorine to ammonia-nitrogen used for generating chloramines for drinking water is between 3:1 and 5:1. Higher ratios begin to generate di- and tri-chloramines which can cause taste and odor problems. Lower ratios allow free ammonia into the distribution system and can cause nitrification in the distribution system. There has been some research that shows that biofilms are more sensitive to inactivation by chloramination than chlorination. However, if nitrification occurs in a distribution system, raising the chloramine residual will not prevent nitrification. Typically, the use of a free chlorine residual or flushing of the distribution system is the only way to eliminate nitrification, once it has begun.

The major advantage of chloramine disinfection is the reduction of DBP concentrations and the fact that no detectable trichloroacetic acids are produced as byproducts. Other benefits include reduced taste and odor, potential inactivation of biofilms in the distribution system, and greater resistance to decay than chlorine. Disadvantages of chloramines are potential nitrification in the

distribution system, which requires breakpoint chlorination, and more complicated operation and higher costs than chlorine. Another disadvantage to chloramines is that when flushing the distribution system, any flushed water that may run-off into surface waters must be handled and neutralized prior to being discharged as chloramines are extremely toxic to fish.

4.9.4 Potassium Permanganate

Potassium permanganate (KMnO_4) is a strong oxidizing agent used primarily to control taste and odors, remove color, control biological growth in treatment plants, and remove nuisance organisms, iron, and manganese. Because of this, potassium permanganate is often used in conjunction with chlorine for water treatment. The use of KMnO_4 has not been shown to result in significant reductions in TOC.

Although potassium permanganate is an excellent oxidizer, it is a poor disinfectant whose effectiveness against bacteria and viruses is questionable, except at extremely high doses. It is currently not registered with the EPA as a disinfectant.

To be most effective, potassium permanganate requires a long detention time. When added to the water, the water will turn straw colored. If it is overdosed, the water will turn pink. Hence, it is important not to overdose potassium permanganate.

Currently, jar testing using potassium permanganate is being conducted by Mr. Tom Sawyer, an independent consultant. Tests are being conducted to evaluate the effectiveness of potassium permanganate in controlling tastes and odors and in TOC removal. If the testing proves successful, Cohasset should consider the addition of potassium permanganate.

4.9.5 Ozone

The use of ozone (O_3) is quickly gaining popularity in the United States because it is both a strong oxidant and an effective disinfectant. Ozone very effectively removes tastes, odors, and color in water. It also oxidizes organic substances, which reduces the formation of DBPs. Other benefits of ozone include improved coagulation, which lowers the costs of coagulant chemicals and sludge disposal, reduction of chlorine demand, and removal of iron, manganese, and sulfide.

Ozone's oxidizing strength comes from its spontaneous decomposition during water treatment to form hydroxyl free radicals, which are among the most reactive oxidizing agents in water. Because ozone is an unstable molecule, it is generated at the point of application for use in water treatment. Ozone can be generated on-site by means of a generator that converts oxygen gas into ozone through a uniformly charged air space with electrical energy. As a result, chemical storage and delivery are not needed if air is used as the source of oxygen. Liquid oxygen can also be used as the oxygen source for this application. Considering the size of the Cohasset water system, it is suggested that ozone be generated utilizing the liquid oxygen method. However, should Cohasset decide to use ozone for water treatment purposes, a more detailed investigation of the source of oxygen should be conducted. Ozone generation requires considerable energy input and can significantly raise electrical costs.

Ozone is a bluish, toxic gas with a pungent odor that is hazardous to health at relatively low concentrations in air: the threshold odor level is 0.05 ppm and the 8-hour OSHA standard is 0.1 ppm. Therefore, destruction of the off-gas from ozone is necessary for safety reasons. Once the ozone has been produced, it is diffused through the raw water in a contact chamber. Any excess ozone gas that has passed through the raw water without being consumed is captured and converted back to oxygen gas before being released to the atmosphere. Three methods that may be used to eliminate off-gas are thermal destruction, thermal/catalytic destruction and catalytic destruction. The use of ozone as an alternative disinfectant produces bromate, a DBP also having adverse health effects. Monitoring for bromate would be required.

Ozone is chemically unstable and leaves no residual. As a result, it is necessary to use chlorine or chloramines to maintain a disinfectant residual in the distribution system.

Nonhalogenated DBPs can form with the use of ozone as an oxidant. Ozone can oxidize organics and form simple organic compounds that commonly appear as biodegradable dissolved organic compounds (BDOC) or assimilated organic carbon (AOC). These compounds can contribute to the growth of biofilms in the distribution system. Typically, this is not a problem if some form of filtration follows the ozone process.

