California Urban Water Agencies

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Drinking Water Treatment Evaluation

Project Report

April 2011

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Acronyms Used in the Report

CAA	California Aqueduct Source Water Area
CAAW	California Aqueduct West Branch Source Water Area
CCI	Construction Cost Index
CD	Central Delta Source Water Area
CDPH	California Department of Public Health
Central Valley Water Board	Central Valley Regional Water Quality Control Board
CHAB	Cyanobacterial Harmful Algal Bloom
CCL3	Contaminant Candidate List 3
CUWA	California Urban Water Agencies
Delta	Sacramento- San Joaquin Delta
DOC	Dissolved Organic Carbon
DON	Dissolved Organic Carbon
DS	Distribution System
EC	Electrical Conductivity
EPAWTPM	EPA Water Treatment Plant Model
EPDS	Entry Point to the Distribution System
ENR	Engineering News Record
FC	Fecal Coliform
GAC	Granular Activated Carbon
HAA	Haloacetic Acids
LRAA	Locational Running Annual Average
LT2ESWTR	Long-Term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum Contaminant Level
MGD	Million gallons per day
NBA	North Bay Aqueduct Source Water Area
NDMA	N-nitrosodimethylamine
O&M	Operation and Maintenance
PHG	Public Health Goal
SDWA	Safe Drinking Water Act
SWTR	Surface Water Treatment Rule
TC	Total Coliform
TDS	Total Dissolved Solids
THM	Total Trihalomethanes
TOC	Total Organic Carbon
UCMR	Unregulated Contaminant Monitoring Rule
USEPA	United States Environmental Protection Agency
UW	Upper Watersheds Source Water Area
VWTP	Virtual Water Treatment Plant
WHO	World Health Organization
Work Group	Central Valley Drinking Water Policy Work Group
WTP	Water Treatment Plant
WRF	Water Reclamation Facility

Executive Summary

The Drinking Water Treatment Evaluation project objective was to determine the effects of changing regulatory environment under future water quality conditions at treatment plants that utilize surface water from the Central Valley of California.

Study boundaries were defined by identifying areas of similar source water quality and outlining existing water treatment practices in each source water area. Four source water areas were identified:

- Upper Sacramento and Upper-Eastern San Joaquin Watersheds (Upper Watersheds)
- Central Delta including the South Bay Aqueduct (Central Delta)
- California Aqueduct – Coastal and East Branches (CAA)
- California Aqueduct – West Branch (CAA-West)

Projections of future water quality for two of the four source water areas were reviewed. It was found that the historical data (generally available from 1998 to 2008) did not exactly match the projected future total organic carbon (TOC), bromide, and temperature from a modeled sixteen year data set. To best interpret the modeled future water quality results, the relative differences between various future scenarios were used. It was found that although the water quality slightly improved with respect to TOC in more conservative future scenarios, a meaningful change to disinfection by-product (DBP) modeling results was not observed (i.e. modeled DBPs using historical water quality and current virtual representative plants did not significantly differ from modeled DBPs using projected future water quality and current virtual representative plants). For this reason, historical water quality was used for the four source water areas for the remainder of the evaluation to analyze the effect of the projected future regulatory environment.

To represent existing treatment practices in each source water area, representative virtual water treatment plants (VWTPs) were developed. The VWTPs do not exactly represent any one WTP in the source water area but are a general representation of the treatment plants in the source water area. Five VWTPs were developed to represent the four source water areas. In general, three common treatment trains emerged:

- Conventional particulate removal with chlorine disinfection (primary and secondary)
- Conventional particulate removal with ozone pre-oxidation, chlorine primary disinfection, and secondary disinfection with chloramines.
- Conventional particulate removal with chlorine primary disinfection and secondary disinfection with chloramines.

Regulatory scenarios for the year 2030 were developed from a group consensus of technical experts and advisors, based on the team's experience with the United States Environmental Protection Agency (USEPA) and California Department of Public Health (CDPH), and on best professional judgment. Scenarios were divided into three categories:

- Current - includes contaminants that are currently regulated. Cost estimates were developed for this scenario and it was used as a baseline.
- Plausible - includes contaminants that are considered likely to be regulated in some form.
- Outer Boundary- includes the same contaminants; however, the requirements could be more stringent. This scenario was provided to bracket the regulatory possibilities.

The regulatory scenarios evaluation determined that it is plausible for the regulations about chlorate, bromate, total trihalomethane (THM4), haloacetic acids (HAA5 and HAA9), N-nitrosodimethylamine (NDMA), nitrite, nitrate, algal toxins, and some emerging pathogens could be modified or newly developed in the future:

- In an effort to reduce the cancer risk to 1×10^{-4} or lower, the bromate maximum contaminant level (MCL) could be reduced to 10 µg/L, or 5 µg/L (plausible), or lower (1 to 4 µg/L) (outer boundary).
- To limit variability and reduce possible reproductive and acute human health effects, it is plausible that the monitoring for THM regulation will change to single sample not to exceed; however, the numerical target could remain at 80 µg/L. This could include multiple samples collected instantaneously at a given location to average results and avoid an unrepresentative sample or could include re-sampling in the case of an outlier result. Intention is to obtain a sample that is representative of the quality of the water in a particular location at a unique point in time. As an increasing amount of health effects data become available, regulations may be directed to individual THM and HAA species to reduce associated health risks (outer boundary).
- To limit variability and reduce acute human health effects, it is plausible that the monitoring for HAA5 regulation will change to single sample not to exceed; however, the numerical target could remain at 60 µg/L (plausible). As additional human health effect data become available, regulations may be directed to individual species (outer boundary).
- HAA9 is not currently regulated. Future regulation is plausible at a level of 80 µg/L on a locational running annual average (LRAA) basis. Although it is less likely, HAA9 regulation may be changed to 80 µg/L single sample not to exceed or depending on available human health effects data on an individual species basis (outer boundary).

- Iodinated DBPs (I-DBPs), including I-THMs and I-HAAs, were included in the outer boundary. Despite some of the noted health effects of I-DBPs, it is anticipated that THMs and HAAs will remain a surrogate for halogenated DBPs. More occurrence and toxicology data are needed to justify a plausible regulation.
- It is plausible that the future regulation of NDMA will be in the 3 to 10 ng/L range as a LRAA (plausible). Although less likely, regulations requiring treatment for dissolved organic nitrogen (DON) as a precursor similar to the TOC removal requirements set forth in the Stage 1 DBP Rule could be established (outer boundary). If the health effect data and occurrences justify individual regulations of various nitrosamines species, regulation of individual compounds could result (outer boundary).
- Hydrazine regulation not plausible. Although it is unlikely, future regulation of hydrazine at 10 ng/L single sample not to exceed could occur to reduce the cancer risk level (outer boundary).
- Due to the increasing concern over nitrogenous DBP formation, it is plausible that chloramination may become a less preferred disinfection method. As an increasing number of studies indicate the adverse health effects associated with US disinfection practices, chloramination may be prohibited in the future (outer boundary).
- It is likely total dissolved solids (TDS) will be monitored in the future, and the regulation likely will not change (plausible). With the increasing importance of water recycling, TDS reductions may be necessary (outer boundary); however, it is unlikely that a Safe Drinking Water Act (SDWA) regulation would require this.
- Chlorite and chlorate were included in the regulatory scenarios. It is not expected that the chlorite regulation will change. Due to the toxicological effects of chlorate similar to those of perchlorate, chlorate regulation is plausible at 700 μg/L.
- Nitrite and nitrate were included in the regulatory scenarios. It is not expected for the regulated concentration of these contaminates to change. It is plausible that the monitoring location will be moved from the Entry Point to the Distribution System (EPDS) to the distribution system (DS) to account increases in these contaminants from ammonia nitrification.
- With increasing awareness and measurement of algal toxins worldwide, cyanotoxins were included in the USEPA unregulated contaminant monitoring rule (UCMR) 3. With potential data from the UCMR 3 and a growing body of toxicological data, microcystin could be regulated at the World Health Organization (WHO) drinking water guideline value of 1 μg/L (plausible scenario).
- The third USEPA Contaminant Candidate List (CCL3) is evaluating several emerging pathogens; however, none of these pathogens are more difficult to remove, oxidize, or inactivate compared to the current microbial standards for *Giardia*, virus, and *Cryptosporidium*.

Following the development of the future regulatory scenarios and VWTPS, threshold levels (i.e., treatment triggers) where the plausible regulatory scenario creates the need for capital or operational modifications to a treatment process, were determined. These treatment triggers, were developed for current and plausible future regulations for each VWTP. The treatment triggers can be used to determine the costs associated with varying levels of water quality in the future.

All baseline VWTPs met current regulations at the 90th percentile water quality conditions. Some general observations regarding the treatment triggers for the plausible regulatory scenario with the VWTPs include:

- Bromide and TOC concentrations dictate the ability of VWTPs to comply with current and plausible future THM and HAA regulations. A matrix of varying bromide and TOC concentrations was developed for each VWTP for the purpose of this evaluation.
- Chlorate is a common contaminant associated with hypochlorite solutions. WTPs utilizing hypochlorite (on-site generation or bulk) should consider: diluting the solution upon delivery, storing the solution at lower temperatures, controlling the pH of the stored solution between 11 and 13, and using fresh solution when possible.
- All VWTPs have sufficient chlorine contact time to oxidize 10 µg/L of microcystins and some NDMA precursors.
- VWTPs utilizing pre-ozonation will also oxidize microcystins and NDMA precursors.
- It is uncertain whether NDMA treatment will be necessary because of the complexity of NDMA formation and low plausible regulatory levels, even though oxidation of NDMA precursor will occur.
- Nitrification will not likely form nitrate at levels approaching the MCL at the representative VWTPs considered in this study. VWTPs utilizing chloramines dose ammonia at 0.6 mg/L, in which case ammonia will not be present at levels above the 0.8 mg/L as N treatment trigger and will not trigger the nitrite MCL violation.
- The CCL3 is evaluating several emerging pathogens; however, none of these pathogens are more difficult to remove, oxidize, or inactivate compared to the current microbial standards for *Giardia*, virus, and *Cryptosporidium*. For this reason, no treatment triggers were developed for emerging pathogens.

The assumption that future water quality will remain equivalent to historical water quality resulted in treatment upgrades being based on the ability of a VWTP to meet treatment targets (80 percent of the MCL) in the plausible regulatory scenario, not changes in water quality. Recommended treatment upgrades included:

- UW-1 had two options:
  - A- Utilize chloramines as secondary disinfectant, or

  - B- Install GAC contactors and continue to use free chlorine as a secondary disinfectant.
- CD-1: include a reduction in ozone dose and addition of UV disinfection.
- CAA-2: include a reduction in ozone dose and addition of UV disinfection.

For the outer boundary future regulatory scenario, upgrades will be needed for all VWTPs. As the regulatory scenario for the outer boundary could not be defined more specifically, an assumption is made that all plants will move away from ozone and chloramines to avoid bromate and nitrogenous DBPs. As a result it is assumed that in the outer boundary all plants will implement the addition of GAC contactors and UV disinfection.

The added cost of treatment upgrades to a VWTP was expanded to represent each source water area by taking into account the area's total regional treatment capacity. The fraction of the total regional treatment capacity that was represented by the VWTP was calculated, and this fraction was then applied to the VWTP costs. For example, CD-1 has 40 mgd capacity in a source water area with a total treatment capacity of 284 mgd. Dividing 284 mgd by 40 mgd gives a fraction of 7.1 to be applied to the cost estimate. Multiplying 7.1 by the added capital cost of CD-1, results in a total regional capital cost to meet the plausible future scenario. A summary of the added costs for each source water area is presented in Table ES-1. These costs are based on current treatment capacity. Future treatment capacity is likely to increase with increasing population, so 2030 costs are likely to be higher.

Table ES-1:
Regional Added Costs for Upgrades

VWTP	VWTP Design Capacity (mgd)	Representative Regional Treatment Capacity/ VWTP Capacity	Scenario	Added Capital Cost ($)	Added Annual O&M Cost ($/yr)
Upper Watersheds- 818 mgd Total Regional Treatment Capacity					
UW-1	100	8.18	Plausible	$10 - $21M	$0.3 - $0.6M
				or	
				$883 - $1893M	$35.3 - $118.5M
			Outer Boundary	$1581 - $3387M	$55.3 – 118.5M
Central Delta- 284 mgd Total Regional Treatment Capacity					
CD-1	40	7.1	Plausible	$270 - $579M	$6.2 - $13.4M
			Outer Boundary	$634 - $1359M	$20.8 - $44.5M
CAA- 2201 mgd Total Regional Treatment Capacity					
CAA-1	40	3.86	Plausible*	-	-
			Outer Boundary	$345 - $739M	$11.3 – $24.2M
CAA-2	500	6.78	Plausible	$2699 - $5783M	$110.0 - $235.8M
			Outer Boundary	$5226 – $11198M	$286.2 - $613.3M
CAA-West - 836 mgd Total Regional Treatment Capacity					
CAAW-1	800	1.04	Plausible*	-	-
			Outer Boundary	$1288 - $2760M	$76.3 – $163.5M
TOTAL			Plausible	$2978 - $6382M	$116.6 - $249.8M
				Or	
				$3852 – $8254M	$151.6 - $324.8M
			Outer Boundary	$9074 - $19443M	$449.8 - $963.9M

*No upgrades needed, baseline costs remain.

All costs in December 2010 dollars, CCI = 8952.

Costs are representative of AACE Class 5 estimates. AACE Class 5 estimates are planning level costs prepared based on 0 to 2% of full project definition with accuracy ranges of -20% to -50% on the low side and +30% to +100% on the high side. Accuracy range for cost estimates presented in this project are -30% to +50%.

1. Introduction and Project Background

This section provides a brief project background and outlines the purpose and contents of this report. Please refer to Appendix A for a detailed project history and timeline.

1.1. Project Motivation and Background

The surface water in the Central Valley has the potential to impact the water treatment costs for more than 25 million Californians who receive a portion of their water from the Sacramento-San Joaquin Delta (Delta) and the tributaries to the Delta (CALFED Water Quality Program, 2008). The tributaries to the Sacramento and San Joaquin rivers that originate in the Sierra Nevada Mountains generally have high quality water; however, pollutants from a variety of sources (urban, industrial, agricultural, and natural) can degrade the quality of water as it flows to and downstream of the Delta, creating a number of drinking water treatment challenges.

Currently, water quality regulations applicable to the Central Valley include MCLs issued by the CDPH and a Water Quality Control Plan (Basin Plan) for the Sacramento-San Joaquin River Basins. The Basin Plan was developed by the Central Valley Regional Water Quality Control Board (Central Valley Water Board) and designated beneficial uses, including municipal and domestic water supply, for the Sacramento and San Joaquin rivers and Delta. The Basin Plan also specifies numeric and narrative water quality objectives and implementation strategies to protect designated beneficial uses.

Current plans and policies for Central Valley surface waters do not contain numeric quality objectives for several key drinking water constituents of concern, including DBP precursors and pathogens. For this reason, the Central Valley Water Board is working with stakeholders to develop a comprehensive Central Valley Drinking Water Policy.

The Drinking Water Policy may be considered as a Basin Plan amendment in the future. To provide the technical information needed for the development of the Drinking Water Policy, a Central Valley Drinking Water Policy Workgroup (Work Group), comprised of interested stakeholders and technical experts (listed below), was formed to develop and implement a work plan.

- California Bay-Delta Authority
- CDPH
- Central Valley Regional Water Quality Control Board
- Central Valley Clean Water Association
- State Water Resources Control Board

- Sacramento Regional County Sanitation District
- Northern California Water Association
- California Urban Water Agencies (CUWA)
- California Rice Commission
- USEPA
- California Department of Water Resources
- Sacramento Stormwater Quality Partnership

The work plan includes:

- An assessment of the ability to control sources of key drinking water constituents in the Delta and is tributaries (source water protection approach).
- An assessment of the ability to remove key drinking water constituents in water treatment plants (water treatment approach).
- An analysis of the feasibility, costs, and risks associated with both approaches to managing key drinking water constituents (source water protection and water treatment).

This project addresses the water treatment approach for priority constituents. The drinking water constituents considered to have the highest priority by the Work Group include DBP precursors, dissolved minerals, nutrients, pathogens, and pathogen indicator organisms (Table 1-1).

Table 1-1.
Priority Constituents of Concern for Central Valley Drinking Water Policy

Constituent Class	Source Water Constituents	Treated Water Constituents
Disinfection Byproduct Precursors	TOC, DOC, bromide, alkalinity	DBPs, THMs, HAAs, bromate
Dissolved Minerals	TDS, electrical conductivity (EC), and chloride	TDS, EC, and chloride
Nutrients	Nitrogen species (total, total Kjeldahl, organic, nitrate, nitrite, ammonia) Phosphorus species (total, dissolved)	Impacts of algal growth: taste and odor, algal toxins, treatment challenges
Pathogens and Indicator Organisms	*Giardia*, *Cryptosporidium*, total coliform, fecal coliform, *Enterococcus*, *E.coli*	*Giardia*, *Cryptosporidium*, total coliform, fecal coliform, *Enterococcus*, *E.coli*

Source: Drinking Water Treatment Evaluation Scope of Work

1.2. Water Treatment Evaluation Project Objective

The Drinking Water Treatment Evaluation project objective was to determine the effects of future water quality changes at treatment plants that utilize surface water from the Central Valley of California. Current, plausible future, and outer boundary regulations were considered.

1.3. Project Progress and Schedule

Task work was completed in two project phases:

Phase I

- Define Study Boundaries
- Develop and Describe a Representative VWTP for each Source Water Area
- Identify Threshold Values that Trigger Treatment Changes

Phase II

- Evaluate VWTP Performance using Future Water Quality Scenarios
- Estimate VWTP Upgrades Needed to Meet Future Regulations
- Estimate Costs Associated with VWTP Upgrades

1.4. Technical Memorandum Organization

The purpose of this technical memorandum is to capture revisions to previously completed work (Phase I) and to summarize the work completed as part of Phase II of the project. This memorandum is organized into five sections:

- Section 1 provides an introduction to the project, reviews the project objectives and work completed, and outlines of the technical memorandum organization.
- Section 2 describes the regulatory scenarios.
- Section 3 summarizes historical water quality and describes the future water quality scenarios used for the analysis.
- Section 4 provides the approach used to develop VWTPs, an example VWTP development for a source water area, and a summary of the selected VWTPs.
- Section 5 provides a description of the threshold values that trigger the need for treatment change.
- Section 6 models VWTP performance with future water quality and identifies the upgrades needed to meet future regulatory scenarios.
- Section 7 provides a sensitivity analysis of the water quality data and WTP modeling.
- Section 8 provides cost estimates for the recommended future VWTP upgrades and extrapolates costs to the regional level.
- Section 9 provides a summary of the evaluation and major findings.
- Section 10 summarizes references used in the report.

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2. Regulatory Scenarios

Regulatory scenarios for the year 2030 were developed in Phase I project work from a group consensus of technical experts and advisors, based on the team's experience with the USEPA and CDPH, and on best professional judgment (Table 2-1). Scenarios were divided into three categories:

- Current - includes contaminants that are currently regulated.
- Plausible - includes contaminants that are considered likely to be regulated in some form; this is regulatory scenario that will be used to evaluate potential WTP modifications to estimate treatment costs.
- Outer Boundary- includes the same contaminants; however, the requirements could be more stringent. This scenario will only be considered qualitatively in future evaluations and are provided to bracket the regulatory possibilities.

Table 2-1:
Regulatory Scenarios

Constituent	Regulatory Scenarios		
	Current	**Plausible[1]**	**Outer Boundary[2]**
Disinfection Byproduct Precursors			
Organic Carbon and Organic Nitrogen	Enhanced Coagulation Treatment Technique under the Stage 1 D/DBP Rule	Same as current	Control TOC as a precursor Control DON as a precursor
Disinfection Byproducts			
Chlorite	1 mg/L (daily at EPDS, monthly in DS)	Same as current	Same as current
Chlorate	-	700 μg/L (daily at EPDS, monthly in DS)	Same as plausible
Bromate	10 μg/L(RAA)	5 or 10 μg/L*	1 to 4 μg/L*
THMs			
THM4	80 μg/L(LRAA)	80 μg/L*	Regulate individual species*
Iodinated THMs	-	-	Regulate iodinated THMs as a group*
HAAs			
HAA5	60 μg/L(LRAA)	60 μg/L*	Individual levels for selected species
HAA9	-	80 μg/L(LRAA), additional species to current regulations	1. 80 μg/L* 2. Individual levels for selected species*

Constituent	Regulatory Scenarios		
	Current	**Plausible**[1]	**Outer Boundary**[2]
Iodinated HAAs	-	-	Regulate as a group or individual species*
Nitrogenous Organic Compounds			
Nitrosamines	3 ng/L[3] Public Health Goal (PHG), 10 ng/L[3] Notification Level (NDMA)	NDMA at 3 to 10 ng/L(LRAA)[4]	Regulate select compounds*
Hydrazine	-	-	10 ng/L*
Disinfection Practices and Views			
Chloramination	Accepted technology	Other technologies preferred	Technology prohibited
View of low to no use of disinfectants	View generally not accepted in U.S	Same as current	View begins to be accepted in U.S.
Dissolved Minerals			
TDS	500 mg/L secondary MCL	Same as current	Reduction required to reduce salinity load and recycled water
Nutrients			
Nitrite	1 mg/L (as N) at EPDS	1 mg/L(as N) in DS	Same as plausible
Nitrate	10 mg/L(as N) at EPDS	10 mg/L (as N) in DS	Regulation pending heath data
Algal Toxins			
Microcystin	-	1 μg/L WHO guideline	Same as plausible
Anatoxin-a	-	-	3 μg/L (suggested, Australia)
Saxitoxin	-	-	3 μg/L (suggested, Australia)
Pathogens and Indicators			
Total coliform (TC), Fecal coliform (FC), and *E. coli*	Monitoring based upon population. TC triggers assessment and corrective action. Failure to take corrective action is considered a treatment technique violation. A violation of E. Coli MCL occurs when routine and repeat TC samples are positive and one is also E. Coli positive. Failure to take repeat sample after E. Coli positive is also considered E. Coli violation. A violation triggers public notice.	Same as current	Same as current
Cryptosporidium	2-log removal credit (IESWTR[6]); Additional inactivation needed based on source water concentration (LT2ESWTR)	Same as current	Additional 1-log
Giardia and enteric viruses	3-log inactivation and/or removal of Giardia cysts and 4-log inactivation and/or removal of enteric viruses.	Same as current	Same as current

Constituent	Regulatory Scenarios		
	Current	Plausible[1]	Outer Boundary[2]
CCL3 Pathogens	-	Regulated, but less challenging to remove/inactivate than SWTR and LT2ESWTR standards	Same as plausible

[1]Scenario will be used in treatment selection and future costing.
[2]Scenario will be discussed qualitatively, but not included in future costing.
[3]CDPH regulation.
[4]NDMA is considered by the regulatory agency as an indicator of other nitrosamines' levels
[5]Current regulation represents the proposed revisions to the Total Coliform Rule based on the 2008 Total Coliform Rule/Distribution System Advisory Committee Agreement in Principle.
[6]Interim Enhanced Surface Water Treatment Rule (IESWTR)
*Single sample not to exceed. This could include multiple samples collected instantaneously a given location to average results and avoid an unrepresentative sample or could include re-sampling in the case of an outlier result. Intention is to obtain a sample that is representative of the quality of the water in a particular location at a unique point in time.

2.1. Disinfection Byproducts

Currently regulated DBPs include chlorite, bromate, THM4, and HAA5. There are a number of reasons that the USEPA may consider modifying the current regulations for these DBPs as well as regulating other DBPs:

- Cancer is not the only health endpoint being detected in epidemiology studies; there are new concerns about potential adverse reproduction and developmental effects (Richardson 2005).
- New human exposure studies are including inhalation and dermal absorption routes of exposure to DBPs in addition to ingestion, which is revealing increased cancer risks (Richardson 2007).
- Brominated DBPs may be more carcinogenic than their chlorinated analogs (Richardson 2005, WHO 2000, Woo et al. 2002).
- Iodinated DBPs may be more carcinogenic than their brominated analogs (Richardson 2005, Plewa et al. 2004, Woo et al. 2002)

Chlorite is currently regulated DBP of chlorine dioxide and has an MCL of 1 mg/L. Chlorite can also be formed as an intermediate between hypochlorite and chlorate during hypochlorite decomposition. The California public health goal (PHG) for chlorite is much lower than the MCL at 0.050 mg/L (OEHHA 2009). PHGs are developed based on the latest toxicological information and reference the concentration at which no potential adverse health effect will occur. PHGs, along with economic and technology factors, are considered by CDPH in the development of MCLs. In general, MCLs are set as close to the PHG as economically feasible. Despite the relatively low PHG for chlorite, economic and technology factors make it unlikely that the current MCL regulation will change by 2030 but was added to include all currently regulated DBPs.

Chlorate is a contaminant produced during on-site generations of hypochlorite solutions, the decomposition of hypochlorite, and as a chlorine dioxide DBP. There is not currently a CDPH or USEPA MCL for chlorate. The state of California currently has set a notification level of 0.8 mg/L for chlorate (CDPH 2007). The World Health Organization (WHO) has set a provisional guideline value of 700 μg/L for chlorate (WHO 2008). Chlorate exhibits the same mechanism of action on the thyroid as perchlorate, albeit with lower potency (Synder 2009, USEPA 1999). Despite the lower potency relative to perchlorate, chlorate occurrence in drinking waters is much higher than perchlorate in drinking water. As increasing health effect information becomes available, chlorate could be regulated at the WHO guideline of 700 μg/L (plausible).

Bromate is currently regulated at 10 μg/L, which corresponds to a cancer risk factor of 2×10^{-4} (typically, the basis for MCLs is 10^{-4} to 10^{-6}). It is anticipated that this MCL could be reduced to 5 μg/L (plausible) or lower (outer boundary) in an effort to reduce the cancer risk to 1×10^{-4} or lower. This risk has to be balanced with the fact that bromate could be present in the common disinfectant chemical, sodium hypochlorite.

THMs are regulated as a group (THM4) on a LRAA basis at 80 μg/L under the Stage 2 DBP Rule (effective from 2012). Epidemiological evidence has produced uncertain and sometimes conflicting conclusions on the reproductive effects of exposure to DBPs. For example, an extensive literature review by Reif et al. 2000 found that evidence for an increased risk of spontaneous abortion and stillbirth exists but is uncertain (Health Canada 2006). A more recent study by American Water Works Research Foundation (AwwaRF) found no association between THM exposure and pregnancy loss (Savitz et al. 2005). More research is needed; however, due to the fact that contaminant levels can significantly vary with the LRAA calculation method, it is possible that the THM regulation will change to single sample not to exceed 80 μg/L to reduce variability and limit acute or reproductive health effects (plausible). A single sample not to exceed requirement could include the collection of multiple samples instantaneously at a given location to average results and avoid an unrepresentative sample. In the case of an outlier result, the regulation could include a requirement for re-sampling. The intention of a single sample not to exceed condition is to obtain a sample that is representative of the quality of the water in a particular location at a unique point in time. As an increasing amount of health effects data becomes available, regulations may be directed to individual species to reduce associated health risks (outer boundary).

Similar to THMs, HAAs are regulated under the Stage 2 DBP Rule as a group (HAA5) at 60 μg/L on an LRAA basis. To limit variability and reduce acute human health effects, HAA5 regulation will possibly change to a single sample not to exceed (plausible). Further, as additional human health effect data becomes available, regulations may be directed to individual species (outer boundary). It is recognized that additional regulation may be necessary to represent the entire group of HAAs that can be formed (HAA9).

HAA9 is not currently regulated; however, it is possible that HAA9 will be regulated in the future and could be regulated as a group at a level of 80 μg/L LRAA (plausible). Although it is less likely, HAA9 regulation may be directed to 80 μg/L single sample not to exceed or depending on available human health affect data on an individual species basis (outer boundary).

Iodinated DBPs including I-THMs and I-HAAs are not currently regulated. I-DBPs are of increasing concern due to their occurrence in finished water systems that use chloramines (Krasner et al. 2006) and increased human health risks relative to chlorinated and brominated DBPs (Richardson 2005). Despite the increased health risks relative to chlorinated and brominated DBPs, more occurrence and toxicology data are needed for I-THMs and I-HAAs. In addition, THMs and HAAs are surrogates for halogenated DBPs, including I-DBPs. If additional data become available, regulation of I-DBPs may be possible as a group or as individual species, which was designated as the outer boundary condition.

2.2. Nitrogenous Organic Compounds

Nitrogenous organic compounds, including nitrosamines, have been hypothesized to account for the bladder cancer incidence noted in epidemiological studies of chlorinated water (Walse 2008, Mostafa 1999). NDMA is one nitrosamine that is both a DBP and can be an industrial pollutant (independent of disinfection). It is possible that the future regulation of NDMA will be in the 3 to 10 ng/L range as a LRAA (plausible). Although less likely, regulations requiring treatment for dissolved organic nitrogen (as a precursor) similar to the TOC removal requirements set forth in the Stage 1 DBP Rule could be established (outer boundary). If the health effect data and occurrences justify individual regulations of various nitrosamines species, regulation of individual compounds could result (outer boundary).

Hydrazine is a probable human carcinogen that can be formed through the reaction of monochloramine and ammonia. Hydrazine is formed as a result of the addition of these chemicals, not due to source water quality. Additionally, hydrazine formation is not detectable in drinking waters with pH lower than 9.0 (Najm 2007). For this reason, regulation of hydrazine is not likely (plausible). However, the cancer risk level for hydrazine at 10 ng/L is 10-6, and this risk level is within the range typically captured by an MCL. Although it is unlikely, plants using lime softening or distribution system conditions that result in pH excursions may create the need for future regulation of hydrazine at 10 ng/L single sample not to exceed (outer boundary).

2.3. Disinfection Practices and Views

With the increasing concern over DBPs, disinfection practices are increasingly scrutinized. The benefits of the inactivation of pathogens must continuously be balanced with the formation of compounds that adversely affect human health. For this reason, it is likely that chloramination may become the less preferred disinfection method, specifically because of potential nitrogenous DBP formation (plausible). In some countries outside of the United States, the practice of maintaining minimal or no residual in the distribution is common. This viewpoint is not likely to be accepted in the United States; however, as an increasing number of studies indicate the adverse health effects associated with US disinfection practices, chloramination may be prohibited in the future (outer boundary).

2.3.1. Dissolved Minerals

Dissolved minerals are becoming an increasingly important issue in drinking water treatment. Currently, USEPA and CDPH have established secondary MCLs for TDS. The USEPA secondary MCL is 500 mg/L and is an unenforceable guideline. CDPH has established a secondary maximum contaminant level range for TDS. Secondary MCLs in California are enforceable limits based on a consumer acceptance contaminant level; however, the consumer acceptance contaminant level for TDS is not fixed (Table 2-2). As salinity continues to increase, adverse affects on the treatment process and the ability to recycle water may be experienced. It is likely TDS will be monitored in the future, and the regulation likely will not change (plausible). With the increasing importance of water recycling, TDS reductions may be necessary (outer boundary); however, it is unlikely that a SDWA regulation would require this.

Table 2-2.
Consumer Acceptance Contaminant Level

Constituent, Units	Recommended[1]	Upper[2]	Short Term[3]
Total Dissolved Solids, mg/L	500	1,000	1,500
Or			
Specific Conductance, µS/cm	900	1,600	2,200
Chloride, mg/L	250	500	600
Sulfate, mg/L	250	500	600

Source: CDPH, 2008.
Notes:
(1) Constituent concentrations lower than the recommended contaminant level are desirable for a higher degree of consumer acceptance.
(2) Constituent concentrations ranging to the Upper contaminant level are acceptable if it is neither reasonable nor feasible to provide more suitable waters.
(3) Constituent concentrations ranging to the short term contaminant level are acceptable only for existing community water systems on a temporary basis pending construction of treatment facilities or development of acceptable new water sources.

2.4. Nutrients

Nitrite and nitrate are currently regulated at MCLs of 1 and 10 mg/L as N, respectively. These regulations could be revised as a part of EPA's six-year review process in the next few years. Although it was postulated that the MCLs will remain the same, it is plausible that the regulation may move the monitoring location from EPDS to DS locations, to account for contribution from nitrification (plausible). Although it is less likely, there is a chance that the nitrate MCL could be lowered if toxicological data emerges showing health effects similar to perchlorate (outer boundary).

2.4.1. Algal Toxins

Algal toxins are toxins formed by cyanobacteria that dominate the freshwater phytoplankton communities during periods of calm, stratified conditions (AwwaRF 2008). Algal toxins are of increasing interest in the US and in other countries around the worldbecause it has been observed that increased discharges of nutrients can lead to increased algal blooms (and their toxins), which have been associated with an increased incidence of fish kills, deaths of livestock and wildlife, and human illness and death (Richardson 2007). The most common algal toxins are microcystins, anatoxins, and saxitoxins. Others have recognized the need to regulate these toxins, and it is possible that the US will follow. The World Health Organization (WHO) has a guideline value for microcystin of 1 μg/L, and it is possible that this could become an MCL by 2030 (plausible). Anatoxin-a and saxitoxin do not have WHO guidelines; however, Australia has a suggested limit for these toxins of 3 μg/L. Although it is not likely, there is a possibility that an MCL for anatoxin and saxitoxin could be established at the Australia suggested limit of 3 μg/L (outer boundary).

2.4.2. Pathogens and Indicators

Currently, 2-log removal of *Cryptosporidium* is required by the IESWTR with additional inactivation required based on the bin classification outlined in the LT2ESWTR. These requirements are not likely to change by 2030, so the plausible scenario for *Cryptosporidium* inactivation will not require additional inactivation. However, future changes in source water quality could change bin classifications, triggering additional inactivation requirements. In the unlikely event that the requirements for *Cryptosporidium* removal/inactivation are increased to protect human health, it is predicted that an additional 1-log removal/inactivation will be required (outer boundary).

It is predicted that although pathogens other than *Cryptosporidium* will be regulated; none will be more challenging to remove or inactivate than *Cryptosporidium.* Table 2-3 summarizes a number of pathogens that could possibly be regulated by 2030 based on the recommendations of expert panels from American Water Works Association (AWWA) and USEPA. Many are pathogens on the CCL3. Also summarized in Table 2-3 are the treatment requirements that may be necessary to remove or inactive these pathogens. Based on this summary, it appears that the other pathogens that are likely to be regulated will not be more difficult to remove or inactivate compared to *Cryptosporidium.*

Table 2-3:
Treatment of Pathogens

Organism	Free Chlorine	Ozone	UV
Caliciviruses	Aggregated calicicivirus required CTs greater than EPA Guidance Manual CT values. Disspersed calicicivirus required CTs less than EPA Guidance Manual CT values.[2]	<0.01 to 0.03 mg/L*min for 4-log inactivation at a pH of 7 and 5° C.[28]	29 to 36 mJ/cm2 for 4-log inactivation[3]
Campylobacter jejuni	Suseptible at doses effective for E. coli[4]	NA[1]	4.6 mJ/cm2 for 4-log inactivation[5]
Entamoeba histolytica	Similar resistance to chlorine as Giardia lamblia.6 Normal water treatment practices are able to remove Entamoeba cysts.[7]	NA[1]	NA[1]
Escherichia coli (0157)	4 log inactivation at CTs of approximately 1.1 to 1.2 mg/L*min[8]. 2-log inactivation at a CT of 0.119 mg/L* min[9]	0.09 mg/L*min for 2-log inactivation[9]	6 mJ/cm2 for 4-log inactivation[10]
Helicobacter pylori	2-log CT of 0.299 mg/L*min[9]	0.24 mg/L*min for 2-log inactivation[9]	NR[1]
Hepatitis A virus	CT table for SWTR are based on Hepatitis A	NR[1]	21 mJ/cm2 for 4-log inactivation[11]
Legionella pneumophila	2 to 13.5 mg/L*min for 2-log inactivation[12]	.5 to 1.5 mg/L*min for 2-log inactivation at a pH of 7.2 and 25° C.[12]	9.4 mJ/cm2 for 4-log inactivation[13]
Naegleria fowleri	2-log CT of 6 and 31 mg/L*min at a pH of 7.5 and 23°C for trophozoite and cyst form, respectively.[29]	NA[1]	63 mJ/cm2 for 2-log inactivation[29]
Salmonella enterica	Salmonella spp. are sensitive to chlorine and do not pose a risk when conventional drinking water treatment is applied.[14]	NA[1]	7 to 10 mJ/cm2 for 4-log of Salmonella spp.[10,15]
Shigella sonnei	Shigella spp. are sensitive to chlorine and do not pose a risk when conventional drinking water treatment is applied.[14]	0.9 to 1.4 mg/L*min for 1-log inactivation at a pH of 7.2 and 25° C.[30]	8.2 mJ/cm2 for 4-log inactivation[16]
Vibrio cholerae	Vegetative bacterium is widely known to be sensitive to chlorination and does not pose a risk when drinking water is properly disinfected.[14]	Can be inactivated by Ozone.[17]	2.9 to 21 mJ/cm2 for 4-log inactivation[18]
Mycobacterium avium	51 to 204 mg/L*min for 3-log inactivation at 23°C and a pH of 7.[19]	0.1 to 0.17 mg/L*min for 3-log inactivation at a pH of 7 and 23° C.[19]	NA[1]
Rotavirus	1.6 to 6.0 for 3-log inactivation at 4°C with pHs from 6 to 8.[20]	0.6 to 3.2 mg/L*min for 3-log inactivation with pHs from 6 to 8 at 4° C.[21]	36 mJ/cm2 for 4-log inactivation.[5]
Enteroviruses (Coxsackieviruses and Echoviruses)	0.14 to 33.66 mg/L*min for 2-log inactivation for Coxsackieviruses and 0.24 to 49.0 for Echoviruses at pHs from 6 to 10 at 5°C.[22]	0.1 mg/L*min for 3-log inactivation of unassociated coxsackievirus. 1.5 mg/L*min for 3-log inactivation of cell associated coxsackievirus at 5 NTU.[23]	32.5 to 36 mJ/cm2 for 4-log inactivation of Coxsackieviruses. 28 to 33 mJ/cm2 for 4-log inactivation of Echoviruses.[24]
Adenovirus	0.16 to 0.75 mg/L*min for 4-log inactivation at pHs from 6 to 8 and at 5° C. 36.09 mg/L*min for 4-log inactivation at pH of 8 and 15° C.[2]	0.07 to 0.6 mg/L*min for 4-log inactivation at a pH of 7 and 5° C.[25]	100 to 124 mJ/cm2 for 4-log inactivation with low pressure UV lamps.[26,27] Approximately 40 mJ/cm2 for 4-log inactivation with medium pressure UV lamps.[28]
Giardia	24 to 389 mg/L*min for 3-log inactivation depending on temperature, chlorine concentration, and pH.[32]	0.48 to 2.9 mg/L*min for 3-log inactivation depending on temperature.[32]	22 mJ/cm2 for 4-log inactivation.[31]
Cryptosporidium	Free chlorine is ineffective at inactivating Cryptosporidium.[33]	4.7 to 72 mg/L*min for 3-log inactivation depending on temperature.[31]	22 mJ/cm2 for 4-log inactivation.[31]

1. NA = Not Available, results were not found during literature search. 2. Thurston-Enriquez et al. 2003a., 3. Thurston-Enriquez et al. 2003b., 4. Blaser et al. 1986, 5. Wilson et al. 1992, 6. Jarroll et al. 1981, 7. Karanis 2006, 8. Rice et al. 2008, 9. Baker et al. 2002 , 10. Tosa and Hirata 1999, 11. Wiedenmann et al. 1993, 12 Domingue et al 1998, 13 Oguma et al. 2004, 14 AWWA 2008., 15 Yaun et al 2003, 16 Chang et al. 1985 , 17. Burlson et al. 1975, 18. Hoyer 1998, 19. Taylor et al. 2000, 20. Vaughn et al. 1986, 21. Vaughn et al. 1987, 22. Engelbrecht et al. 1980, 23. Emerson et al. 1982, 24. Gerba et al. 2002, 25. Thurston-Enriquez et al. 2005, 26. Meng and Gerba 1996, 27. Ballester and Malley 2004, 28. Linden et al. 2007. 29. CAP 2008. 30. Lezcano et al. 1999. 31. USEPA 2006. 32. USEPA 1991. 33. Venczel et al. 1997

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3. Historical and Projected Future Water Quality

Understanding the source water quality for the existing Central Valley WTPs is paramount when evaluating whether existing WTPs will meet potential future regulations and determining what treatment changes (if any) may be necessary. Accordingly, identifying areas that use Central Valley surface water that have similar water quality will simplify the necessary analyses. This section presents the source water areas and the associated water quality that was used in the analysis.

3.1. Areas of Similar Source Water Quality

The Work Group identified four geographical areas that utilize water from the Delta and its tributaries, and have similar source water quality (similar levels of constituents of concern):

- Upper Sacramento and Upper-Eastern San Joaquin Watersheds (Upper Watersheds)
- Central Delta including the South Bay Aqueduct (Central Delta)
- California Aqueduct – Coastal and East Branches (CAA)
- California Aqueduct – West Branch (CAA-West)

Initially, the North Bay Aqueduct was also included as a source water area in the evaluation; however, the Work Group decided to remove it from the analysis with the assumption that WTPs in this area would likely not be affected by the development of a comprehensive Central Valley Drinking Water Policy.

Geographical area boundaries were not designated; the source water areas were bounded by the WTPs in each region with similar intake water quality (Figure 3-1). A total of 49 WTPs that use Delta water as a major source were considered.

Figure 3-1: Source Water Areas and Associated WTPs

3.2. Historical Water Quality

To characterize the water quality for each source water area, a review of available water quality data and reports was performed during Phase I of the project. This section provides a summary of the data review; the detailed analysis is included in Appendix B.

The Work Group identified water quality monitoring locations that are representative of each source water area (Table 3-1). These monitoring locations were used to summarize the water quality trends of key contaminants of concern (Table 3-2). With the exception of Upper Watershed, one monitoring location was used to represent each source water area. In the Upper Watershed, the Sacramento River at W. Sac Intake Structure monitoring station was used to represent dissolved ammonia, while the Sacramento River at Hood monitoring station was used to represent all other water quality parameters.

Table 3-1.
Representative Water Quality Monitoring Locations

Source Water Area	Monitoring Location	DWR Monitoring Station Number
Upper Watersheds	Sacramento River at Hood	B9D82211312
	Sacramento River at W. Sac Intake Structure	A0210451[1]
Central Delta	Banks Pumping Plant	KA000331
CAA	Check 13	KA007089
CAA- West Branch	Castaic Lake Tower	CA002000

Source: Representative monitoring locations provided by Work Group.

[1]During Phase II of the Evaluation, the Work Group determined that dissolved ammonia levels at the Sacramento River at Hood monitoring location were not representative of the Upper Watersheds source water area. To obtain more representative ammonia data, the Sacramento River at West Sac Intake Structure monitoring station was used.

Organic carbon and bromide are the primary DBP precursors for THMs and HAAs. Bromide can also react with ozone to form bromate, another regulated DBP. The regulatory scenarios projected for 2030 contain regulations for a number of DBPs, of which TTHM, HAA5, HAA9, and bromate can be estimated using a computer model. This project utilized the EPA Water Treatment Plant Model (EPAWTPM) Version 2.0 to evaluate the affect of changing source water quality on DBP formation. The EPAWTPM is an empirical model that simulates DBP formation (TTHM, HAA5, HAA9, Total Organic Halides, bromate, and chlorite) under given treatment conditions.

Table 3-2:
Historical Water Quality

Parameter		Upper Watersheds	Central Delta	CAA	CAA-West
(monitoring station)		(Hood)	(Banks)	(Check 13)	(Castaic Lake)
TOC, mg/L	Median	1.8	3.2	3.2	2.9
	90th Percentile	3.0	4.8	5.2	3.8
DOC, mg/L	Median	1.7	3.3	3.1	2.9
	90th Percentile	2.7	4.7	5.0	3.6
Bromide, mg/L	Median	0.01	0.18	0.19	0.19
	90th Percentile	0.02	0.48	0.38	0.26
Temperature, °C	Median	16.7	17.6	14.7	16.4
	90th Percentile	22.4	25.3	23.3	18.4
	99th Percentile	24.0	28.5	25.7	21.9

Notes: A detailed summary of water quality is provided in Appendix B. Historical data were generally available from 1998 and updated to include data up to 2008.

3.3. Predicted Future Water Quality Scenarios

The Work Group provided future water quality scenarios based on hydrodynamic modeling work completed under another project. Three scenarios for future conditions (2030) were compiled: the Planned scenario reflects changes required in existing waste discharge permits for wastewater treatment plants and urban runoff discharges, and a hypothetical 2 percent reduction in loading from agricultural land. Plausible represents more aggressive treatment of wastewater and urban runoff and a hypothetical 6 percent reduction in loading from agricultural land. The Outer Boundary scenario demonstrates the limits of what can be achieved with current technology for wastewater discharges, aggressive treatment of urban runoff, and a hypothetical 10 percent reduction in loading from agricultural land. These scenarios were modeled in the WARMF model for the Sacramento and San Joaquin basins. It should be noted, that within the Delta it was not possible to incorporate the urban runoff and agricultural load reductions due to budget and schedule constraints so only the wastewater future scenarios were modeled. Outputs from two primary computer models were used to simulate future water quality conditions:

- DSM2 outputs represented water at Clifton Court Forebay, which is representative of the Central Delta source water area.
- WARMF outputs represented water at I-Street from the watersheds feeding the Delta, which is applicable to the Upper Watersheds source water area.

The modeling results provided simulations of monthly average DOC, bromide, and temperature for current, planned future, plausible future, and outer boundary future conditions (Appendix C). TOC was calculated based on the historical relationship between DOC and TOC at Clifton Forebay, where DOC typically accounts for 92 percent of TOC. From these data, a 90th percentile was calculated (Table 3-3). Based on the input from the modelers, the model results are more reliable to demonstrate differences between various scenarios compared to the specific values predicted for any given time period. For example, based on the model results one can say that the TOC value in the outer boundary condition to be 95% of the current value (5.42/5.72) more confidently than saying that the exact value of TOC is 5.42 mg/L in the future outer boundary.

Table 3-3:
Future Water Quality Scenarios

Central Delta Source Water Area				
Parameter	**DSM2 Outputs- Clifton Court Forebay (Monthly Averaged Data)**			
	Current (2010)	**Future Planned**	**Future Plausible**	**Future Outer Boundary**
90th Percentile TOC, mg/L[1]	5.72	5.61	5.52	5.42
90th Percentile DOC, mg/L	5.26	5.16	5.08	4.99
90th Percentile Bromide, mg/L	0.41	0.41	0.41	0.39
99th Percentile Temperature, °C	24	24	24	24
Average Temperature, °C	17	17	17	17
Upper Watersheds Source Water Area				
Parameter	**WARMF I-Street (Daily Data)**			
	Current (2010)	**Future Planned**	**Future Plausible**	**Future Outer Boundary**
90th Percentile TOC, mg/L[1]	2.57	2.54	2.47	2.50
90th Percentile DOC, mg/L	2.36	2.34	2.27	2.30
90th Percentile Bromide, mg/L[2]	-	-	-	-
99th Percentile Temperature, °C	23	23	23	23
Average Temperature, °C	15	15	15	15

[1]TOC was calculation using the relationship DOC = 0.92 TOC.