4.9.6 Chlorine Dioxide

Chlorine dioxide (ClO_2) is another strong oxidizing agent that must be prepared onsite. It is most often used as an alternative disinfectant to chlorine for reducing DBPs. Chlorine dioxide disinfects by oxidation, but does not chlorinate. Its most popular use is as an initial oxidant for treating raw water whose DBP precursors are high, which often helps obtain CT disinfection credits. It also controls iron and manganese; removes color, and organic and sulfuric compounds; and controls tastes and odors. Because chlorine dioxide can add a specific taste and odor to water, its maximum residual should be 0.4-0.5 mg/L as ClO_2 .

Chlorine dioxide is a relatively small, volatile, highly energetic molecule that is a free radical even while in dilute aqueous solutions. It is very soluble in water (approximately 10 times more soluble than chlorine) and can easily be removed from dilute aqueous solutions with minimum aeration. Chlorine dioxide cannot be compressed or stored commercially as a gas because it is explosive under pressure. As a result, chlorine dioxide is commonly generated on-site and is applied as aqueous solutions between 0.1 and 0.5 percent for potable water treatment.

One disadvantage in using chlorine dioxide as an alternative disinfectant is that it produces chlorite and chlorate, DBPs also having adverse health effects. Chlorate and chlorite are inorganic compounds that form during the generation of chlorine dioxide. Approximately 50 to 70 percent of the chlorine dioxide consumed by oxidation reactions is converted to chlorite under typical conditions in water treatment. Chlorite is relatively stable in the presence of organic material, but can be oxidized to chlorate by free chlorine. Therefore, chlorate is most often produced through the reaction of residual chlorite and free chlorine during secondary disinfection. Chlorite and chlorate can also form under highly alkaline conditions ($\text{pH} > 9$). Like TTHMs and HAA5s, the health effects due to chlorate and chlorite include potential risks of cancer and adverse reproductive outcomes in human populations. Chlorate is also known to cause abdominal pain, diarrhea, and comas.

4.9.7 Mixed Oxidants

A mixed oxidant process produces a liquid stream of oxidants from salt, water and electricity. The process generates a combination of ozone, chlorine dioxide, hypochlorite ion, hypochlorous

acid and elemental chlorine from the passage of an electric current through a continuous-flow brine (salt) solution.

Compared to the use of a single oxidant, the use of mixed oxidants can be more effective. The combination of oxidants can allow for better results over a wider range of conditions. Similarly, the residuals from this process will be more effective over a wider range of conditions and over a greater diversity of microorganisms. The increased effectiveness as compared to chlorination is due to the combined use of ozone and chlorine dioxide, both of which are more effective in the inactivation of microorganisms than ozone or chlorine alone.

The combination of oxidants results in shorter required contact time since the reaction rate of mixed-oxidants is shorter as compared to chlorination due to the combined action of ozone, chlorine dioxide and chlorine. However, since there is not sufficient information regarding the exact components of the product, the more conservative CT tables for chlorine will need to be used until such time that the CT values for mixed oxidant processes have been determined and EPA approved.

A disadvantage of a mixed oxidant process is that it is difficult to characterize the relative proportion of each oxidant generated. As a result, it is difficult to evaluate the effectiveness of the mixed-oxidant. The use of chlorine dioxide as one of the oxidants produces chlorite and chlorate, DBPs also having adverse health effects and would require monitoring. Mixed oxidants have not proven to be reliable for removing turbidity and are only able to provide slight reductions in color.

G:\WATER\COHASSET\203151 DBP\REPORT\REPORT_FINAL.DOC

5.0 RECOMMENDATIONS AND ESTIMATED COSTS

5.1 General

The following summarizes the recommended sequence of improvements that Cohasset should undertake to reduce DBPs in their system. After each sequential improvement is completed, water quality monitoring should be conducted to quantify the effectiveness of the improvements to reduce DBPs. *It may not be necessary to institute all the recommended improvements to achieve compliance with the DBP rules.* The Commission has determined that the objective of these improvements should be to reduce the DBPs to a level that is 80 percent of the maximum contaminant levels (MCLs) for total trihalomethanes (TTHMs) and haloacetic acids (HAA5s). The corresponding target concentrations are 64 µg/L and 48 µg/L for TTHMs and HAA5s, respectively.

Recommended improvements are broken down into two phases. The following sections summarize each improvement by phase including a general description of the construction and/or equipment requirements. Costs for each improvement is included in Section 5.4 of this chapter.

At this point in time, there is insufficient TOC data to fully evaluate a treatment approach to lower DBPs in the Lily Pond WTP and distribution system. Once additional TOC data have been collected, preferably during the warmer summer months and at least a full year of monthly data is available, the following phased improvements can be further defined. It is recommended that this report be updated once additional data has been obtained.