[2] WARMF model did not provide bromide results; however, historically minimal bromide was present in Upper Watersheds.

Table 3-4 presents the TOC and bromide values that were used for modeling DBP formation. As shown in the table, the 10-year historical data and modeled results, which were based upon a longer historical data set, did not exactly match. For this evaluation, in order to resolve the difference between the historical and modeled results, the model parameter values were adjusted as shown in Table 3-4.

Table 3-4:
Adjustment of Modeled Future Water Quality for Consistency with Historical Data

Central Delta Source Water Area						
Parameter	**Historical**	**Modeled Current**	**Historical to Modeled Ratio**	**(Ratio) * (Future Modeled Scenario)**		
				Future Planned	**Future Plausible**	**Future Outer Boundary**
TOC, mg/L	4.79	5.72	0.84	4.70	4.63	4.54
Bromide, mg/L	0.48	0.41	1.17	0.48	0.48	0.46
Upper Watersheds Source Water Area						
Parameter	**Historical**	**Modeled Current**	**Historical to Modeled Ratio**	**(Ratio) * (Future Modeled Scenario)**		
				Future Planned	**Future Plausible**	**Future Outer Boundary**
TOC, mg/L	3.00	2.57	1.17	2.97	2.89	2.92

Note: WARMF model did not provide bromide results; however, historically minimal bromide was present in Upper Watersheds.

All future scenarios show an improvement in water quality (in terms of organic carbon) in both the Central Delta and Upper Watersheds. However, the reduction in TOC is not large enough to translate to a significant reduction in DBP formation. For example, if the TOC is reduced from 4.79 mg/L to 4.54 mg/L in the Central Delta source water area, the modeled TTHM are reduced from 49 to 43 µg/L (Table 3-5). Similarly, in the Upper Watersheds, if the TOC is reduced from 3.00 to 2.92 mg/L, the TTHM are reduced from 66 to 65 µg/L. Reductions in TTHM in the 2 to 6 µg/L range are well within the noise of the EPAWTPM and are not considered significant changes. This demonstrates that the source control measures, even in the most aggressive outer boundary scenario, does not result in TOC or bromide water quality improvements large enough to be discernable by the EPAWTPM (i.e., the changes are smaller than the overall accuracy of the EPAWTPM).

Table 3-5:
EPAWTPM Results for Future Water Quality Scenarios

Parameter	Historical Data	Future Water Quality Scenarios		
		Future Planned	Future Plausible	Future Outer Boundary
Central Delta (CD-1)				
Input TOC, mg/L	4.79	4.70	4.63	4.54
3-day TTHM, µg/L	49	45	44	43
3-day HAA5, µg/L	14	13	13	13
3-Day HAA9, µg/L	29	26	26	26
Bromate, µg/L	8	8	7	7
Upper Watersheds (UW-1)				
Input TOC, mg/L	3.0	2.97	2.89	2.92
3-day TTHM, µg/L	66	66	64	65
3-day HAA5, µg/L	48	48	47	47
3-Day HAA9, µg/L	55	55	54	54
Bromate, µg/L	0	0	0	0

Because modeling indicates water quality improvements for future water quality scenarios for the Central Delta and Upper Watersheds source water areas, it was determined that although a slight improvement in future TOC is projected, it is not significant enough to reveal meaningful changes DBP modeling results. These findings were presented to the Work Group and it was decided that the DBP modeling completed during Phase I of the project that used historical water quality could be used in Phase II project work, including the determination of treatment upgrades and estimation of costs.

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4. Virtual Water Treatment Plant Development

VWTPs were developed to represent the central tendencies of treatment in each source water area that were described in *Technical Memorandum 1: Definition of Study Boundaries* (Appendix B). These VWTPs were then used to evaluate compliance with future regulatory scenarios. This section describes the approach used to select VWTPs and the baseline conditions used to model VWTPs performance.

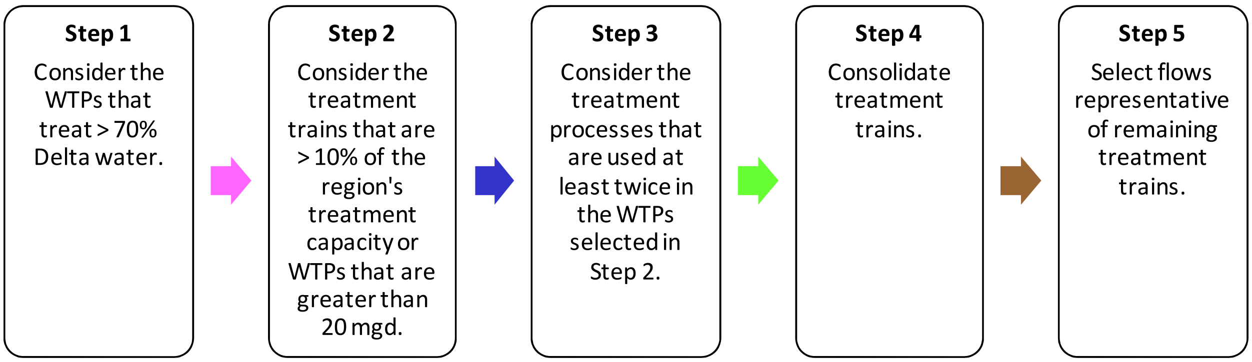
4.1. Approach

To accurately represent each source water area, a review of current WTP practices was performed. Common water treatment processes that were considered are summarized in Table 4-1. The WTPs considered were outlined previously in *Technical Memorandum 1: Definition of Study Boundaries*, and the treatment processes for each plant were reviewed for accuracy by the Work Group and CUWA Water Quality Committee. The majority of plants utilize similar treatment processes; however, not all plants could be represented equally due to variations in source water utilization, treatment capacity, and relative contribution to total source water area treatment capacity. To account for these variations, selection criteria were included in the approach to developing the VWTPs (Figure 4-1). The step-wise approach is described below using the CAA source water area as an example. The development of all VWTPs is described in detail in Appendix D.

Table 4-1.
Water Treatment Processes

Treatment Process		Description/Purpose
Particulate Removal	Pre-pH Adjustment	Acid addition for enhanced coagulation
	Rapid Mix	Mixing during coagulant addition
	Conventional	Flocculation and sedimentation
	Direct Filtration	Coagulant addition followed directly by filtration
	Slow Sand	Slow sand filtration
	Rapid Sand, Multi-media	Rapid sand or multi-media filtration
	Pressure Sand	Pressure sand filtration vessels
	Membranes	Membrane filtration
Disinfection	Pre - Chlorination	Chlorine as primary disinfectant
	Pre-Ozonation	Ozone for taste and odor control and some disinfection credit
	Post-Ozonation	Ozone for primary disinfection
	Post-chlorination	Chlorine as secondary disinfectant
	Chloramines	Chlormamines as secondary disinfectant
	MIOX	MIOX for secondary disinfection
DBP Control	GAC	GAC contactors for DBP precursor removal and taste and odor
	PAC	PAC addition for DBP precursor removal and taste and odor

Figure 4-1:
5-Step Approach to VWTP Development



Step 1- Consider WTPs that Treat More Than 70 Percent Delta Water

Many WTPs have access to water sources other than Delta water (groundwater, Colorado River, etc.). As water quality in the Delta changes or as regulations become more stringent, these facilities could potentially incorporate blending as a treatment option. Blending is beyond the scope of this analysis, so plants that utilize this option (i.e., use less than 70% Delta and blend other sources) were no longer considered in the VWTP development.

Eighteen WTPs totaling approximately 2200 mgd of capacity were evaluated in the development of CAA VWTPs (Table 4-2). Of the facilities considered, only one WTP (Plant R) used less than 70 percent Delta water and could be eliminated from VWTP development (Table 4-3).

Table 4-2:
WTPs Considered for CAA VWTP Development

Plant ID	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal								Disinfection						DBP Control	
				Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A	-	-	*		x	x			x			x							
B	2.2	0.1%	*			x				x					x				
C	3	0.1%	*			x			x							x		x	
D	3.1	0.1%	*		x	x			x						x				
E	4	0.2%	100*			x			x						x				
F	5	0.2%	*			x			x								x	x	
G	10	0.5%	100*			x			x						x				
H	12	0.5%	*		x	x			x						x	x			
I	14	0.6%	100*						x			x			x				
J	30	1.4%	80-100*			x			x						x			x	
K	43	2.0%	80-100*		x	x			x			x			x	x		x	
L	65	3.0%	100*			x			x							x			
M	80	3.6%	0-100		x	x			x			x			x	x			
N	100	4.5%	0-100		x	x			x				x		x	x			
O	160	7.3%	100	x	x	x			x				x			x			
P	520	23.6%	45-86	x	x	x			x			x	x			x			
Q	520	23.6%	39-75	x	x	x			x			x	x			x			
R	630	28.6%	32-55	x	x	x	x		x			x	x			x			
	2201	Total Regional Treatment Capacity																	

Source: WTP data were provided by the Work Group.
*Approximate value

Table 4-3:
Step 1- Consider CAA WTPs that Treat More Than 70% Delta Water

				Particulate Removal								Disinfection						DBP Control	
Plant ID	Size (MGD)	% Regional Treatment Capacity	**% Delta Water[1]**	Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A	-	-	**-**		x	x			x			x							
B	2.2	0.1%	**-**			x				x					x				
C	3	0.1%	**-**			x			x							x		x	
D	3.1	0.1%	**-**		x	x			x						x				
E	4	0.2%	**100**			x			x						x				
F	5	0.2%	**-**			x			x								x	x	
G	10	0.5%	**100**			x			x						x				
H	12	0.5%	**-**		x	x			x						x	x			
I	14	0.6%	**100**						x			x			x				
J	30	1.4%	**80-100**			x			x						x			x	
K	43	2.0%	**80-100**		x	x			x			x			x	x		x	
L	65	3.0%	**100**			x			x							x			
M	80	3.6%	**0-100**		x	x			x			x			x	x			
N	100	4.5%	**0-100**		x	x			x				x		x	x			
O	160	7.3%	**100**	x	x	x			x				x			x			
P	520	23.6%	**45-86**	x	x	x			x			x	x			x			
Q	520	23.6%	**39-75**	x	x	x			x			x	x			x			
R[2]	*630*	*28.6%*	***32-55***	*x*	*x*	*x*	*x*		*x*			*x*	*x*			*x*			
	2201	Total Regional Treatment Capacity																	

Source: WTP data were provided by the Work Group.
Notes:
[1]Approximate value
[2]Highlighted italicized WTPs were removed from table and no longer used in VWTP development.

Step 2- Consider Treatment Trains that are Greater than 10 percent of the Total Source Water Area's Treatment Capacity or WTPs Greater than 20 Million Gallons per Day (MGD)

Each source water area varies in total treatment capacity and number of WTPs. Many of the WTPs within a given source water area utilize a similar treatment train; however, some incorporate treatment processes that are unique. It would not be appropriate to represent an entire source water area with a unique treatment train that is used at one relatively small facility. For this reason, the total treatment capacity of the source water area was calculated, and if a treatment train (from one or the sum of many WTPs) was not at least 10 percent of the total source water area treatment capacity, it was no longer considered in the VWTP development.

It is equally important to consider the cases when the majority of the total source water area treatment capacity is the result of one or two large WTPs. However, it is not appropriate to eliminate a WTP from consideration because it shares a source water area with a very large plant. This is captured in the second part of Step 2: plants greater than 20 mgd (that would have been previously eliminated for being less than 10 percent of the total source water area treatment capacity) are still considered for VWTP development.

The CAA source water area has the largest treatment capacity of all of the source water areas. The CAA WTPs considered range in size from 2.2 to 520 mgd (Table 4-4). It would not be appropriate to represent an entire source water area with a unique treatment train that is used at one relatively small facility (Plants A through I). However, due to the presence of a few relatively large WTPs in this source water area, it was important to capture the second part of these step; plants less than 10% of the total CAA capacity, but greater than 20 mgd are still considered (Plants J, K, L, M, N, O).

Table 4-4:
Step 2- Consider CAA Treatment Trains that are Greater than 10% of the Total CAA Source Water Area Treatment Capacity OR CAA WTPs Greater than 20 mgd

Plant ID	Size (MGD)	% Regional Treatment Capacity	% Delta Water[1]	Particulate Removal: Pre-pH Adjustment	Particulate Removal: Rapid Mix	Particulate Removal: Conventional	Particulate Removal: Direct Filtration	Particulate Removal: Filtration: Slow Sand	Particulate Removal: Filtration: Rapid Sand, Multi-media	Particulate Removal: Filtration: Pressure Sand	Particulate Removal: Membranes	Disinfection: Pre - Chlorination	Disinfection: Pre-Ozonation	Disinfection: Post-Ozonation	Disinfection: Post-chlorination	Disinfection: Chloramines	Disinfection: MIOX	DBP Control: GAC	DBP Control: PAC
A[2]	-	**-**	-		*x*	*x*			*x*			*x*							
B[2]	*2.2*	***0.1%***	-			*x*				*x*					*x*				
C[2]	*3*	***0.1%***	-			*x*			*x*							*x*		*x*	
D[2]	*3.1*	***0.1%***	-		*x*	*x*			*x*						*x*				
E[2]	*4*	***0.2%***	*100*			*x*			*x*						*x*				
F[2]	*5*	***0.2%***	-			*x*			*x*								*x*	*x*	
G[2]	*10*	***0.5%***	*100*			*x*			*x*						*x*				
H[2]	*12*	***0.5%***	-		*x*	*x*			*x*						*x*	*x*			
I[2]	*14*	***0.6%***	*100*						*x*			*x*			*x*				
J	**30**	**1.4%**	80-100			x			x						x			x	
K	**43**	**2.0%**	80-100		x	x			x			x			x	x		x	
L	**65**	**3.0%**	100			x			x							x			
M	**80**	**3.6%**	0-100		x	x			x			x			x	x			
N	**100**	**4.5%**	0-100		x	x			x				x		x	x			
O	**160**	**7.3%**	100	x	x	x			x				x			x			
P	520	**23.6%**	45-86	x	x	x			x			x	x			x			
Q	520	**23.6%**	39-75	x	x	x			x			x	x			x			
	2201	**Total Regional Treatment Capacity**																	

Source: WTP data were provided by the Work Group.
Notes:
[1]Approximate value
[2]Highlighted italicized WTPs were removed from table and no longer used in VWTP development.

Step 3- Consider the Unit Treatment Processes that are Used at Least Twice in the Source Water Area

Of the remaining WTPs being considered for VWTP development, it is important to consider the treatment processes most commonly used. This step eliminates individual unit processes that are not used by the majority of WTPs in a source water area. In the CAA source water area example, only one of the remaining WTPs uses chlorine for secondary disinfection (Table 4-5). It would not be appropriate to represent the entire region with a plant that uses chlorine for secondary disinfection, so this WTP was removed from VWTP development.

Table 4-5:
Step 3- Consider the unit treatment processes that are used at least twice in the CAA source water area

				Particulate Removal								Disinfection						DBP Control	
Plant ID	Size (MGD)	% Regional Treatment Capacity	% Delta Water[1]	Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
J[2]	*30*	*1.4%*	*80-100*			*x*			*x*						*x*			*x*	
K	43	2.0%	80-100		x	x			x			x			x	x		x	
L	65	3.0%	100			x			x							x			
M	80	3.6%	0-100		x	x			x			x			x	x			
N	100	4.5%	0-100		x	x			x				x		x	x			
O	160	7.3%	100	x	x	x			x				x			x			
P	520	23.6%	45-86	x	x	x			x			x	x			x			
Q	520	23.6%	39-75	x	x	x			x			x	x			x			

Source: WTP data were provided by the Work Group.
Notes:
[1]Approximate value
[2]Highlighted italicized WTPs were removed from table and no longer used in VWTP development.

Step 4- Consolidate Remaining Treatment Trains

This step builds the VWTPs by consolidating the remaining treatment processes. Plants K, L, and M are all conventional facilities with chloramines (Table 4-6) and plants N, O, P, and Q are conventional facilities with ozone, chloramines, and pH adjustment. For this reason, these two treatment trains were selected for the VWTPS. It is also important to note that the predominant treatment trains may not be the same process sequence as the virtual treatment process.

Table 4-6:
Step 4- Consolidate Remaining CAA Treatment Trains

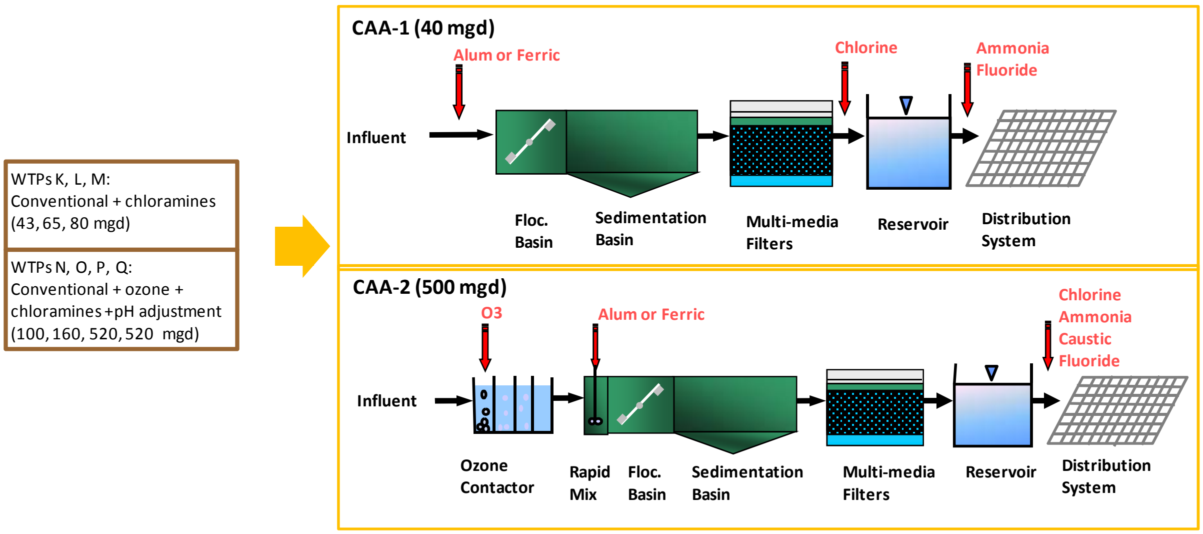
				Particulate Removal								Disinfection						DBP Control	
Plant ID	Size (MGD)	% Regional Treatment Capacity	% Delta Water[1]	Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
K	43	2.0%	80-100		x	x			x			x			x	x		x	
L	65	3.0%	100			x			x							x			
M	80	3.6%	0-100		x	x			x			x			x	x			
N	100	4.5%	0-100		x	x			x				x		x	x			
O	160	7.3%	100	x	x	x			x				x			x			
P	520	23.6%	45-86	x	x	x			x			x	x			x			
Q	520	23.6%	39-75	x	x	x			x			x	x			x			

Source: WTP data were provided by the Work Group.
Notes:
[1]Approximate value

Step 5- Select Treatment Capacities Representative of Remaining Treatment Trains

The focus up to this point has been on the treatment process. This step selects a representative treatment capacity for each VWTP treatment train based on the relative sizes of WTPs in the source water area. In the CAA source water area, the conventional process with chloramines represented the smaller facilities (<100 mgd) in the area, whereas the process with ozone was representative of the larger plants (Figure 4-2). The economy of scale for costs could be significant between 40 and 80 mgd. To be conservative, the lower end of the range, 40 mgd, was selected for CAA-1. The same is not true in the 100 to 500 mgd range. To represent the larger plants, 500 mgd was selected for CAA-2.

Figure 4-2:
Step 5- Select Treatment Capacities Representative of Remaining CAA Treatment Trains



4.2. Summary of Source Water Area VWTPs

Using the approach described in Section 4.1, VWTPs were developed for each source water area. In some source water areas two or three VWTPs were necessary to represent the variety of treatment processes and range of treatment capacities. The development of all VWTPs is summarized in detail in Appendix D. A summary of the initial selection of representative VWTPs is presented in Table 4-7 below.

Table 4-7.
Initial VWTPs

Source Water Area	VWTP Identifier	Size (MGD)	Particulate Removal	Primary Disinfection	Secondary Disinfection	pH Adjustment
Upper Watersheds	UW-1	100	Conventional*	Chlorine	Chlorine	Yes
	UW-2	100	Direct Filtration	Chlorine	Chloramines	No
Central Delta	CD-1	40	Conventional*	Ozone + Chlorine	Chloramines	Yes
CAA	CAA-1	40	Conventional*	Chlorine	Chloramines	No
	CAA-2	500	Conventional*	Ozone + Chlorine	Chloramines	Yes
CAA- West Branch	CAAW-1	800	Conventional*	Ozone + Chlorine	Chloramines	Yes

*Convention particulate removal includes alum coagulation, flocculation, sedimentation, and multi-media filtration.

The VWTPs initially selected were presented to a group of CUWA members on August 19, 2008. The CUWA members reviewed the treatment processes used in the analysis for accuracy, and the analysis was then presented to the Work Group on September 3, 2008. Upon review from the Work Group, it was determined that the direct filtration WTPs in the Upper Watersheds source water area (similar to the elimination of the North Bay Aqueduct source water area) would not be affected by the development of the Drinking Water Policy. Upon direction from the Work Group, UW-2 was eliminated from the analysis.

Table 4-8:
Selected VWTPs

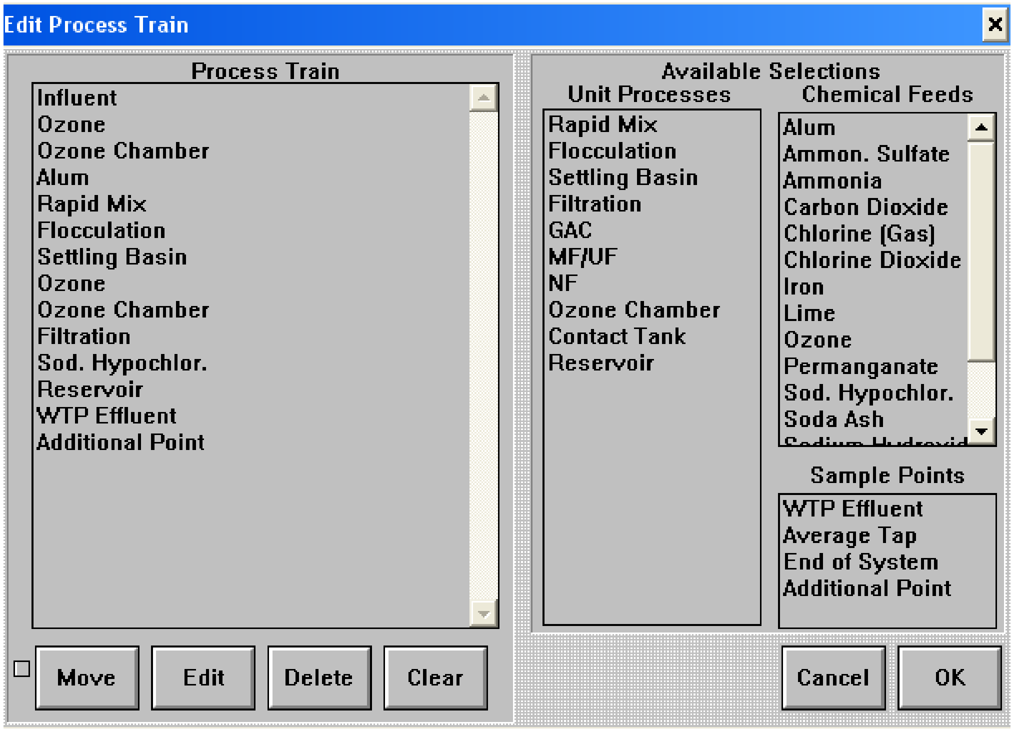
Source Water Area	VWTP Identifier	Size (MGD)	Particulate Removal	Primary Disinfection	Secondary Disinfection	pH Adjustment
Upper Watersheds	UW-1	100	Conventional*	Chlorine	Chlorine	Yes
Central Delta	CD-1	40	Conventional*	Ozone + Chlorine	Chloramines	Yes
CAA	CAA-1	40	Conventional*	Chlorine	Chloramines	No
	CAA-2	500	Conventional*	Ozone + Chlorine	Chloramines	Yes
CAA- West Branch	CAAW-1	800	Conventional*	Ozone + Chlorine	Chloramines	Yes

*Conventional particulate removal includes alum coagulation, flocculation, sedimentation, and multi-media filtration.

4.3. VWTP Baseline Modeling Conditions

The EPAWTPM was used to evaluate the affect of changing source water quality on VWTPs. The EPAWTPM is an empirical model that simulates DBP formation (THM4, HAA5, HAA9, Total Organic Halides, bromate, and chlorite) under given treatment conditions. The EPAWTPM can evaluate a variety of treatment processes and disinfectant options. Examples of some of the unit processes, chemical feeds, and sampling locations that can be used to build a treatment train are captured in a screen shot of the model in Figure 4-3.

Figure 4-3:
EPAWTPM Process Train Screen Shot



Each VWTP was entered into the EPAWTPM to develop baseline treatment conditions. By varying the treatment scenarios or water quality conditions, the model provided an understanding of how the input variables affect disinfection and DBP formation. In all baseline evaluations, 90th percentile historical water quality values were used to develop conservative estimates of treatment capabilities and to outline baseline VWTP conditions.

4.3.1. Treatment Guidelines and Design Assumptions

The treatment processes included in each VWTP represent the central tendencies of treatment within a specific source water area. VWTP treatment and design guidelines were developed that are consistent with traditional treatment practices and generally representative of the treatment strategies used throughout the source water areas. The general treatment guidelines used for each treatment process utilized by the VWTPs are summarized below.

Pre-Oxidation (Ozone) Guidelines

- Adjust pH to 6.6 prior to ozone treatment
- Set ozone dose as 0.5 mg ozone/ mg influent TOC
- Ozone Contactor detention time– 12 minutes

Coagulation Guidelines

- Use alum as coagulant
- Meet Step 1 Enhanced Coagulation TOC removal requirements
- Define upper bound alum dose
  - 10 mg alum/ mg TOC when influent TOC is less than 5 mg/L
  - 8 mg alum/ mg TOC when influent TOC is greater than 5 but less than 8 mg/L
  - 7 mg alum/ mg TOC when influent TOC is greater than 8 but less than 10 mg/L
  - 5 mg alum/ mg TOC when influent TOC is greater than 10 mg/L

Disinfection Guidelines

- Achieve *Giardia* inactivation $CT_{achieved}/CT_{required}$ ratio of 1.5 at 5 °C with chlorine
- If chlorine is used for secondary disinfection, target a residual of 0.5 mg/L at 3 days water age in the distribution system
- If chloramines are used for secondary disinfection, generate 3 mg/L at the WTP effluent
- Target a finished water pH of 7.8 to 8.1

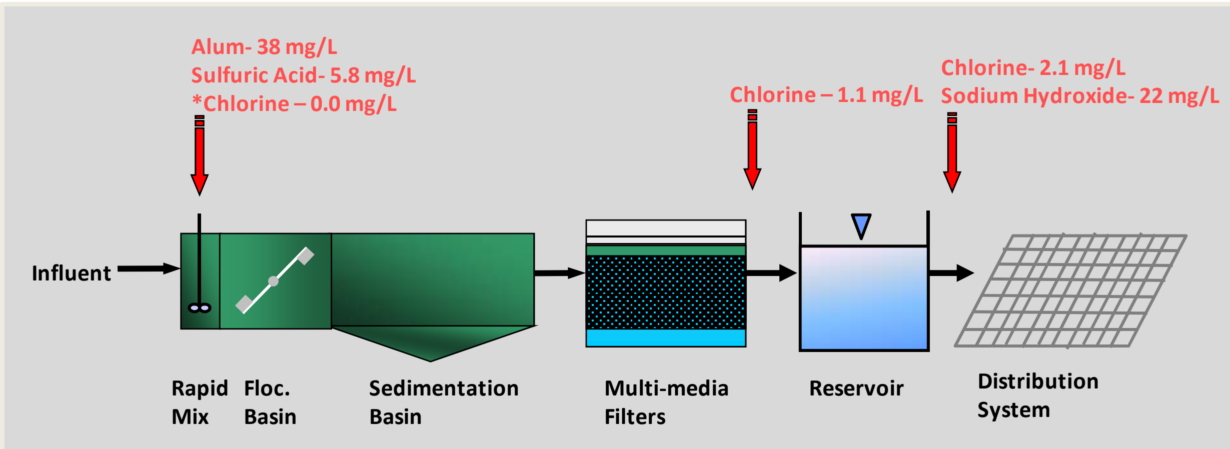
Unit Process Design Guidelines

- Rapid Mix detention time – 30 seconds
- Flocculation detention time - 30 minutes
- Sedimentation surface overflow rate- 1500 gpd/ft^2
- Filtration rate- 6 gpm/ft^2

4.3.2. Baseline VWTPs

Once a process train was outlined in the model, the treatment guidelines and design assumptions described in Section 4.3.1 were used along with 90th percentile historical source water quality data to develop model inputs. Key model inputs and outputs for all of the VWTPs are displayed in the figures and tables below. Detailed baseline VWTP EPAWTPM inputs are included in Appendix E.

Figure 4-4:
UW-1 Baseline VWTP



* Source water ammonia levels at the Sacramento River at Hood monitoring station were 0.63 mg/L (90th percentile), which would require the use of breakpoint chlorination in order to maintain a free chlorine residual. Based on direction from the Work Group, it was determined that Hood ammonia levels were not representative of the Upper Watersheds source water area and that ammonia levels (0.03 mg/L 90th percentile) from the monitoring station at Sacramento River at West Sac. Intake Structure should be used instead.

Table 4-9:
UW-1 Baseline VWTP Inputs and Outputs

Inputs		Outputs	
Size, mgd	100	TOC Removal, %	32
Influent TOC, mg/L	3.0	3-Day* THM, µg/L	65
Influent UV254, 1/cm	0.091	3-Day* HAA5, µg/L	46
Influent Bromide, µg/L	20	Bromate, µg/L	0

*3-Day indicates the EPAWTPM modeled DBP formation in the distribution system at a water age of three days.

Figure 4-5:
CD-1 Baseline VWTP

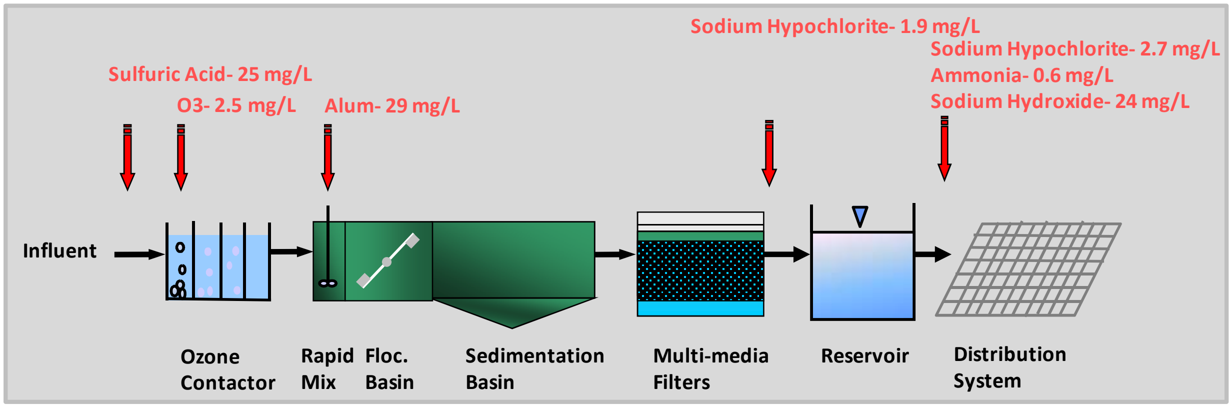


Table 4-10:
CD-1 Baseline VWTP Inputs and Outputs

Inputs		**Outputs**	
Size, mgd	40	TOC Removal, %	30
Influent TOC, mg/L	4.8	3-Day* THM, µg/L	64
Influent UV254, 1/cm	0.193	3-Day* HAA5, µg/L	18
Influent Bromide, µg/L	480	Bromate, µg/L	8

*3-Day indicates the EPAWTPM modeled DBP formation in the distribution system at a water age of three days.

Figure 4-6:
CAA-1 Baseline VWTP

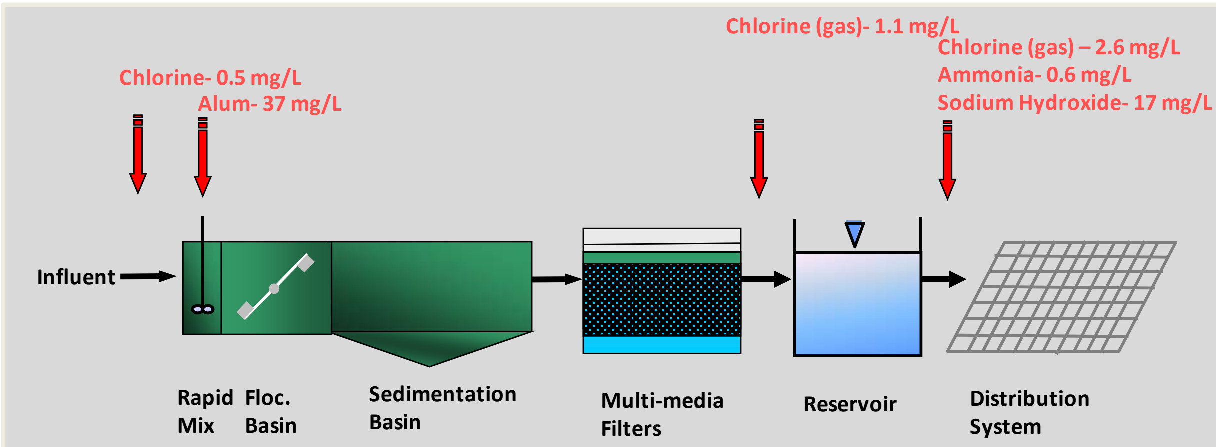


Table 4-11:
CAA-1 Baseline VWTP Inputs and Outputs

Inputs		Outputs	
Size, mgd	40	TOC Removal, %	25
Influent TOC, mg/L	5.2	3-Day* THM, μg/L	64
Influent UV254, 1/cm	0.172	3-Day* HAA5, μg/L	17
Influent Bromide, μg/L	379	Bromate, μg/L	0

*3-Day indicates the EPAWTPM modeled DBP formation in the distribution system at a water age of three days.

Figure 4-7:
CAA-2 Baseline VWTP

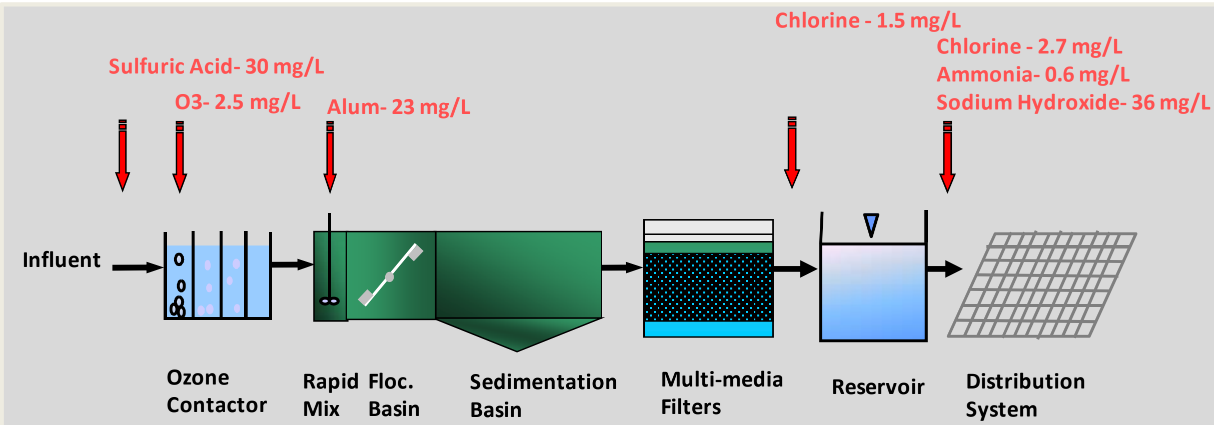


Table 4-12:
CAA-2 Baseline VWTP Inputs and Outputs

Inputs		Outputs	
Size, mgd	500	TOC Removal, %	35
Influent TOC, mg/L	5.2	3-Day* THM, µg/L	60
Influent UV254, 1/cm	0.172	3-Day *HAA5, µg/L	18
Influent Bromide, µg/L	379	Bromate, µg/L	7

*3-Day indicates the EPAWTPM modeled DBP formation in the distribution system at a water age of three days.

Figure 4-8:
CAAW-1 Baseline VWTP

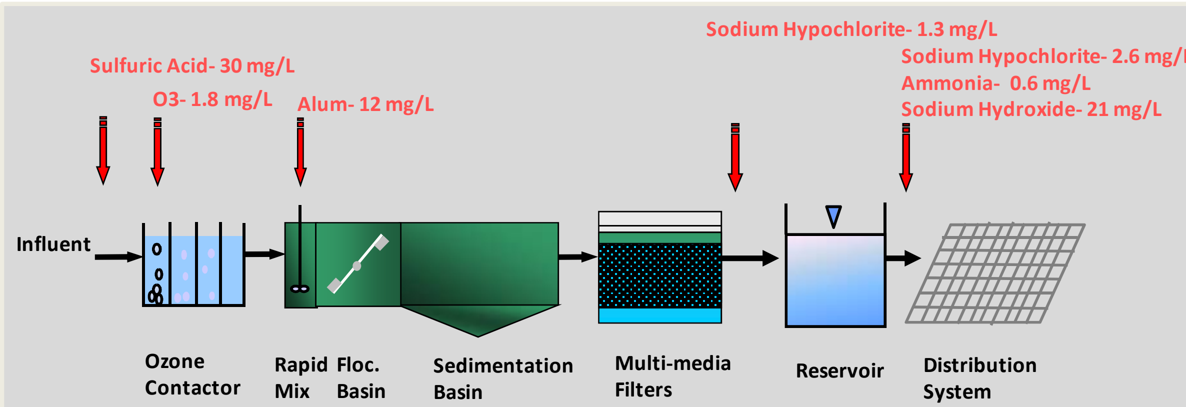


Table 4-13:
CAAW-1 Baseline VWTP Inputs and Outputs

Inputs		Outputs	
Size, mgd	800	TOC Removal, %	25
Influent TOC, mg/L	3.8	3-Day* THM, µg/L	47
Influent UV254, 1/cm	0.100	3-Day* HAA5, µg/L	15
Influent Bromide, µg/L	260	Bromate, µg/L	5

*3-Day indicates the EPAWTPM modeled DBP formation in the distribution system at a water age of three days.

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5. Identification of Treatment Triggers

Phase I of the project defined the boundaries of this evaluation by developing future regulatory scenarios (Section 2), identifying areas of similar source water quality, and outlining existing water treatment practices in each source water area. VWTPs that are representative of each source water area were then developed based on existing treatment practices (Section 4). This section combines that work and presents the threshold source water quality levels (i.e., treatment triggers) where the plausible regulatory scenario would exceed treatment targets (greater than 80 percent of the MCL) and create the need for capital or operational modifications to a VWTP. These treatment triggers were developed for current and plausible future regulations for each VWTP.

5.1. Methods for Developing a Treatment Trigger

To identify and select a treatment trigger, many contaminant properties were considered:

- Occurrence
- Formation/destruction mechanisms and rates
- Water quality conditions that affect formation/destruction

These properties are well understood for THM4, HAA5, chlorite, and bromate and were modeled by the EPAWTPM to determine the treatment trigger. For other contaminants, such as nitrosamines and algal toxins, recent literature was examined to determine treatment triggers.

5.2. THMs, HAAs, Bromate, and Chlorite

Treatment triggers for THM4, HAA5, HAA9, and bromate were developed for each VWTP using the EPAWTPM. Chlorite can also be modeled; however, formation is estimated based on the use of chlorine dioxide and none of the VWTPs utilize chlorine dioxide.

First, the baseline treatment conditions (90^{th} percentile historical water quality for each VWTP) were used as inputs to the EPAWTPM. Next, TOC, UV254, and bromide were varied until a THM, HAA, or bromate target was exceeded. Adjustments were made to the chemical doses with each model iteration to meet the treatment guidelines (Section 4.3.1). This process was completed for both the current and plausible regulatory scenarios. Detailed model inputs are included in Appendix F.

The treatment target used in this evaluation was 80 percent of the MCL. This is a common practice in water treatment engineering both with respect to design and operation of water treatment facilities.

The "influent temperature" input to the model was used to account for the different averaging periods associated with DBP compliance. For example, to evaluate the current regulatory scenario, the annual average temperature was used as the influent temperature input in the EPAWTPM because the current compliance basis is the locational running annual average. When considering the plausible future regulatory scenario, the 99th percentile temperature was used as the influent temperature input because this temperature would form the highest bromate, TTHM4, and HAA5 levels and represent the single sample not to exceed condition. However, HAA9 modeling used the annual average temperature as the influent temperature input to the model because the plausible regulatory scenario was compliance on an LRAA basis.

The tables below summarize the results from the treatment trigger evaluation matrix for each VWTP. Regions of the table are shaded to represent how many treatment targets were exceeded (Table 5-1).

Table 5-1:
Treatment Trigger Evaluation Matrix Legend

(white, bold border)	= 90th percentile water quality
(red)	= 2 or more treatment targets exceeded*
(yellow)	= 1 treatment target exceeded *
(green)	= no treatment targets exceeded

Treatment target equals 80% of the MCL.
*B= Bromate exceeded, T= THM4 exceeded, H5= HAA5 exceeded, H9= HAA9 exceeded.

In the Upper Watersheds source water area, the VWTP UW-1 utilizes conventional particulate removal and chlorine for primary and secondary disinfection. The source water in the area has historically been high quality, with low 90th percentile TOC and bromide at approximately 3.0 mg/L and 0.02 mg/L, respectively. UW-1 meets current regulations under 90th percentile historical water quality conditions; however, as TOC and bromide concentrations increase, THM and HAA5 treatment targets are exceeded (Table 5-2). Under the plausible regulatory scenario, the increase in temperature (representing the shift to single sample not to exceed), causes THM, HAA5, and HAA9 targets to be exceeded (Table 5-3). A more detailed matrix of model inputs using a finer resolution bromide and TOC range is included in Appendix F.

Table 5-2:
UW-1 Treatment Trigger Evaluation Matrix (Current Regulations)

Bromide (mg/L)	**0.20**	T	T	T	T	T
	0.16	T	T	T	T	T
	0.12	T	T	T	T	T
	0.06		T	T	T, H5	T
	0.02				T, H5	T, H5
Influent Temp: 16 °C (average) Min Temp: 5 °C		**2**	**2.5**	**3.0**	**3.5**	**4.0**
		TOC (mg/L)				

[bold outline box]	= 90th percentile water quality
[red]	= 2 or more treatment targets exceeded*
[yellow]	= 1 treatment target exceeded *
[green]	= no treatment targets exceeded

Treatment target equals 80% of the MCL.
*B= Bromate exceeded, T= THM4 exceeded, H5= HAA5 exceeded, H9= HAA9 exceeded.

Table 5-3:
UW-1 Treatment Trigger Evaluation Matrix (Plausible Future Regulations)

Bromide (mg/L)	**0.20**	T	T	T, H5, H9	T, H5, H9	T, H5, H9
	0.16	T	T	T, H5, H9	T, H5, H9	T, H5, H9
	0.12	T	T	T, H5, H9	T, H5, H9	T, H5, H9
	0.06		T	T, H5	T, H5, H9	T, H5, H9
	0.02		T	T, H5	T, H5	T, H5
Influent Temp: 24 °C (99th percentile) Min Temp: 5 °C		**2**	**2.5**	**3.0**	**3.5**	**4.0**
		TOC (mg/L)				

Legend:
- [bold-outlined box] = 90th percentile water quality
- [red] = 2 or more treatment targets exceeded*
- [yellow] = 1 treatment target exceeded *
- [green] = no treatment targets exceeded

Treatment target equals 80% of the MCL.
*B= Bromate exceeded, T= THM4 exceeded, H5= HAA5 exceeded, H9= HAA9 exceeded.

The Central Delta source water area is represented by a VWTP that utilizes pre-ozonation, conventional particulate removal, chlorine for primary disinfection, and chloramines for secondary disinfection (CD-1). Under historical 90th percentile water quality (approximately 5 mg/L TOC and 0.6 mg/L bromide), all treatment targets are met. As TOC and bromide concentrations increase, the ozone dose also increases to meet the 0.5 mg ozone/mg TOC target, and bromate formation becomes a concern (Table 5-4). As the temperature is increased to evaluate the plausible regulatory scenario, THM formation also becomes a concern (Table 5-5).

Table 5-4:
CD-1 Treatment Trigger Evaluation Matrix (Current Regulations)

Bromide (mg/L)	0.8		B	B	B, T	B, T
	0.6			B	B, T	B, T
	0.5			[90th percentile]	B, T	B, T
	0.4				T	B, T
	0.2					T
Influent Temp: 18 °C (average) Min Temp: 5 °C		2	3.5	5	6.5	8
		TOC (mg/L)				

[bold box] = 90th percentile water quality
[red] = 2 or more treatment targets exceeded*
[yellow] = 1 treatment target exceeded *
[green] = no treatment targets exceeded
Treatment target equals 80% of the MCL.
*B= Bromate exceeded, T= THM4 exceeded, H5= HAA5 exceeded, H9= HAA9 exceeded.

Table 5-5:
CD-1 Treatment Trigger Evaluation Matrix (Plausible Future Regulations)

Bromide (mg/L)	**0.8**	B	B	B, T	B, T	B, T
	0.6	B	B	B	B, T	B, T
	0.5		B	B	B, T	B, T
	0.4			B	B, T	B, T
	0.2				T	T
Influent Temp: 28 °C (99th percentile) Min Temp: 5 °C		**2**	**3.5**	**5**	**6.5**	**8**
		TOC (mg/L)				

(bold outline)	= 90th percentile water quality
(red)	= 2 or more treatment targets exceeded*
(yellow)	= 1 treatment target exceeded *
(green)	= no treatment targets exceeded

Treatment target equals 80% of the MCL.
*B= Bromate exceeded, T= THM4 exceeded, H5= HAA5 exceeded, H9= HAA9 exceeded.