5.2 Phase 1

5.2.1 General

Phase 1 improvements to the WTP include the following, which are further discussed in the following sections:

- Enhanced coagulation or the use of polyaluminum chloride
- Construction of baffles within the clearwell
- Filter media replacement with sand/anthracite or GAC

- Installation of a potassium permanganate chemical feed system to reduce taste and odor complaints and to reduce TOC concentrations

It is estimated that the Phase 1 improvements may reduce TTHMs levels by 25 to 30 percent and that HAA5 levels may be reduced by 40 to 50 percent. Based on the running annual averages (RAAs) calculated for the last two quarters of 2003, TTHM levels will be reduced by up to 17.5 to 20.0 micrograms per liter ($\mu\text{g/L}$), resulting in TTHM levels between 66 and 75 percent of the MCL. The RAA for HAA5s over the same time frame will be reduced by up to 29.5 to 39.0 $\mu\text{g/L}$, reducing the RAA to levels between 65 and 74 percent of the MCL. Once a phase improvement has been completed, water quality monitoring should be conducted to quantify the effectiveness of the improvements to reduce DBPs and increase TOC removal.

5.2.2 Enhanced Coagulation/Polyaluminum Chloride

Based on the results of the jar testing program, Cohasset may decide to practice enhanced coagulation with alum or use PACl. Enhanced coagulation obtains improved removal of DBP precursors (TOCs/SUVA) by conventional treatment. The improved TOC removal is accomplished by increasing the coagulant dose to a point where TOC removal is optimized at a pH of 5.5 to 6.0. The current average alum dosage is 40 mg/L. The optimization of the alum dosage may result in an increase of the existing dosage by up to 50 percent. The increased dosage of 20 mg/L has been incorporated into the operation and maintenance costs included herein.

The use of PACl can also improve TOC removal. PACl is typically more expensive than alum. Therefore, we have assumed that the increased operational costs for PACl would be the same as enhanced coagulation. These costs should be re-estimated once actual dosages have been determined.

5.2.3 Filter Media Replacement

Filter media typically requires replacement every 5 to 10 years. The existing sand and anthracite filter media was last replaced in 1995 and is scheduled for replacement within the next several years. The media replacement will improve the efficiency of the treatment process and will

decrease the TOC and turbidity levels leaving the filters. The reduced TOC levels will decrease potential disinfection. It is assumed that filter media replacement will be required every ten years.

Instead of replacing the existing filter media in-kind, GAC could be installed to increase TOC removal within the Lily WTP. Before GAC is installed in a filter, a pilot study should be conducted to determine how long the adsorptive qualities of the GAC will last given the organic loading on the filter and the level of TOC removal. To develop costs for this option, it is assumed that GAC filter media replacement will be required every four years.

5.2.4 Clearwell Modification

The current clearwell is not baffled. The installation of plastic curtain baffle walls would increase the contact time within the clearwell, would increase the T_{10} value and may lower the required pre-chlorination dosage to limit DBP formation.

5.2.5 Potassium Permanganate

The Lily Pond WTP was designed with a potassium permanganate system to treat manganese from the groundwater wellfields. Since the groundwater sources have been off line for a number of years, the potassium permanganate system has not been used. The existing potassium permanganate system will need to be evaluated to determine whether it needs to be repaired, rebuilt or replaced. We have assumed that the existing system is operable. The effectiveness of potassium permanganate as a pre-oxidant to control taste and odor problems and to remove TOC is currently being evaluated. Chemical addition costs have been included assuming that TOC will be reduced.

5.3 Phase 2

Phase 2 improvements include changing either the pre- or post- disinfection chemical feed systems. As was previously discussed in Chapter 4.0 of this report, there are a variety of disinfectants and oxidants that may be used in water treatment. If it is necessary to further reduce DBPs after Phase 1 improvements, it is recommended that the next step be to either convert the post-chlorination system to a chloramine system or to change the pre-chlorination

system to ozone, chlorine dioxide or MIOX. A pilot study of each new chemical feed system will likely be required by DEP and should be conducted prior to selecting an alternate pre-or post-disinfectant.

5.3.1 Chloramines

To create chloramines, chlorine is added to the water prior to entering the clearwell. Ammonia is then added to the water in the effluent pipe as it is pumped from the WTP to the distribution system. The existing chlorine dosage of 2 mg/L will likely be increased to produce a typical chloramine dosage of 3 mg/L. The optimum pH range for chloramines formation is between 8.0 and 8.5. Currently, the finished water pH leaving the WTP is 7.5. The finished water pH may need to be increased to optimize chloramine formation. The ammonia chemical feed system required to convert chlorine gas to chloramines includes an ammonia storage tank, vaporizer, control valves, piping and miscellaneous improvements.