The California Aqueduct source water area was represented by two VWTPs. The first VWTP, CAA-1, utilizes conventional particulate removal, chlorine for primary disinfection, and chloramines for secondary disinfection. Under current conditions, all treatment targets are achieved; however, as the TOC increases, TTHM formation becomes a concern (Table 5-6). As the influent temperature is increased from 15 to 26°C to evaluate the plausible future regulatory scenario, TTHM formation becomes a concern at lower TOC values, although treatment targets can still be met under historical 90th percentile water quality conditions (Table 5-7).

Table 5-6:
CAA-1 Treatment Trigger Evaluation Matrix (Current Regulations)

Bromide (mg/L)	**1.0**				T	T	T
	0.8				T	T	T
	0.6				T	T	T
	0.4				T	T	T
	0.2					T	T
Influent Temp: 15 °C (average) Min Temp: 5 °C		**2**	**3.5**	**5**	**6.5**	**8**	**9.5**
		TOC (mg/L)					

	= 90th percentile water quality
	= 2 or more treatment targets exceeded*
	= 1 treatment target exceeded *
	= no treatment targets exceeded

Treatment target equals 80% of the MCL.
*B= Bromate exceeded, T= THM4 exceeded, H5= HAA5 exceeded, H9= HAA9 exceeded.

Table 5-7:
CAA-1 Treatment Trigger Evaluation Matrix (Plausible Future Regulations)

Bromide (mg/L)							
	1.0			T	T	T	T
	0.8			T	T	T	T
	0.6			T	T	T	T
	0.4				T	T	T
	0.2				T	T	T
Influent Temp: 26 °C (99th percentile) Min Temp: 5 °C		2	3.5	5	6.5	8	9.5
		TOC (mg/L)					

(Cell colors: green = no treatment targets exceeded; yellow = 1 treatment target exceeded. Bold-outlined cell at Bromide 0.4, TOC 5 = 90th percentile water quality.)

= 90th percentile water quality
= 2 or more treatment targets exceeded*
= 1 treatment target exceeded *
= no treatment targets exceeded

Treatment target equals 80% of the MCL.
*B= Bromate exceeded, T= THM4 exceeded, H5= HAA5 exceeded, H9= HAA9 exceeded.

The second representative VWTP for the CAA source water area, CAA-2, is similar to CD-1. CAA-2 utilizes pre-ozonation, conventional particulate removal, chlorine for primary disinfection, and chloramines for secondary disinfection. Under historical 90th percentile water quality, current regulations are met. As the TOC and bromide increase, the ozone dose also increases to meet the 0.5 mg ozone/mg TOC target, and bromate formation becomes a concern (Table 5-8). TTHM formation also becomes a concern at higher TOC concentrations. As the influent temperature is increased to evaluate plausible future regulations, bromate and TTHM formation become a concern at lower bromide and TOC levels (Table 5-9). The target for bromate is exceeded at the historical 90th percentile water quality.

Table 5-8:
CAA-2 Treatment Trigger Evaluation Matrix (Current Regulations)

Bromide (mg/L)	**1.0**	B	B	B	B, T	B, T	B, T
	0.8		B	B	B	B, T	B, T
	0.6			B	B	B, T	B, T
	0.4			[90th percentile]		B	B, T
	0.2						
Influent Temp: 15 °C (average) Min Temp: 5 °C		**2**	**3.5**	**5**	**6.5**	**8**	**9.5**
		TOC (mg/L)					

Legend:
- [bold outlined box] = 90th percentile water quality
- [red] = 2 or more treatment targets exceeded*
- [yellow] = 1 treatment target exceeded *
- [green] = no treatment targets exceeded

Treatment target equals 80% of the MCL.
*B= Bromate exceeded, T= THM4 exceeded, H5= HAA5 exceeded, H9= HAA9 exceeded.

Table 5-9:
CAA-2 Treatment Trigger Evaluation Matrix (Plausible Future Regulations)

Bromide (mg/L)	**1.0**	B	B	B	B, T	B, T	B, T
	0.8	B	B	B	B, T	B, T	B, T
	0.6		B	B	B, T	B, T	B, T
	0.4			B	B, T	B, T	B, T
	0.2				T	T	T
Influent Temp: 26 °C (99th percentile) Min Temp: 5 °C		**2**	**3.5**	**5**	**6.5**	**8**	**9.5**
		TOC (mg/L)					

(bold outlined box)	= 90th percentile water quality
(red)	= 2 or more treatment targets exceeded*
(yellow)	= 1 treatment target exceeded *
(green)	= no treatment targets exceeded

Treatment target equals 80% of the MCL.
*B= Bromate exceeded, T= THM4 exceeded, H5= HAA5 exceeded, H9= HAA9 exceeded.

In the California Aqueduct West Branch source water area, the VWTP CAAW-1 utilizes pre-ozonation, conventional particulate removal, chlorine for primary disinfection, and chloramines for secondary disinfection. Although some of the water quality conditions differ between CAA-2 and CAAW-1, due to the fact that they utilize the same treatment process, the results are similar. Under historical 90th percentile water quality, current regulations are met. As the TOC and bromide increase, the ozone dose also increases to meet the 0.5 mg ozone/mg TOC target, and bromate formation becomes a concern (Table 5-10). TTHM formation also becomes a concern at higher TOC concentrations. As the influent temperature is increased to evaluate plausible future regulations, bromate and TTHM formation become a concern at lower bromide and TOC levels (Table 5-11); however, treatment targets are met at the historical 90th percentile water quality.

Table 5-10:
CAAW-1 Treatment Trigger Evaluation Matrix (Current Regulation)

Bromide (mg/L)	0.60	B	B	B	B	B, T	B, T
	0.45			B	B	B, T	B, T
	0.30		[90th percentile]				T
	0.15						
	0.05						
Influent Temp: 16 °C (average) Min Temp: 5 °C		2.5	4.0	5.5	7.0	8.5	10
		TOC (mg/L)					

Legend:
- [bold box] = 90th percentile water quality
- [red] = 2 or more treatment targets exceeded*
- [yellow] = 1 treatment target exceeded *
- [green] = no treatment targets exceeded

Treatment target equals 80% of the MCL.
*B= Bromate exceeded, T= THM4 exceeded, H5= HAA5 exceeded, H9= HAA9 exceeded.

Table 5-11:
CAAW-1 Treatment Trigger Evaluation Matrix (Plausible Future Regulations)

Bromide (mg/L)							
	0.60	B	B	B	B, T	B, T	B, T
	0.45	B	B	B	B, T	B, T	B, T
	0.30				T	B, T	B, T
	0.15					T	T
	0.05						
Influent Temp: 22 °C (99th percentile) Min Temp: 5 °C		2.5	4.0	5.5	7.0	8.5	10
		TOC (mg/L)					

= 90th percentile water quality
= 2 or more treatment targets exceeded*
= 1 treatment target exceeded *
= no treatment targets exceeded
Treatment target equals 80% of the MCL.
*B= Bromate exceeded, T= THM4 exceeded, H5= HAA5 exceeded, H9= HAA9 exceeded.

5.3. Chlorate

The plausible chlorate MCL was estimated to be 700 µg/L or 0.7 mg/L. Chlorate is a contaminant produced during on-site generations of hypochlorite solutions, the decomposition of hypochlorite, and as a chlorine dioxide DBP. Snyder (2009) investigated the occurrence of contaminants in bulk, on-site generated, and calcium hypochlorite solutions used at eight different utilities. Chlorate contamination from the hypochlorite solutions appeared to impact all of the utilities tested. Chlorate concentrations in the finished water ranged from 0.019 to 1.5 mg/L.

Chlorate can also be formed in drinking water as a chlorine dioxide byproduct. Generally, chlorate formation is approximately 20% of the original chlorine dioxide dose (Gates 2009, Miltner 1976, Thompson 1992). Doses of chlorine dioxide typically used in water treatment range from 0.5 to 1.5 mg/L. During the USEPA Information Collection Rule effort from 1997 to 1998, the median chlorate concentration at WTPs utilizing chlorine dioxide for disinfection was 0.12 mg/L. A recent full-scale study of chlorine dioxide at a dose of 3 mg/L found that chlorate levels did not occur above 0.3 mg/L in distribution system samples (Malcolm Pirnie, unpublished).

In addition to being formed as a DBP, chlorate can also be present because of inefficient chlorine dioxide generation. A typical level for chlorate carryover to the finished water from chlorate feedstock contamination is about 0.050 mg/L for a 1 mg/L dose of chlorine dioxide (Gates 2009, Gates 1998).

Therefore, the use of chlorine dioxide should not generate chlorate levels above the plausible future regulation of 0.7 mg/L, whereas chlorate contamination from hypochlorite solutions could be a concern based on levels reported in Snyder (2009). However, it was not possible to define a numerical treatment trigger of water quality conditions that would cause chlorate to exceed 0.7 mg/L. For this reason, the impact of potential future regulation of chlorate will be evaluated based on documented hypochlorite contamination minimization strategies.

In a study conducted by Snyder, Gordon, and Asami in 2009, recommended strategies to minimize chlorate contamination in hypochlorite solutions included:

- Dilute stored hypochlorite solutions upon delivery: The decomposition of hypochlorite and subsequent formation of chlorate is dependent upon hypochlorite concentration and ionic strength. Higher ionic strength and hypochlorite concentration will drive the reaction towards a greater production of chlorate.
- Store hypochlorite solutions at lower temperatures: Higher temperatures speed up the chemical decomposition of hypochlorite and the formation of chlorate.
- Control the pH of stored hypochlorite solutions at pH 11 to 13, even after dilution: pH values lower than 11 are not recommended due to rapid decomposition of hypochlorite ion/hypochlorous acid and the consequent formation of chlorate. When pH is great than 13, chlorate formation is enhanced due to the ionic strength effect. Utilities should continue to insist that manufacturer specifications include pH control in the range of 11 to 13. On-site generated hypochlorite typically ranges in pH from 9 to 10, such solutions should be used as soon as possible and should not be stored more than one to two days.
- Use fresh hypochlorite solutions when possible: Over time, hypochlorite will naturally decompose to produce oxygen, chlorate, and perchlorate. Less storage time will minimize the formation of these contaminants.

5.4. Nitrosamines

Nitrosamines are probable human carcinogens formed during disinfection of drinking water and wastewater. These compounds are of increasing interest and concern due to the cancer risk associated with concentrations in the low ng/L range. NDMA is detected more frequently and in higher concentrations compared to other nitrosamines, suggesting that NDMA may serve as a surrogate for nitrosamine exposure (Zhao 2008). The plausible regulatory scenario includes NDMA regulation at 3 to 10 ng/L (LRAA).

NDMA is one of six nitrosamines included in the UCMR 2. NDMA has been detected in WTP effluents from 3 to 16 ng/L and in distribution systems from 10 to 88 ng/L for some of the WTPs considered in this evaluation (UCMR 2 Database). UCMR 2 data collection and analysis effort is on-going at this time; however, some initial observations can be drawn:

- Detection of NDMA primarily occurred in drinking water plants utilizing chloramination. In the cases where NDMA was detected at a WTP utilizing chlorine, ammonia was often present in the source water, which could have caused the formation of chloramines and subsequently NDMA.
- Of the chloramination WTPs that detected NDMA, over two-thirds of the samples were from the maximum residence time distribution system location (not the EPDS), indicating that NDMA formation continues to occur in the DS.

NDMA formation chemistry is complex and not completely understood. There are a number of nitrogen-containing compounds that could form NDMA. An extensive review of nitrosamine formation literature by Sacher et al. 2008 indicated:

- Laboratory chloramination experiments indicated that the concentration of NDMA formed from natural organic matter (NOM) precursors will be less than 7.4 ng/L; therefore, NOM is not a major precursor for nitrosamine formation during chloramination.
- Some polyelectrolytes (DADMAC and epiDMA polymers) and anion exchange resins commonly used in water treatment have been documented to cause significant NDMA formation.
- A strong correlation between boron concentration (an indicator of anthropogenic pollution) and NDMA formation potential in laboratory studies implied that water utilities using surface water under the influence of wastewater are at a higher risk for nitrosamine formation during chloramination than those using non-impacted source waters.

Due to the complex nature of NDMA formation, a numerical treatment trigger could not be developed. However, there are a number of documented treatment strategies that can be implemented to reduce NDMA formation. In lieu of a treatment trigger, VWTPs will be evaluated based on the demonstrated NDMA reduction strategies described below.

Depending on the relative percent of municipal or industrial wastewater influence on the source water, consider additional treatment techniques:

- Avoidance of DADMAC polymeric materials during the flocculation process
- Optimization of operational parameters of the chloraminantion process (e.g., minimize dichloramine levels)

- Removal of NDMA precursors by processes such as slow sand filtration, artificial groundwater recharge, riverbank filtration, pre-chlorination, or pre-ozonation.

Studies have shown that NDMA formation can be reduced by greater than 90% with ozonation or chlorination prior to the formation of chloramines (Sacher 2008); however, this strategy must be balanced with the formation of other disinfection byproducts. Table 5-12 presents reductions in NDMA formation that can be achieved with free chlorine contact time. Table 5-13 presents reductions in NDMA formation that can be achieved with ozonation.

Table 5-12:
Reduction of NDMA Formation with Free Chlorine Contact Time

Chlorine Dose (mg/L)	Contact Time (hrs)	pH	Reduction in NDMA Formation[1] (%)	Notes	Reference
2 to 4	2	7.8	69 to 94	0.8 to 1 chlorine to ammonia molar ratio.	Charrois 2007
5.7	0.17	7.0	50	120 hrs of reaction with chloramines. 0.7 to 1 chlorine to ammonia molar ratio.	Chen 2008
2	1.8	9	50	5 days of reaction with chloramines. 1 to 1 chlorine to ammonia molar ratio.	Chen 2008
2.3	0.08	7.2	> 80	WRF Effluent[2]	Cotton 2009
3.4	1	7.2	>90	WRF Effluent[2]	Cotton 2009
5 to 10	2	-	46 to 74	Mannich polymer was used.	Huitric 2006
2 to 7	0.33	8	97	3:1 to 4:1 chlorine to ammonia mass ratio.	AwwaRF 2008
10	1	-	70	WRF Effluent[2]	Pehlivanoglu-Mantas 2006

[1]Reduction compares the use of chloramines without free chlorine contact time to the use of chloramines with free chlorine contact time.
[2]Water Reclamation Facility (WRF) Effluent defined as tertiary treated wastewater.

Table 5-13:
Reduction of NDMA Formation with Ozonation

Ozone Dose (7 mg/L)	Contact Time (hrs)	pH	Reduction in NDMA Formation[1] (%)	Notes	Reference
7	1	7.0	75	40 min of reaction time with preformed monochloramine.	Chen 2008
1 to 2	1.7	n/a	32 to 92	Reduction of NDMA FP in natural waters.	Sacher 2008

[1]Reduction compares the use of chloramines without ozone contact time to the use of chloramines with ozone contact time.

5.5. Nutrients

It is plausible that nitrite and nitrate regulations could be revised to move the monitoring location from the EPDS to DS locations to account for contribution from nitrification. Nitrification can have adverse effects on water quality including a loss of total chlorine residual, release of free ammonia, buildup of nitrite, possible conversion to nitrite and nitrate, decrease in pH, and increase in microbiological activity (McGuire 2009).

Nitrification has the potential to affect WTPs utilizing chloramines or WTPs utilizing chlorine where ammonia is present in the source water. During nitrification, ammonia is released and converted to nitrite (1:1 ratio as mg/L N). If more than 0.8 mg/L (as N) ammonia is added to generate chloramines, or if greater than 0.8 mg/L (as N) ammonia is present in the surface water, nitrite formation could potentially reach or exceed the target of 80 percent of the MCL (0.8 mg/L as N). As nitrite levels increase, conversion to nitrate might occur if nitrite oxidizing bacteria are present, but distribution systems do not commonly experience this full conversion of nitrite to nitrate. Further, typical levels of ammonia available for nitrification will not increase nitrate levels above the nitrate MCL (10 mg/L as N), unless the utility is already serving water very close to the MCL.

Although, some WTPs in California have been affected by nitrification, successful prevention strategies (chlorite addition or breakpoint chlorination) have been implemented. For example, the City of Glendale, California experienced nitrification in its reservoirs and DS that at times generated nitrite as high as 0.25 mg/L as N. With chlorite addition to a clean system (i.e., one not currently experiencing nitrification or one that is breakpoint chlorinated to eliminate nitrification before chlorite addition), nitrification (and the formation of nitrite) was eliminated (McGuire 2009).

Nitrification will not likely form nitrate at levels approaching the MCL at the representative VWTPs considered in this study. VWTPs utilizing chloramines (CD-1, CAA-1, CAA-2, and CAAW-1) dose ammonia at 0.6 mg/L and the VWTPs with ammonia present in the source water (UW-1) utilize breakpoint chlorination. In both cases, ammonia will not be present at levels above the 0.8 mg/L as N treatment trigger.

5.6. Microcystin

Algal toxins are toxins formed by cyanobacteria (blue-green algae) that dominate the freshwater phytoplankton communities during periods of calm, stratified conditions (AwwaRF 2008). It has been observed that increased discharges of nutrients can lead to increased algal blooms (and their toxins), which have been associated with an increased incidence of fish kills, deaths of livestock and wildlife, and human illness and death (Richardson 2007). With increasing awareness and measurement of algal toxins worldwide, it is likely that algal toxins will be included in the UCMR 3. With potential data from the UCMR 3 and a growing body of toxicological data, microcystin could be regulated at the WHO drinking water guideline value of 1 μg/L (plausible scenario).

Formulating a treatment trigger to prevent cyanobacterial harmful algal blooms (CHABs), and therefore Microcystin formation, is not feasible because CHABs are affected by a number of factors including: hydrology, nutrients, sunlight, temperature, and ecosystem disturbance. Due to the complex interactions between physical and ecological processes, it is difficult to point to any single, definitive cause for the development and proliferation of cyanobacteria blooms (ISOC-HAB 2005). For this reason, the impact of potential future regulation of Microcystin was evaluated based on available treatment technologies to remove or oxidize it, not on a threshold water quality value. Demonstrated Microcystin removal strategies are discussed below.

Microcystin can be present as an intracellular (inside of the cell), extracellular (outside the cell) toxin. Conventional water treatment practices (flocculation, coagulation, sedimentation, and filtration) effectively remove intracellular toxins but do not remove extracellular toxins. Extracellular toxins can be oxidized through disinfection processes. Ideally, intact cyanobacterial cells (and therefore intracellular microcystin) would be removed through physical processes (flocculation, coagulation, sedimentation, and filtration), and remaining extracellular cells would be oxidized during disinfection.

Chloramines and chlorine dioxide are not effective at oxidizing microcystin. In one study, chloramine doses as high as 20 mg/L with 2-day exposures did not degrade microcystin (ISOC-HAB 2005, Nicholson 1994). UV disinfection is also not an economically viable option for degradation of Microcystin. UV doses required for degradation of algal toxins range from 1,530 to 20,000 mJ/cm^2 (ISOC-HAB 2005), several orders of magnitude higher than those required for *Cryptosporidium* inactivation.

Ozone can effectively degrade microcystins at levels typically used in drinking water treatment. Ozone doses as low as 0.22 mg/L have been found to completely oxidize extracellular microcystins in as little as 15 seconds (Svrcek 2004, Rositano 1998). The only complication with ozonation of microcystins is the competitive reactions with DOC and alkalinity. Shawwa and Smith (2001) showed a distinct lag before the degradation of microcystins began as the DOC concentration increased. This lag time signified that ozone only had an effect on extracellular microcystin after the DOC demand was satisfied – incomplete oxidation of toxins could occur if no residual ozone concentration remained (Svrcek 2004). For the VWTPs utilizing ozone in this evaluation, ozone treatment guidelines included an ozone dose of 0.5 mg ozone per mg TOC and a contact time of 12 minutes. These conditions should be sufficient to cause cell lysis and oxidation of extracelluar microcystins.

Chlorine also effectively oxidizes microcystins at levels typically used in drinking water treatment. Acero et al. 2005 performed chlorination experiments with influent microcystin-LR of 10 and 50 µg/L at various pH and temperature (Table 5-14). At a pH less than 8, the CT achieved for baseline conditions is sufficient to oxidize 10 µg/L of microcystins at all VWTPs (Table 5-14 and Table 5-15).

Table 5-14:
Chlorine CT Values for Reducing Microcystin Concentration to 1 µg/L

pH	Initial Microcystin-LR (µg/L)	CT values (mg-min/L)			
		10°C	15°C	20°C	25°C
6	50	46.6	40.2	34.8	30.3
	10	27.4	23.6	20.5	17.8
7	50	67.7	58.4	50.6	44
	10	39.8	34.4	29.8	25.9
8	50	187.1	161.3	139.8	121.8
	10	110.3	94.9	82.3	71.7
9	50	617.2	526.0	458.6	399.1
	10	363.3	309.6	269.8	234.9

Source: Acero 2005.

Table 5-15:
Chlorine CT Values Achieved in Baseline VWTPs

VWTP	CT (mg-min/L)
UW-1	36
CD-1	33
CAA-1	37
CAA-2	32
CAAW-1	38

5.7. Other Pathogens

The CCL3 includes several emerging pathogens; however none of these pathogens are more difficult to remove or inactivate compared to the current microbial standards for *Giardia*, virus, and *Cryptosporidium*. Table 2-3 in Section 2.4.2 summarized the treatment requirements that may be necessary to remove or inactive these pathogens. For this reason, no treatment triggers were developed for emerging pathogens.

5.8. Treatment Trigger Summary

The levels at which water quality parameters (singly or in combination) create the need for capital or operational modifications to a treatment process (treatment triggers), were developed for current and plausible future regulations for each VWTP. These treatment triggers can be used by CUWA members to estimate the costs associated with varying levels of water quality in the future.

All current VWTPs were able to comply with current regulations (evaluated with the average temperature and 90^{th} percentile water quality). A range of water quality conditions beyond the 90^{th} percentile were also evaluated and were discussed in Section 5.2).

Table 5-16 summarizes some of the findings from the treatment trigger evaluation for the plausible regulatory scenario, where the 99^{th} percentile temperature and 90^{th} percentile water quality were used. For chlorate, NDMA, and microcystins, numeric treatment triggers were not defined; however a treatment approach could be used to address these contaminants.

Table 5-16:
Summary of Treatment Triggers for VWTPs (Plausible Future Regulations)

<table>
<tr><th></th><th>UW-1</th><th>CD-1</th><th>CAA-1</th><th>CAA-2</th><th>CAAW-1</th></tr>
<tr><td>Summary Table in Section 5.2</td><td>Table 5-3</td><td>Table 5-5</td><td>Table 5-7</td><td>Table 5-9</td><td>Table 5-11</td></tr>
<tr><td>Bromate</td><td>✓</td><td>✗</td><td>✓</td><td>✗</td><td>✓</td></tr>
<tr><td>THM4</td><td>✗</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>HAA5</td><td>✗</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>HAA9</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Chlorate</td><td colspan="5">?
Chlorate is a common contaminant associated with hypochlorite solutions. WTPs utilizing hypochlorite (on-site generation or bulk) should consider: diluting the solution upon delivery, storing the solution at lower temperatures, controlling the pH of the stored solution between 11 and 13, and using fresh solution when possible. If such practices are employed, chlorate should likely remain below the 0.7 mg/L plausible future regulation.</td></tr>
<tr><td>NDMA</td><td colspan="5">?
All VWTPs can oxidize NDMA precursors due to the utilization of free contact time prior to formation of chloramines. For plants using pre-ozonation, additional oxidation of NDMA precursors can be achieved. However, NDMA formation is complex and the plausible regulatory scenario levels are very low. Therefore, it is not currently possible to accurately determine whether the VWTP will have NDMA formation above the plausible 3 to 10 ng/L and if treatment is triggered; however, due to the low level of possible NDMA regulations, it is likely that some treatment change will be triggered for systems utilizing chloramines as their secondary disinfectant.</td></tr>
<tr><td>Nitrate/Nitrite</td><td>✓
To reduce the ammonia present in the source water and to prevent nitrification, breakpoint chlorination is utilized. With this strategy, nitrite and nitrate levels are not likely to increase above the MCL.</td><td colspan="4">✓
Although nitrification could occur, ammonia doses used in the formation of chloramines are less than 0.8 mg/L. At this level, nitrite and nitrate levels are not likely to increase above the MCL.</td></tr>
<tr><td>Microcystin</td><td colspan="5">✓
CT values achieved with chlorine at all VWTPs may sufficient (some minor adjustments may be needed) to oxidize 10 μg/L microcystin. VWTPs utilizing pre-ozonation will also oxidize Microcystin.</td></tr>
<tr><td>Other Pathogens</td><td colspan="5">✓
Of the several emerging pathogens considered, none are more difficult to remove, oxidize, or inactivate compared to the current microbial standards for Giardia, virus, and Cryptosporidium. For this reason, no treatment triggers were developed for emerging pathogens.</td></tr>
</table>

✓ Able to achieve target with existing treatment practices, 99th percentile temperature, and 90th percentile water quality.

✗ Not able to achieve target with existing treatment practices, 99th percentile temperature and 90th percentile water quality.

? Not able to determine treatment trigger.

6. Evaluation of Future Regulatory Compliance and Recommended VWTP Upgrades

Phase I project work focused on developing future regulatory scenarios, creating VWTPs representative of each source water area, and defining water quality threshold values that would trigger the need for treatment upgrades. Phase II of the project assessed future regulatory compliance, determined needed VWTP upgrades, and developed cost estimates. This section summarizes VWTP performance under future regulatory scenarios and recommends treatment upgrades necessary to stay in compliance.

6.1. VWTP Performance with Current Regulations

VWTP performance was assessed based on the ability of the treatment process to meet treatment targets for modeled DBP formation, which were defined as 80 percent of the MCL (a typical conservative practice in the water industry). As discussed in Section 4 and 5, all baseline VWTPs were able to meet treatment targets with historical 90th percentile water quality.

6.2. VWTP Performance with Future Regulations

Future regulatory scenarios were more stringent for DBPs and as a result many VWTPs that were able to meet treatment targets for current regulations began to exceed treatment targets for the future, despite the fact that there was not a change in water quality. The following sections discuss VWTP performance under the plausible and outer boundary future regulatory scenarios.

6.2.1. Plausible Future Regulatory Scenario

To simulate the stricter DBP regulations of single sample not to exceed included in the plausible regulatory scenario, the influent temperature input to the WTPM was increased from an annual average temperature (used to model current regulatory scenario for LRAA) to the 99th percentile temperature. HAA9 was an exception, the plausible future regulatory scenario remained on an LRAA basis, and therefore the annual average temperature was used. Table 6-1 presents a summary of the EPAWTPM results. CAA-1 and CAA-W were able to meet treatment targets for TTHM, HAA5, HAA9, and bromate under the plausible future regulatory scenario. UW-1, CD-1, and CAA-2 exceed treatment targets (bold cells in Table 6-1) and would require upgrades to maintain future compliance.

Table 6-1:
VWTP Performance under Plausible Future Regulatory Scenario

Parameter	UW-1	CD-1	CAA-1	CAA-2	CAAW-1
Influent Temperature, °C	24	28	26	26	22
Influent TOC, mg/L	3.0	4.7	5.2	5.2	3.8
Influent Bromide, mg/L	0.02	0.48	0.38	0.38	0.26
TOC Removal, %	25	42	37	50	43
TTHM, µg/L	**80**	60	58	50	35
HAA5, µg/L	**57**	17	16	15	12
HAA9, µg/L	55	28	34	25	22
Bromate, µg/L	0	**11**	0	**9**	5

Notes: Detailed EPAWTPM runs for a matrix of TOC and bromide values are presented in Appendix F. Historical water quality data were used to determine influent water quality inputs.

6.2.2. Outer Boundary Future Regulatory Scenario

As the outer boundary scenario cannot be specifically defined and also the fact that the current EPAWPM is not capable of predicting water quality parameters under consideration in the outer boundary scenario, this scenario was not assessed through modeling with the EPAWTPM. The outer boundary scenario includes greater degree of removal of DBP precursors (TOC and DON), regulating individual TTHM and HAA species, regulating new compounds (iodinated DBPs, select nitrosamines, algal toxins), increasing *Cryptosporidium* inactivation, and discontinuing the use of chloramines for secondary disinfection. UW-1, CD-1, and CAA-2 exceeded treatment targets under the plausible scenario and would continue to have compliance problems in the outer boundary. In the case of CAA-1 and CAAW-1, individual species DBP regulations would likely become a concern. The additional *Cryptosporidium* inactivation may pose a challenge for all WTPs and with the discontinuation of chloramination, VWTPs will have to rely on other disinfection alternatives to meet disinfection and DBP goals.

6.3. Treatment Upgrades Needed to Comply with Future Regulations

Some VWTPs are not able to meet treatment goals under the plausible future regulatory scenario and all VWTPs will be challenged with the outer boundary future regulatory scenario. This section presents recommended treatment upgrades for the VWTPs that will ensure future regulatory compliance.

6.3.1. Plausible Future Regulatory Scenario

No treatment upgrades were needed to VWTPs CAA-1 and CAAW-1, as these plants were able to meet treatment goals under plausible regulations. CD-1 and CAA-2 are

VWTPS that both utilize pre-ozonation and exceed bromate treatment goals. The ozone dose was set to achieve adequate pre-oxidation and was determined based on the influent TOC level. The treatment guideline called for the use of 0.5 mg/L of ozone for every 1 mg/L of TOC. By lowering the ozone to TOC ratio used to determine the ozone dose from 0.5 to 0.25, bromate formation would be reduced. However, there are additional implications to lowering the ozone dose. Lowering the ozone dose will result in less oxidation of DBP precursors, which could result in increased formation of TTHM, HAA, and nitrosamines. Also, there is an opportunity to achieve some disinfection contact time with ozonation (although this was not modeled for the VWTPs), which would be reduced with the reduction ozone. To offset the negative effects of reducing the ozone dose, the installation of UV disinfection is also recommended for CD-1 and CAA-2. When UV disinfection is included, free chlorine contact time in the reservoir is no longer needed; however, a free chlorine contact basin ahead of the reservoir should be added to achieve a short (10 minute) contact time prior to the formation of chloramines. This will help oxidation of precursors to DBPs associated with chloramination (nitrosamines).

UW-1 is a conventional plant that is the only VWTP to utilize free chlorine for secondary disinfection, resulting in it being the only VWTP to exceed TTHM and HAA treatment targets under the plausible regulatory scenario. The most simple and cost effective upgrade to achieve compliance would be to convert to chloramines for secondary disinfection. However, if chloramines are not an option for the Upper Watersheds source water area, granular activated carbon (GAC) contactors will need to be included to reduce TOC and prevent the formation of TTHMs and HAAs with free chlorine.

The EPAWTPM was run with the upgraded VWTPs to demonstrate that treatment goals can be met with the recommended upgrades (Table 6-3). Bold cells in the table indicate that a treatment goal was exceeded.

Table 6-2:
VWTP Performance under Plausible Future Regulatory Scenario

Parameter	UW-1	Upgraded UW-1 A*	Upgraded UW-1 B*	CD-1	Upgraded CD-1*	CAA-1		CAA-2	Upgraded CAA-2*	CAAW-1	
TTHM, µg/L	**80**	31	<10	60	31	58	No Upgrades Needed	50	40	35	No Upgrades Needed
HAA5, µg/L	**57**	22	<10	17	12	16		15	13	12	
HAA9, µg/L	55	26	<10	28	22	34		25	24	22	
Bromate, µg/L	0	0	0	**11**	1	0		**9**	3	5	

Notes: Historical water quality data were used to determine influent water quality inputs. *A summary of VWTP upgrades is discussed in Section 6.3.1 above and in Table 6-3 below.

6.3.2. Outer Boundary Future Regulatory Scenario

In the outer boundary regulatory scenario, all VWTPs will need to be upgraded. As chloramination becomes an unacceptable treatment technology, VWTPs will have to convert back to using free chlorine as a secondary disinfectant. To meet increasingly strict and new DBP regulations, GAC contactors will be needed. To achieve increased *Cryptosporidium* inactivation (as well as the inactivation of other pathogens), UV disinfection will also need to be included.

6.3.3. Summary of VWTP Upgrades

A summary of all recommended VWTP upgrades is presented in Table 6-3 and Figure 6-1 to Figure 6-5.

Table 6-3:
VWTP Upgrades Needed to Meet Future Regulations

VWTP	Scenario	Description
UW-1	Current	Conventional particulate removal, free chlorine disinfection
	Plausible	Convert to chloramines or
		Add GAC, free chlorine disinfection remains
	Outer Boundary	Add GAC and UV disinfection, free chlorine disinfection remains
CD-1	Current	Pre-ozonation, conventional particulate removal, chloramines
	Plausible	Reduce ozone dose and add UV disinfection
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine
CAA-1	Current	Conventional particulate removal, chloramines
	Plausible*	No upgrades
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine
CAA-2	Current	Pre-ozonation, conventional particulate removal, chloramines
	Plausible	Reduce ozone dose and add UV disinfection
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine
CAAW-1	Current	Pre-ozonation, conventional particulate removal, chloramines
	Plausible*	No upgrades
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine

*No upgrades needed, baseline costs remain.