The Town of Hingham currently uses chlorine as a disinfectant. Should Cohasset begin to chloramine the water, the water quality between the systems will need to be evaluated to verify that the water quality of each system is compatible. Competing water quality is not anticipated to be a problem as several communities in Massachusetts, including Wilmington, Peabody and other Massachusetts Water Resource Authority (MWRA) communities currently mix chlorinated water with chloraminated water without detrimental effects.

5.3.2 Ozone

The ozone chemical feed system includes ozone generators, off-gas destruct units, injection equipment, a baffled contact tank located adjacent to the WTP building and miscellaneous improvements and site work. The cost savings from the elimination of the pre-chlorination dosage has been incorporated into the operation and maintenance costs presented herein.

5.3.3 Chlorine Dioxide

The chlorine dioxide system includes chlorine dioxide generators, storage tanks, injection equipment and miscellaneous improvements and site work. The use of chlorine dioxide may

reduce the existing pre-chlorination dosage by up to 50 to 60 percent. The reduced dosage and annual cost has been incorporated into the operation and maintenance costs included herein.

5.3.4 Mixed Oxidant Process

The mixed oxidant (MIOX™) chemical feed system includes mixed oxidant generators, brine and oxidant storage tanks, injection equipment and miscellaneous valves and piping. The cost savings from the elimination of the pre-chlorination dosage has been incorporated into the operation and maintenance costs presented herein.

5.4 Cost Summary

The estimated costs include construction costs, engineering costs, and contingencies. Engineering design, construction administration costs and contingencies were estimated at a graduated scale of 40 to 50 percent of construction costs. The costs were developed in part by using recent construction costs for similar work in the northeast. These costs were updated to an estimated Engineering News Record (ENR) Boston index of 7976 for December 2003. Other sources include recent project bid data, the 2003 Means “Building Construction Costs Data,” and manufacturers’ quotations.

Operation and maintenance (O&M) costs include chemical, labor, energy/power, and general maintenance costs. Maintenance costs include costs for equipment repair/replacement, etc. Electricity costs for ozonation were based on a rate of \$0.11 per kilowatt-hour (kw-hr). A present worth analysis over a 20-year period was used to compare costs assuming a 3-percent inflation rate.

The installation of a new chemical feed system (i.e. chloramines, potassium permanganate, ozone, chlorine dioxide or mixed oxidants) assumes that the equipment is sized to provide 100 percent redundancy. Standby power will need to be provided to these systems. The costs included herein do not include costs for a standby generator for the case that the existing generator does not have sufficient capacity to provide power to these systems. According to the Massachusetts Guidelines and Policies for Public Water Systems, ammonia, ozone and chlorine dioxide chemical feed systems must be housed in a separate room with an inspection window,

similar to the requirements for chlorine gas. Construction of a separate room or building will be required to house these chemical feed systems. Capital and O&M costs are based on a plant flowrate of 3.0 million gallons per day (mgd).

These costs are preliminary and will need to be further evaluated and /or pilot tested prior to the implementation of an improvement. *As previously mentioned, it may not be necessary to institute all the recommended improvements to achieve compliance with the DBP rules.*

**TABLE 5-1
SUMMARY OF ESTIMATED COSTS**

Phase	Improvement	Estimated Construction Costs	Estimated O&M Costs	20-year Present Worth Cost
Phase 1				
A	Enhanced Coagulation or use of Polyaluminum Chloride	NA	\$11,000	\$310,000
	Construction of baffles in the clearwell.	\$85,000	NA	\$85,000
B	Reactivate potassium permanganate chemical feed system.	\$0	\$39,000	\$1,101,000
C	Source water quality improvements	Costs being developed or included in other reports		
	Re-activation of the groundwater sources	Costs already incurred		
D	Install granular activated carbon in existing filter beds OR	\$230,000	NA	\$1,073,000 ¹
	Replacement of the filter media	\$151,000	NA	\$353,000 ¹
Phase 2				
A	Convert final disinfection from chlorine to chloramines	\$196,000	\$8,000	\$422,000
B	Convert pre-chlorination to ozone OR	\$1,500,000	\$17,000	\$1,980,000
	Convert pre-chlorination to chlorine dioxide OR	\$196,000	\$41,000	\$1,353,000
	Convert pre-chlorination to a mixed oxidant system	\$412,000	\$5,000	\$553,000

¹Assumes GAC filter media replacement is required every 4 years and sand/anthracite filter media replacement is required every 10 years.