Figure 6-1: Process Schematic of UW-1 Future Treatment Upgrades Needed

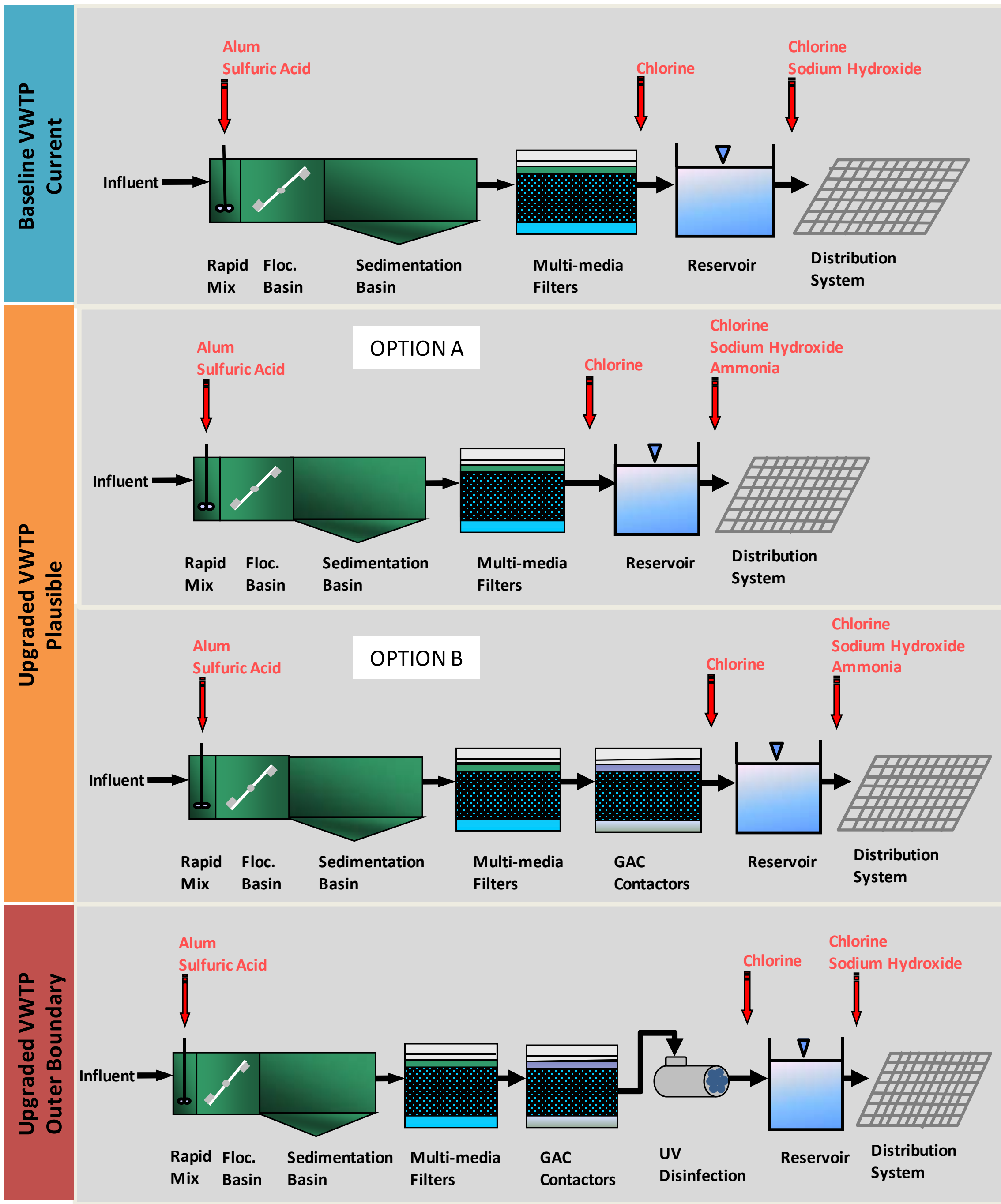


Figure 6-2: Process Schematic of CD-1 Future Treatment Upgrades Needed

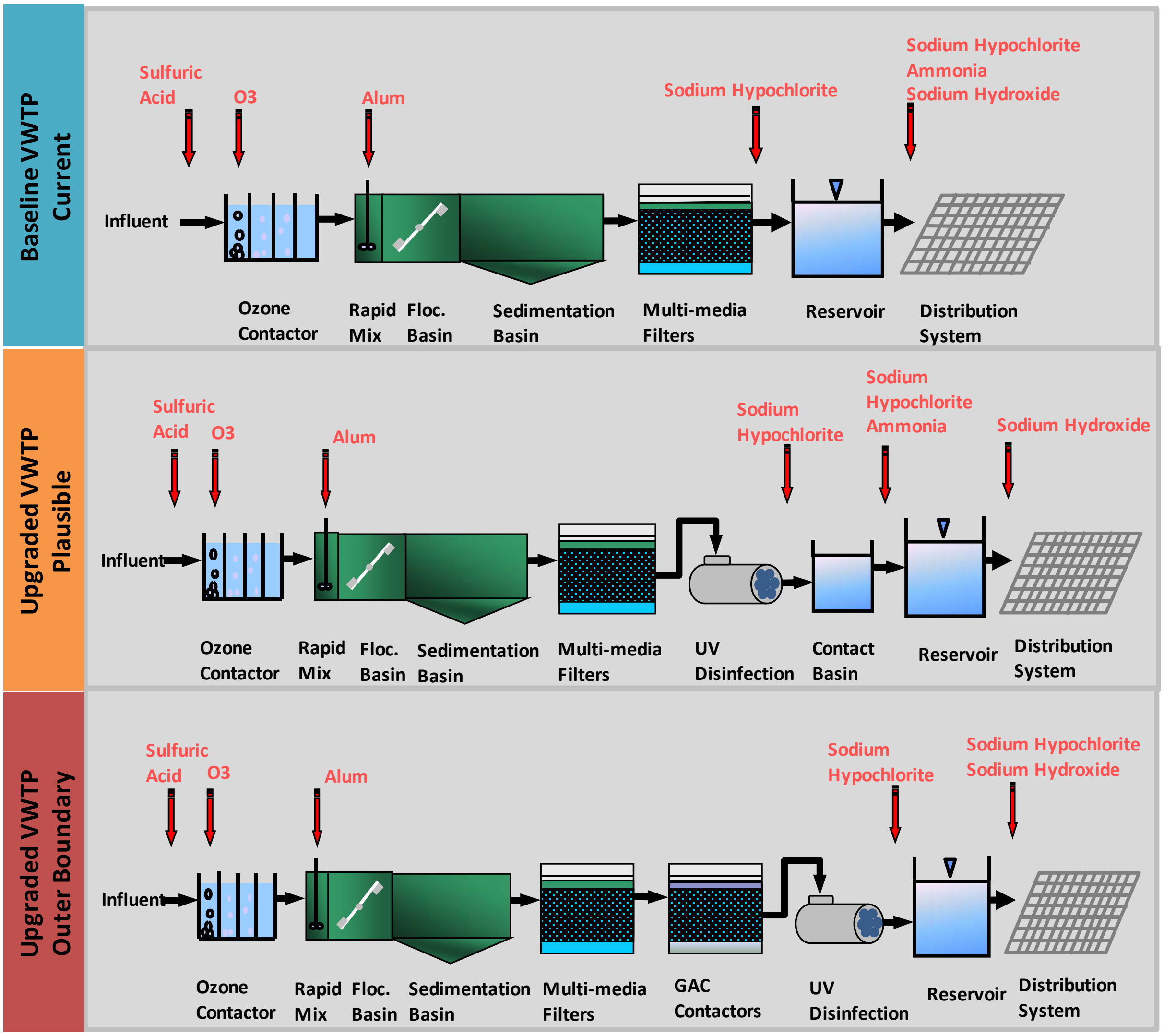


Figure 6-3: Process Schematic of CAA-1 Future Treatment Upgrades Needed

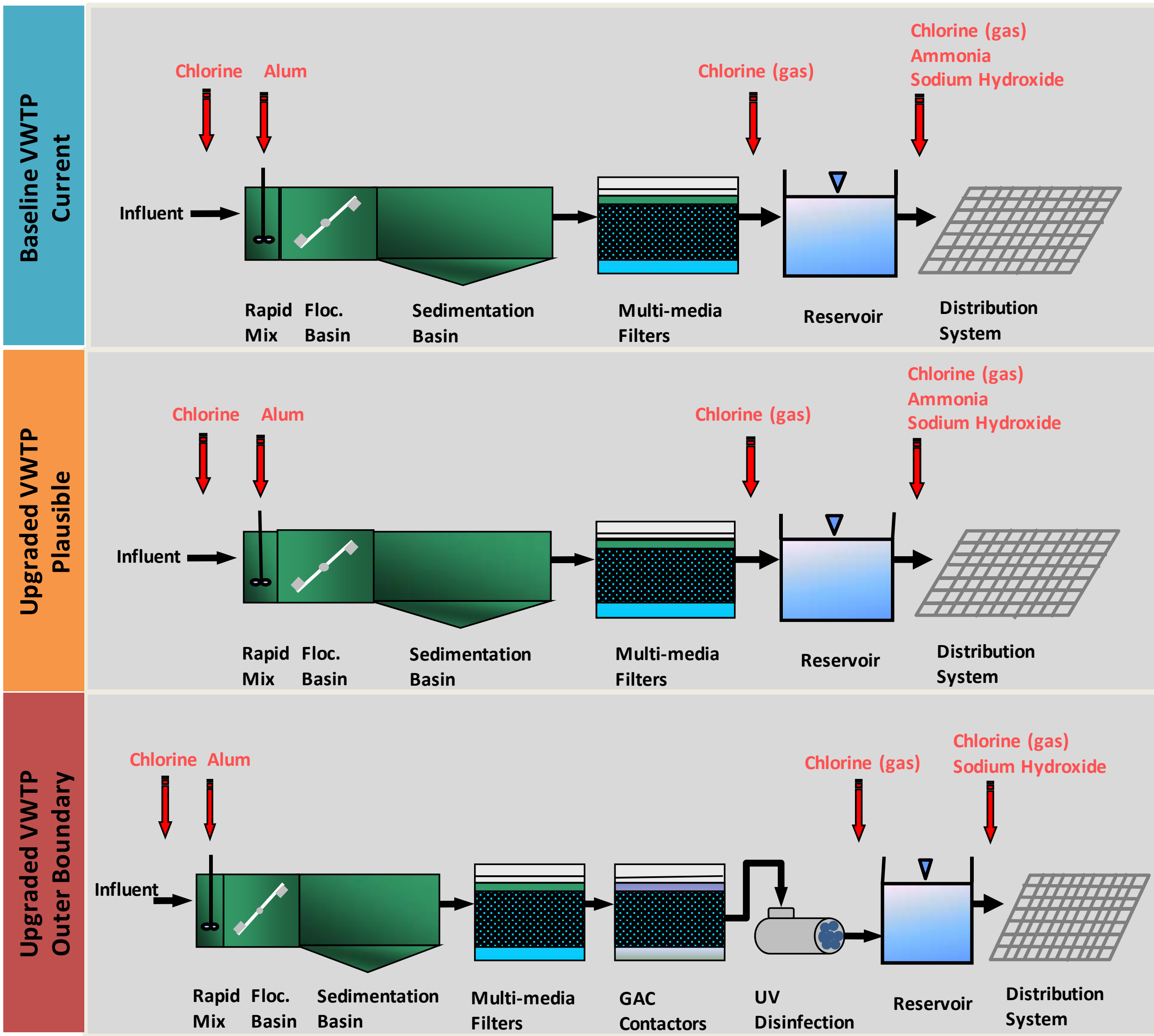


Figure 6-4: Process Schematic of CAA-2 Future Treatment Upgrades Needed

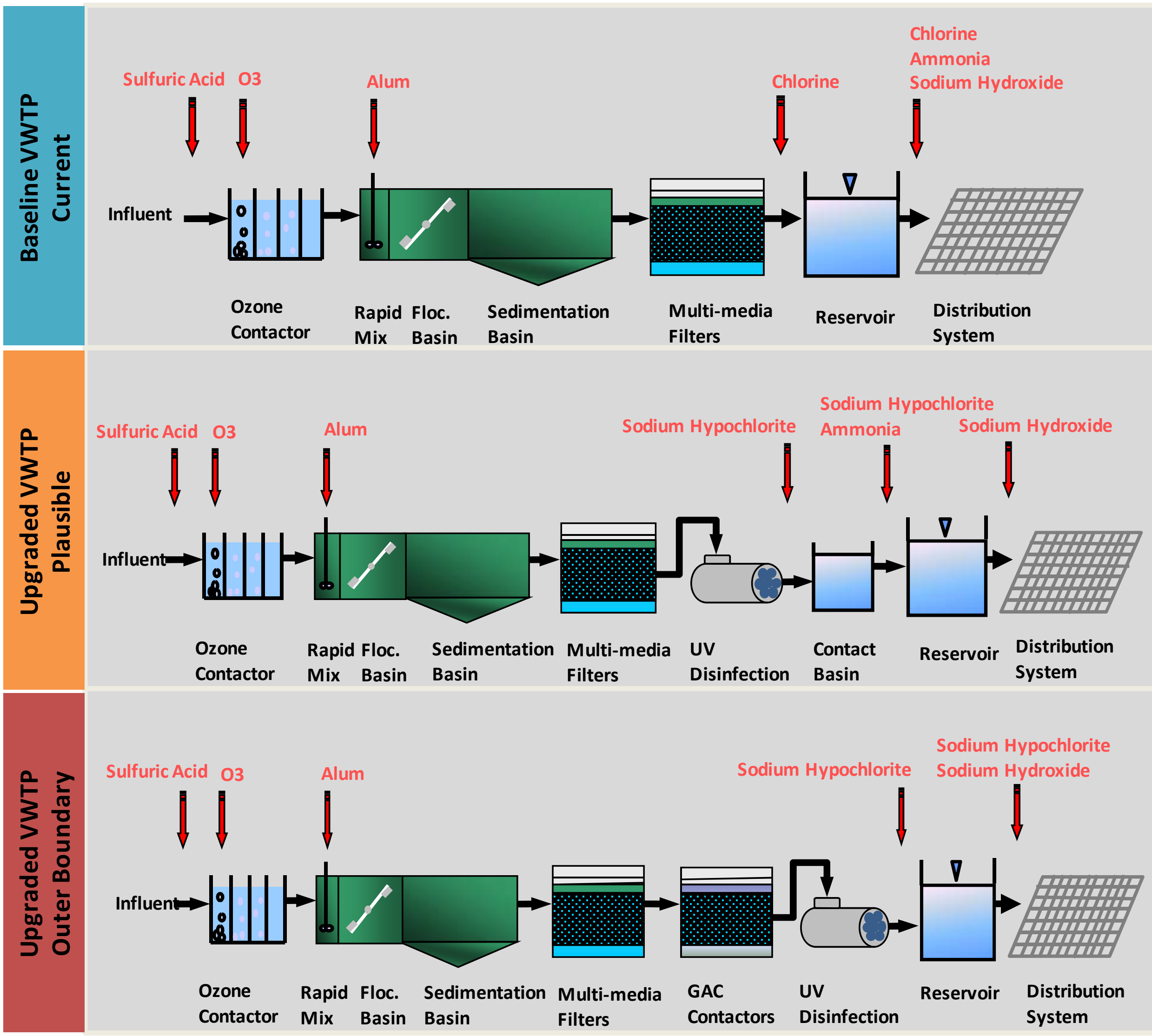
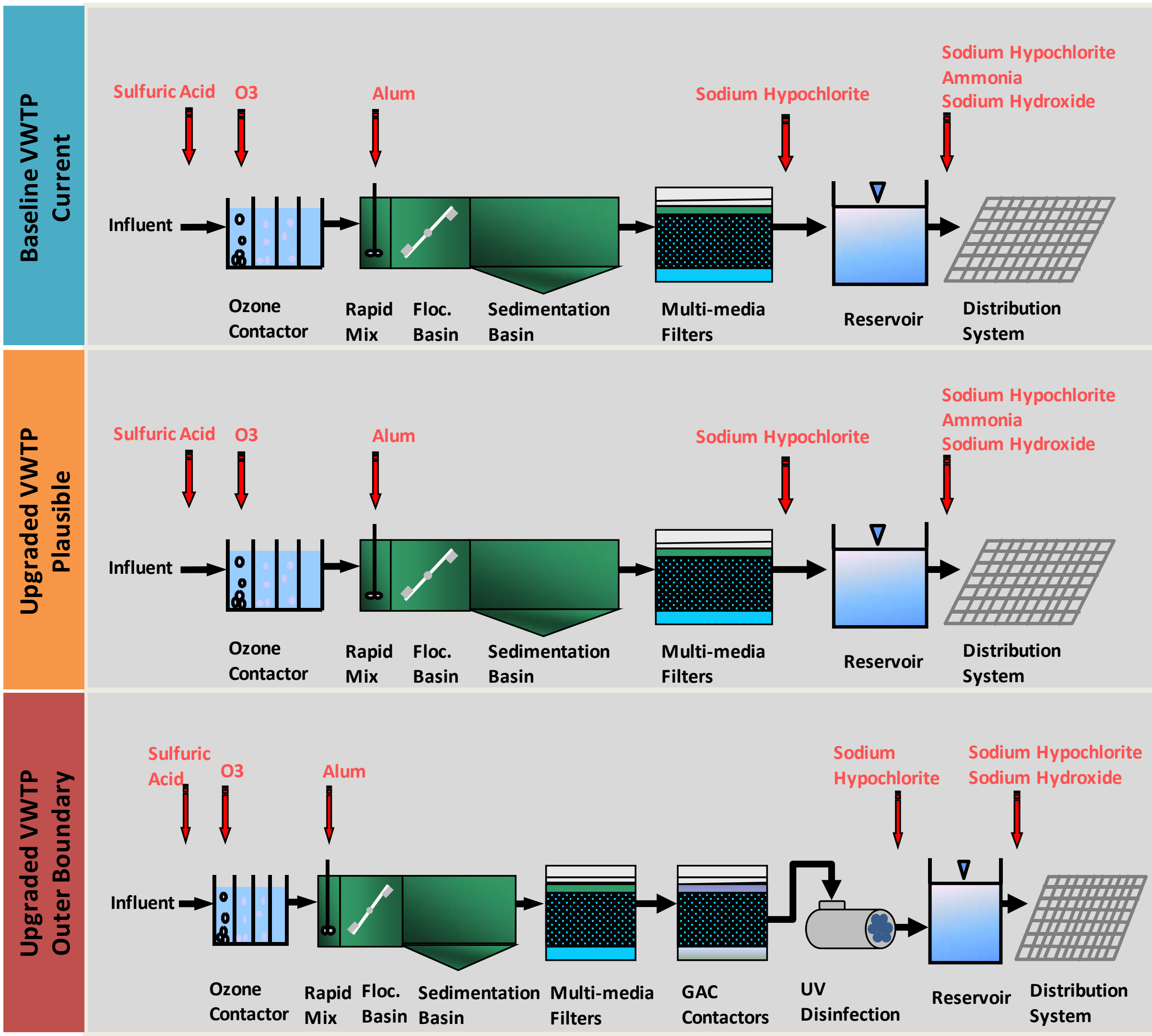


Figure 6-5: Process Schematic of CAAW-1 Future Treatment Upgrades Needed



6.4. Constituents of Concern that Could Not be Modeled

VWTPs were evaluated and treatment upgrades recommended based on the ability to meet treatment targets with respect to TTHM, HAA, and bromate, as these contaminants could be predicted using the EPAWTPM. Treatment upgrades will also address other constituents of concern, as discussed in this section.

6.4.1. Chlorite and Chlorate

Chlorite and chlorate are disinfection byproducts from chlorine dioxide use. As none of the VWTPs utilize chlorine dioxide, nor was it included as a treatment upgrade, so these DBPs were considered in the analysis. If plants were to install chlorine dioxide, the formation of chlorite and chlorate from its use is well-defined and can be modeled to ensure future compliance. Chlorate is also a common contaminant associated with hypochlorite solutions. Based on the treatment trigger analysis, WTPs utilizing hypochlorite (on-site generation or bulk) should also consider: diluting the solution upon delivery, storing the solution at lower temperatures, controlling the pH of the stored solution between 11 and 13, and using fresh solution when possible.

6.4.2. Nitrosamines

Nitrosamine formation is complex and not completely understood. Based on the treatment trigger analysis, VWTPs utilizing pre-ozonation will also oxidize some NDMA precursors. Also, studies have shown that if sufficient free chlorine contact time is provided prior to ammonia addition (as simulated in the VWTPs), formation of NDMA is reduced. However, even though oxidation of NDMA precursor will occur, it is still uncertain whether additional upgrades for NDMA treatment will be necessary. In the plausible scenario, some VWTPs convert to chloramines or reduce the pre-ozonation dose; these changes will not reduce the formation NDMA. In the outer boundary scenario, plants eliminate the use of chloramines and return to free chlorine for primary disinfection, which will reduce or eliminate NDMA formation at the VWTPs.

6.4.3. Nutrients and Taste and Odor

Nitrification has the potential to affect WTPs utilizing chloramines or WTPs utilizing chlorine where ammonia is present in the source water. It is plausible that nitrite and nitrate regulations could be revised to move the monitoring location from the EPDS to DS locations to account for contribution from nitrification. Nitrification can have adverse effects on water quality including a loss of total chlorine residual, release of free ammonia, buildup of nitrite, possible conversion to nitrite and nitrate, decrease in pH, and increase in microbiological activity (McGuire 2009).

Nutrient concentrations for the future water quality scenarios were not provided, though nitrification will not likely form nitrate at levels approaching the MCL at the representative VWTPs considered in this study. VWTPs utilizing chloramines dose ammonia at 0.6 mg/L, in which case ammonia will not be present at levels above the 0.8 mg/L as N treatment trigger and will not trigger the nitrite MCL violation. In the outer boundary scenario, chloramination is discontinued, further reducing the potential for nitrification challenges.

Aside from nitrification, increased levels of nutrients can also lead to algal and vascular plant growth. Associated treatment concerns include taste and odor problems, increased levels of organic carbon, filtration impacts, and potentially higher levels of nitrogenous DBPs (e.g., NDMA) and algal toxins. The USEPA established nitrogen and phosphorus reference conditions in a 2001 Ambient Water Quality Criteria Recommendations Report to assist states in developing nutrient water quality standards for receiving waters. These values are guidelines and are not enforceable. The nitrogen and phosphorus reference conditions generally represent nutrient levels that protect against the adverse effects of nutrient over enrichment and generally apply to the source water areas in this analysis. The reference concentration for total nitrogen is 0.31 mg/L and total phosphorus is 0.047 mg/L (USEPA 2001). Total nitrogen includes nitrate, nitrite, ammonia, and organic nitrogen. Total phosphorus includes particulate and dissolved phosphorus. The particulate phosphorus includes organic phosphorus incorporated in planktonic organisms, inorganic mineral phosphorus in suspended sediments, and phosphate adsorbed to inorganic particles. The dissolved phosphorus includes dissolved organic phosphorus, orthophosphate, and polyphosphates.

Data from approximately 1998 to 2008 showed that total nitrogen and total phosphorus concentrations in the Delta and its tributaries are significantly higher than USEPA's total nitrogen and total phosphorus reference concentrations (USEPA 2001), which indicates that VWTPs could be subject to increased algal blooms and experience taste and odor challenges. In this evaluation, it was understood that current WTPs are able to manage taste and odor challenges. If future nutrient levels were to remain at historical levels, future VWTPs should be able to manage algal blooms and taste and odor events. Additionally, taste and odor compounds can be removed through many of the proposed future upgrades.

6.4.4. Microcystin

As discussed in Section 6.4.3, nutrients in the source waters can lead to algal gowth resulting in the production of algal toxins. Similar to taste and odor, it was determined that in the current, plausible, and outer boundary scenarios, all VWTPs have sufficient pre-ozone and/or free chlorine contact time to manage algal blooms and oxidize microcystin.

6.4.5. Pathogens

The CCL3 is evaluating several emerging pathogens; however, none of these pathogens are more difficult to remove, oxidize, or inactivate compared to the current microbial standards for *Giardia*, virus, and *Cryptosporidium*. In the outer boundary scenario where other pathogens could remotely play a role, UV disinfection is included and additional *Cryptosporidium* inactivation is achieved.

Pathogen levels were not provided for the predicted future scenarios. This evaluation assumed that future levels of pathogens in the source waters are consistent with historical levels. Increasing levels of pathogens in future source waters would result in an increased treatment cost that was not captured in this analysis.

6.4.6. Compounds of Emerging Concern (CECs)

Compounds of emerging concern including pharmaceuticals, personal care products, and endocrine disruptors can be present in treated drinking water. Future water quality scenarios and treatment plant upgrades this evaluation did not consider CECs and drinking water treatment of CECs could result in significant additional treatment costs. However, with adequate source water protection and a multiple barrier concept, CECs entering the environment through anthropogenic sources could be reduced, therefore reducing the risk of increased future water treatment costs.

7. Sensitivity Analysis of Water Quality Inputs and VWTP Modeling

DBP formation is a function of multiple parameters including water temperature, TOC, bromide, pH, chlorine dose, and water age. These parameters are used as inputs (along with other water quality and treatment parameters) in the EPAWTPM, which predicts TTHM, HAA, and bromate formation based on empirical relationships. This section presents a sensitivity analysis performed on the water temperature, TOC, and bromide inputs to the EPAWTPM.

7.1. Interpreting Historical Data

Historical data can be used in many ways. In this evaluation, data were generally available from 1998 to 2008. 90^{th} percentile water quality values of the entire data set were calculated and used as EPAWTPM inputs. This method is a conservative approach to the analysis; it assumes that 90^{th} percentile water quality conditions occur simultaneously. In reality, they may occur at different times of year and vary seasonally. To account for seasonal variations in water quality, monthly data sets can be used. Taking the 90^{th} percentile water quality of paired data for each month and using the EPAWTPM to model DBP formation would allow for a more representative picture of DBP formation on a seasonal basis.

To understand how the differences in water quality inputs to the EPAWTPM and the resulting affect on modeling DBPs, a sensitivity analysis was performed for the Central Delta source water area:

1. Data were organized by month and a box and whisker plot (Figure 7-1, Figure 7-3, and Figure 7-5, for temperature, TOC, and bromide, respectively) showing the distribution of data was created. The seasonal variation of each water quality parameter is shown in this plot.
2. A percentile plot (Figure 7-2, Figure 7-4, and Figure 7-6) was created to understand the range of data and how data were distributed.
3. The median and 90^{th} percentile of paired water quality data was calculated for each month and used as inputs to the EPAWTPM.
4. DBP results from the paired data sets were compared to results obtained for the current and plausible future regulatory scenario analysis, where 90^{th} percentiles of the unmatched data set were used (Table 7-1 to Table 7-5).

Figure 7-1: Central Delta Water Temperature by Month

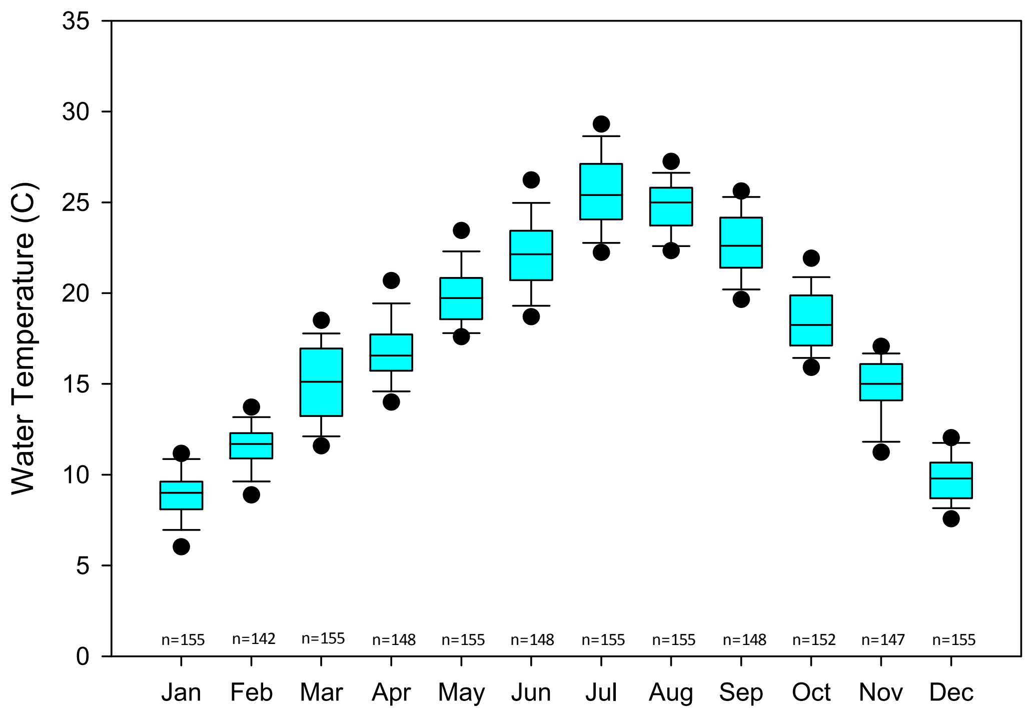


Figure 7-2: Central Delta Water Temperature Percentile Plot

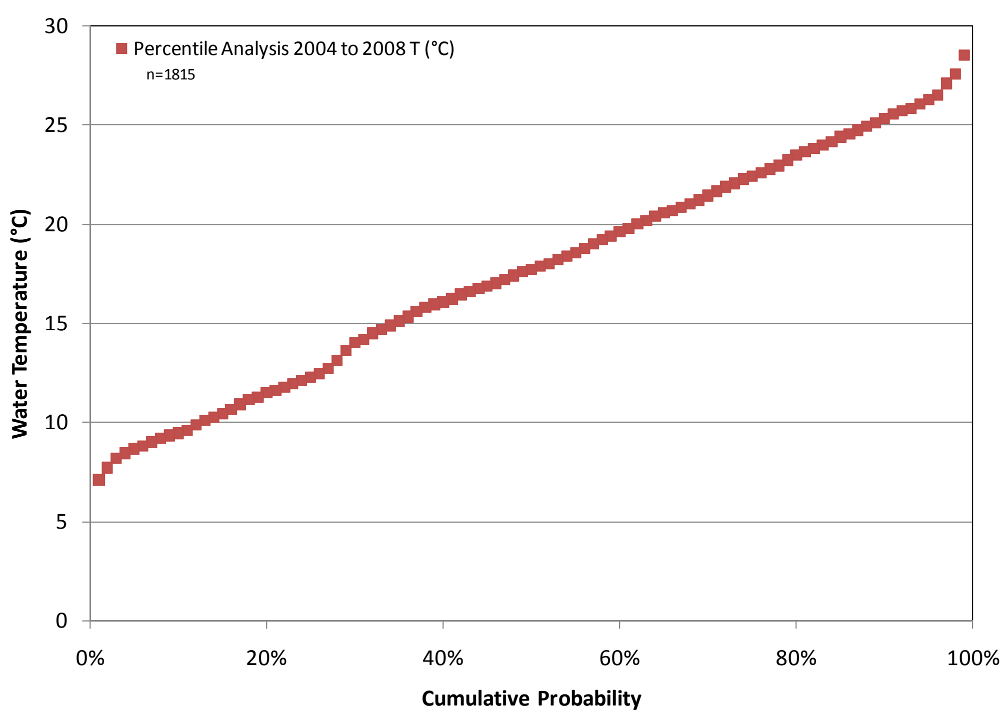


Figure 7-3: Central Delta TOC by Month

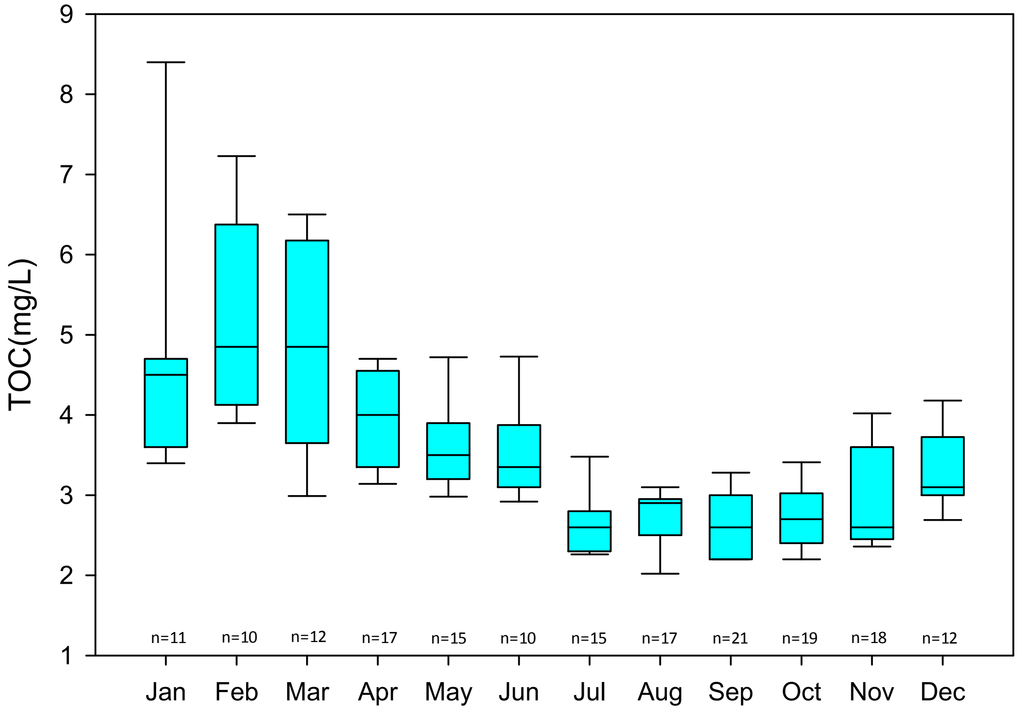


Figure 7-4: Central Delta TOC Percentile Plot

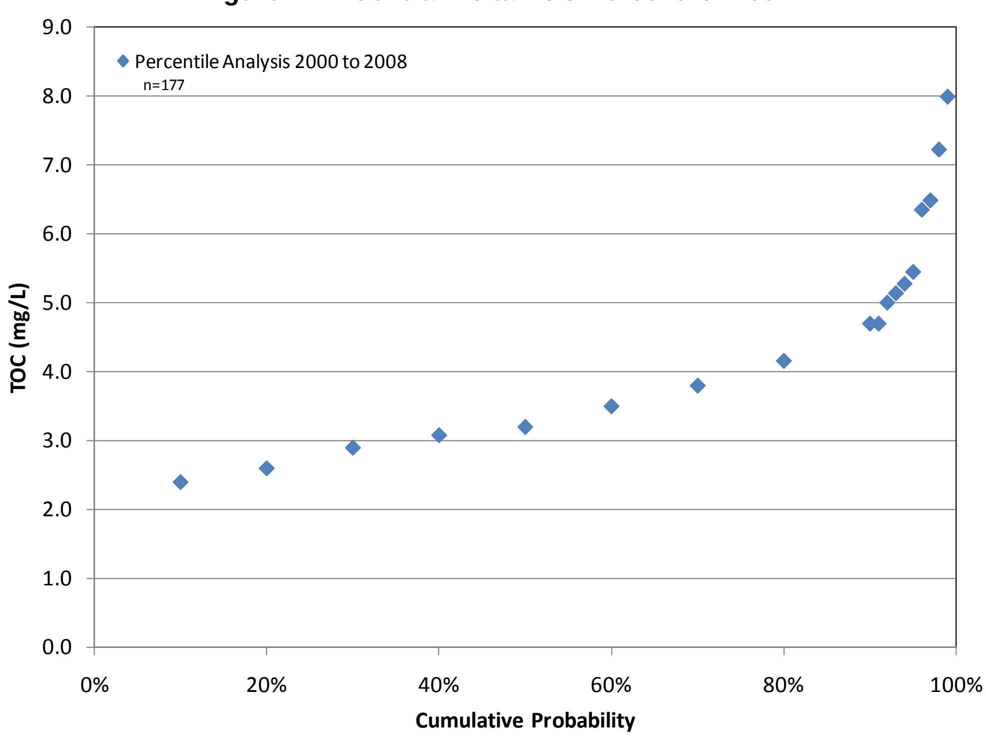


Figure 7-5: Central Delta Bromide by Month

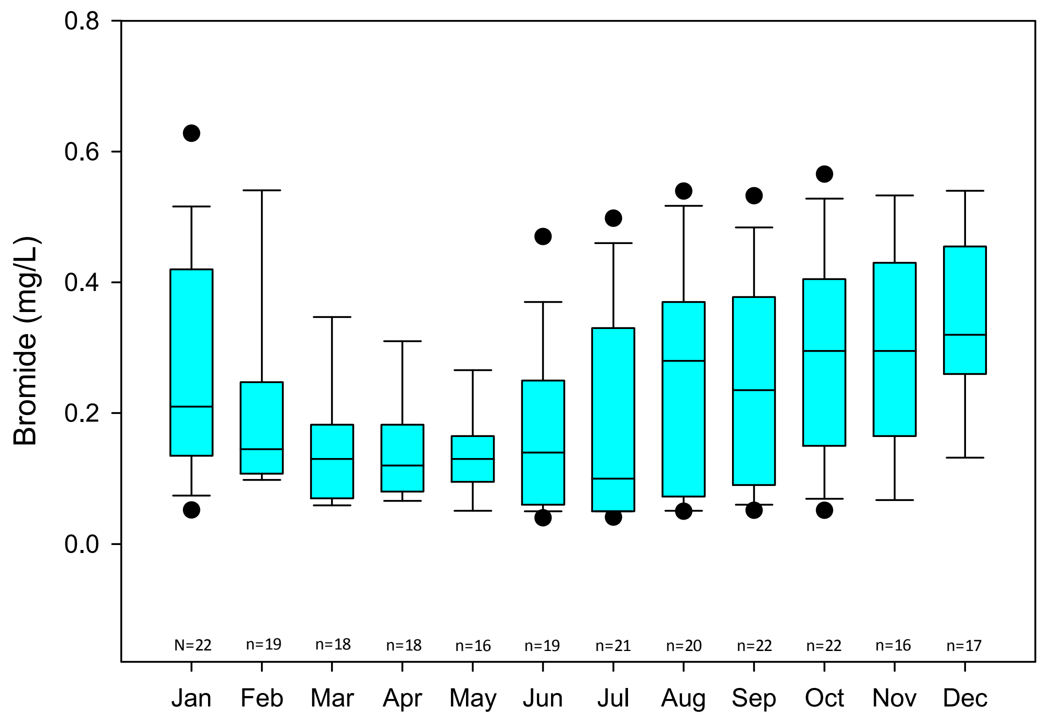


Figure 7-6: Central Delta Bromide Percentile Plot

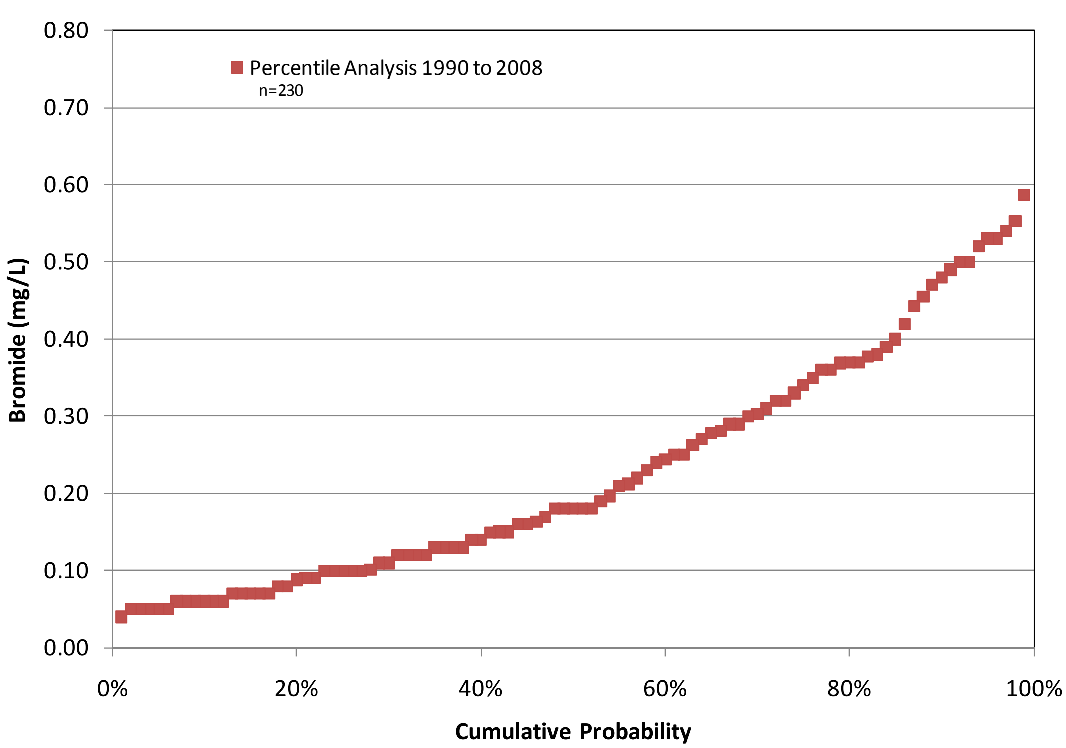


Table 7-1:
EPAWTPM DBP Modeling Using Central Delta Paired Monthly Data for Quarter 1

Parameters	January		February		March	
	Median	90th Percentile	Median	90th Percentile	Median	90th Percentile
Temperature(°C)	9.0	10.8	11.7	13.2	15.1	17.8
TOC (mg/L)	4.5	8.4	4.85	6.67	4.85	6.49
UV254	0.151	0.301	0.165	0.234	0.165	0.227
Bromide (mg/L)	0.22	0.50	0.16	0.41	0.13	0.27
TOC Removal	39	40	41	35	41	35
3-day TTHM	32	64	35	59	37	61
3-day HAA5	12	20	14	18	15	21
3-day HAA9	24	37	27	36	29	41
Bromate	3	9	2	7	2	5

Table 7-2:
EPAWTPM DBP Modeling Using Central Delta Paired Monthly Data for Quarter 2

Parameters	June		April		May	
	Median	90th Percentile	Median	90th Percentile	Median	90th Percentile
Temperature(°C)	22.1	24.8	16.6	19.3	19.7	22.2
TOC (mg/L)	3.35	4.17	4	4.64	3.5	4.2
UV254	0.107	0.139	0.132	0.157	0.113	0.140
Bromide (mg/L)	0.14	0.36	0.12	0.22	0.13	0.19
TOC Removal	33	39	37	41	34	39
3-day TTHM	36	49	34	43	34	42
3-day HAA5	14	15	14	15	14	15
3-day HAA9	28	31	26	32	27	31
Bromate	2	7	2	4	2	3

Table 7-3:
EPAWTPM DBP Modeling Using Central Delta Paired Monthly Data for Quarter 3

Parameters	July		August		September	
	Median	90th Percentile	Median	90th Percentile	Median	90th Percentile
Temperature(°C)	25.4	28.6	25.0	26.5	22.6	25.2
TOC (mg/L)	2.6	3.12	2.9	3.1	2.8	3.2
UV254	0.078	0.098	0.090	0.098	0.086	0.101
Bromide (mg/L)	0.1	0.38	0.28	0.41	0.235	0.47
TOC Removal	28	33	31	32	30	33
3-day TTHM	31	46	38	45	35	45
3-day HAA5	13	14	12	13	11	13
3-day HAA9	25	29	26	28	25	27
Bromate	2	7	4	7	3	7

Table 7-4:
EPAWTPM DBP Modeling Using Central Delta Paired Monthly Data for Quarter 4

Parameters	October		November		December	
	Median	90th Percentile	Median	90th Percentile	Median	90th Percentile
Temperature(°C)	18.3	20.8	15.0	16.6	9.8	11.7
TOC (mg/L)	2.8	3.4	2.65	4.03	3.1	3.89
UV254	0.086	0.109	0.080	0.133	0.098	0.128
Bromide (mg/L)	0.295	0.50	0.295	0.53	0.32	0.52
TOC Removal	29	34	28	37	30	36
3-day TTHM	32	42	28	42	29	37
3-day HAA5	10	12	9	12	9	10
3-day HAA9	22	25	20	24	20	21
Bromate	4	7	3	7	3	6

Table 7-5:
Comparison of Current and Plausible DBP Results to Paired Monthly Data DBP Results

Parameters	Unpaired Data Used in Treatment Evaluation		Monthly Paired Data	
	Current Scenario[1]	Plausible Scenario[2]	Maximum Month (Median)	Maximum Month (90th Percentile)
3-day TTHM, µg/L	48	61	38	64
3-day HAA5, µg/L	14	17	15	21
3-day HAA9, µg/L	29	29	29	41
Bromate, µg/L	8	11	4	9

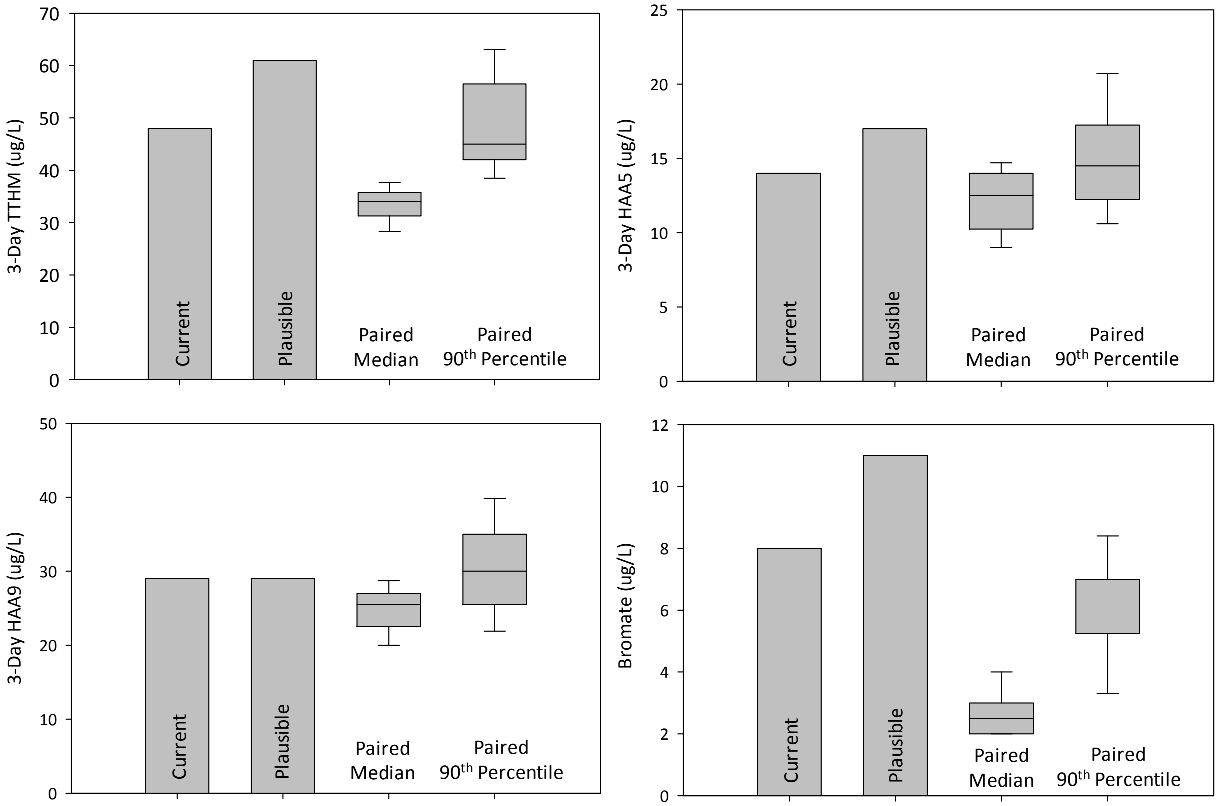
[1]Current scenario utilized 90th percentile of entire (unpaired) water quality data set with annual average water temperature in the EPAWTPM to model DBP formation.

[2]Plausible Scenario utilized 90th percentile of entire (unpaired) water quality data set with 99th percentile water temperature in the EPAWTPM to model DBP formation.

The approach utilized in this treatment evaluation assumed that the 90th percentile water temperature, TOC, and bromide occur simultaneously. In reality, these parameters peak at different times of year. However, the 90th percentile of an individual parameter can be higher in a given month than was calculated across a year, resulting in higher DBP formation, despite lower levels of other contaminants. For example, the peak TOC occurs in December-January-February timeframe and the peak temperature occurs in the summer months. When monthly 90th percentiles are calculated, the input TOC in January is much higher than the 90th percentile of the entire data set; therefore, despite the relatively low temperature in January, higher DBP formation results.

With the assumption that the 90th percentile water temperature, TOC, and bromide occur simultaneously, DBP formation was predicted for the current and plausible scenarios. The current scenario utilized the 90th percentile of entire (unpaired) water quality data set with annual average water temperature in the EPAWTPM to model DBP formation. The plausible scenario utilized the 90th percentile of entire (unpaired) water quality data set with 99th percentile water temperature in the EPAWTPM to model DBP formation. Comparing the resulting TTHM, HAA, and bromate values to the set of monthly DBP prediction results from the paired water quality data, it can be concluded that despite the assumption that the 90th percentiles occur simultaneously; finished water quality results are similar (Figure 7-7).

Figure 7-7: TTHM, HAA5, HAA9, and Bromate in the Central Delta



Notes: Current scenario utilized 90th percentile of entire water quality data set with annual average water temperature in the EPAWTPM to model DBP formation. Plausible Scenario utilized 90th percentile of entire (unpaired) water quality data set with 99th percentile water temperature in the EPAWTPM to model DBP formation.

7.2. Sensitivity Analysis of Water Quality Inputs

One method used to understand how sensitive the DBP modeling results are to changes in water quality inputs is to determine the maximum levels of these inputs that can be used while still meeting DBP targets. For this method, one variable is changed while the others are held constant. This type of sensitivity analysis was performed on the Central Delta VWTP CD-1 to answer the following questions:

- At what water temperature are DBP targets exceeded using the 90th percentile TOC?
- At what water temperature are DBP targets exceeded using the 90th percentile TOC?

By answering these types of questions, an understanding will be developed of when and how frequently problems occur at different combinations of input variables (water temperature and TOC in this example). To perform this analysis, 90th percentiles of the entire (unpaired) available data were used. It was found that:

- Using the 90th percentile TOC of 4.7 mg/L (other water quality at 90th percentile as well), the maximum temperature input that met treatment goals was 20 °C. Above this temperature bromate targets were exceeded. A water temperature of 20 °C is equivalent to the 60th percentile temperature (water temperature remains below 20 °C sixty percent of the time).
- Using the 50th percentile TOC of 3.2 mg/L (other water quality at 90th percentile), the maximum temperature input that met treatment goals was 28 °C. Above this temperature bromate targets were exceeded. A water temperature of 28 °C is equivalent to the 99th percentile temperature (water temperature remains below 28 °C ninety-nine percent of the time).

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8. Estimation of Costs Associated with Future VWTP Upgrades

A number of treatment upgrades were recommended to help the VWTPs meet treatment goals in the plausible and outer boundary future scenarios. This section provides an estimation of the costs associated with performing these upgrades at each VWTP.

8.1. Methodology and Assumptions

8.1.1. Range of Accuracy for Cost Estimates

The cost estimates presented in this report are representative of Class 5 estimates as defined by the Association for the Advancement of Cost Engineering International (AACE, 2005):

> "Class 5 estimates are generally prepared based on very limited information, and subsequently have wide accuracy ranges….Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation…The level of project definition required for a Class 5 estimate is 0% to 2% of full project definition…Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc…Typical accuracy ranges for Class 5 estimates are -20 percent to -50 percent on the low side, and +30 percent to +100 percent on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances."

Class 5 estimates rely on stochastic estimating methods including cost/capacity curves and factors, and scaling factors. Scaling factors have been applied to selected estimates or historical construction costs for actual example projects, and to summary studies and published literature characterizing the cost of constructing and operating the identified treatment processes. For developing a range of costs for the estimates developed in this project, a range of -30% to +50% was used.

8.1.2. ENR CCI

Each source of cost information is based on a date and location of the project and must be adjusted to reflect current local conditions. The 20-City average construction cost index

(CCI) is published monthly by Engineering News Record (ENR) and the index can be used to adjust the cost of construction for one location and point in time to different location and time. To be consistent with other cost estimates developed by CUWA, this analysis used an ENR CCI of 8952 (the 20-Cities Average ENR CCI for December 2010)

8.1.3. References Used during Unit Cost Development

Multiple references were used to develop design assumptions and estimate treatment unit costs:

- CWC Engineering Software W/WW Cost Model Version 3.0
- December 2005 LT2ESWTR Technology & Cost Document
- October 2006 Final Ground Water Rule Technology & Cost Document
- McGivney and Kawamura 2008. Cost Estimating Manual for Water Treatment Facilities. John Wiley & Sons.

8.1.4. Cost Multipliers and Contingency

Cost multipliers and contingencies are included in the cost estimates to account for portions of the project that are not adequately defined due uncertainties about site-specific constraints and bidding climate variability (Table 8-1).

Table 8-1:
Capital Cost Multipliers and Contingency

Multiplier	Percentage of Subtotal
Subtotal for Treatment Units and Chemical Systems	
Site Work	5%
Electrical	12%
Instrumentation and Controls	12%
Subtotal	
Contractor OH & Profit	15%
Contractor bonds, insurance, mob, demob	6%
Sales Tax	3.64%
Subtotal	
Engineering Fee	25%
Legal/Administrative Fee	5%
Subtotal	
Contingency	50%

8.2. Baseline VWTP Costs

Low range and high range baseline costs were developed for each VWTP to give a perspective to the added costs of treatment upgrades (Table 8-2 and Table 8-3). Detailed cost summaries for each VWTP are provided in Appendix G.

Table 8-2:
Low Range Cost Estimates for Baseline VWTPs

VWTP	Capital Cost		Annual O&M Cost		Present Worth of Annual O&M	Total Present Worth	Annualized Capital Cost	Total Equivalent Annual Cost
	($)	$/gal capacity	($/yr)	$/kgal	($)	($)	($/yr)	($/yr)
UW-1	$93M	$0.93	$3.3M	$0.18	$38M	$132M	$8M	$11M
CD-1	$72M	$1.80	$2.6M	$0.36	$30M	$102M	$6M	$9M
CAA-1	$46M	$1.14	$1.0M	$0.13	$11M	$57M	$4M	$5M
CAA-2	$577M	$1.15	$32.1M	$0.27	$368M	$945M	$50M	$82M
CAAW-1	$923M	$1.15	$59.2M	$0.27	$679M	$1,602M	$80M	$140M

Assumptions: Years (n) = 20, Rate (i) = 6%. All costs in December 2010 dollars, CCI = 8952.

Table 8-3:
High Range Cost Estimates for Baseline VWTPs

VWTP	Capital Cost		Annual O&M Cost		Present Worth of Annual O&M	Total Present Worth	Annualized Capital Cost	Total Equivalent Annual Cost
	($)	$/gal capacity	($/yr)	$/kgal	($)	($)	($/yr)	($/yr)
UW-1	$200M	$2.00	$7.2M	$0.39	$82M	$282M	$17M	$25M
CD-1	$154M	$3.86	$5.7M	$0.78	$65M	$219M	$13M	$19M
CAA-1	$98M	$2.45	$2.1M	$0.29	$24M	$122M	$9M	$11M
CAA-2	$1,237M	$2.47	$68.7M	$0.58	$788M	$2,024M	$108M	$176M
CAAW-1	$1,978M	$2.47	$126.8M	$0.58	$1,454M	$3,433M	$172M	$299M

Assumptions: Years (n) = 20, Rate (i) = 6%. All costs in December 2010 dollars, CCI = 8952.

8.3. Cost Estimates for the Plausible Future Scenario

In the plausible future scenario, VWTPs UW-1, CD-1, and CAA-2 needed upgrades to meet treatment targets:

- UW-1 had two options:
  - A- Utilize chloramines as secondary disinfectant, or
  - B- Install GAC contactors and continued to use free chlorine as a secondary disinfectant.
- CD-1: include a reduction in ozone dose and addition of UV disinfection.
- CAA-2: include a reduction in ozone dose and addition of UV disinfection.

VWTPs CAA-1 and CAAW-1 met plausible treatment targets; therefore, costs presented for the plausible scenario are equal to baseline VWTP costs. All costs are presented for the entire VWTP (Table 8-4); added costs of a treatment upgrades are presented in Section 8.6.

Table 8-4:
Low Range Cost Estimates for VWTPs in the Plausible Regulatory Scenario

VWTP	Capital Cost		Annual O&M Cost		Present Worth of Annual O&M	Total Present Worth	Annualized Construction Cost	Total Equivalent Annual Cost
	($)	$/gal capacity	($/yr)	$/k gal	($)	($)	($/yr)	($/yr)
UW-1 A	$94	$0.94	$3.4	$0.18	$39	$133	$8	$12
UW-1 B	$201	$2.01	$7.7	$0.42	$88	$289	$18	$25
CD-1	$110	$2.75	$3.5	$0.48	$40	$151	$10	$13
CAA-1*	$46	$1.14	$1.0	$0.13	$11	$57	$4	$5
CAA-2	$975	$1.95	$48.3	$0.41	$554	$1,529	$85	$133
CAAW-1*	$923	$1.15	$59.2	$0.27	$679	$1,602	$80	$140

*No upgrades needed, baseline costs remain.

Assumptions: Years (n) = 20, Rate (i) = 6%. All costs in December 2010 dollars, CCI = 8952.

Table 8-5:
High Range Cost Estimates for VWTPs in the Plausible Regulatory Scenario

VWTP	Capital Cost		Annual O&M Cost		Present Worth of Annual O&M	Total Present Worth	Annualized Construction Cost	Total Equivalent Annual Cost
	($)	$/gal capacity	($/yr)	$/k gal	($)	($)	($/yr)	($/yr)
UW-1 A	$202M	$2.02	$7.2M	$0.40	$83M	$285M	$18M	$25M
UW-1 B	$431M	$4.31	$16.4M	$0.90	$188M	$619M	$38M	$54M
CD-1	$236M	$5.90	$7.6M	$1.03	$87M	$323M	$21M	$28M
CAA-1*	$98M	$2.45	$2.1M	$0.29	$24M	$122M	$9M	$11M
CAA-2	$2,089M	$4.18	$103.5M	$0.87	$1,187M	$3,276M	$182M	$286M
CAAW-1*	$1,978M	$2.47	$126.8M	$0.58	$1,454M	$3,433M	$172M	$299M

*No upgrades needed, baseline costs remain.

Assumptions: Years (n) = 20, Rate (i) = 6%. All costs in December 2010 dollars, CCI = 8952.

8.4. Cost Estimates for the Outer Boundary Future Scenario

In the outer boundary future regulatory scenario upgrades at all VWTPs were recommended to include GAC contactors and UV disinfection. Additionally, the scenario included utilizing free chlorine for disinfection and discontinuing the use of the ammonia feed to form chloramines. Costs are presented for the entire outer boundary VWTP in Table 8-6 below.

Table 8-6:
Low Range Cost Estimates for VWTPs in the Outer Boundary Regulatory Scenario

VWTP	Capital Cost		Annual O&M Cost		Present Worth of Annual O&M	Total Present Worth	Annualized Construction Cost	Total Equivalent Annual Cost
	($)	$/gal capacity	($/yr)	$/k gal	($)	($)	($/yr)	($/yr)
UW-1	$287M	$2.87	$10.1M	$0.55	$116M	$402M	$25M	$35M
CD-1	$161M	$4.03	$5.6M	$0.76	$64M	$225M	$14M	$20M
CAA-1	$135M	$3.38	$3.9M	$0.53	$45M	$180M	$12M	$16M
CAA-2	$1,348M	$2.70	$74.3M	$0.63	$852M	$2,200M	$118M	$192M
CAAW-1	$2,162M	$2.70	$132.5M	$0.61	$1,520M	$3,682M	$188M	$321M

Assumptions: Years (n) = 20, Rate (i) = 6%. All costs in December 2010 dollars, CCI = 8952.

Table 8-7:
High Range Cost Estimates for VWTPs in the Outer Boundary Regulatory Scenario

VWTP	Capital Cost		Annual O&M Cost		Present Worth of Annual O&M	Total Present Worth	Annualized Construction Cost	Total Equivalent Annual Cost
	($)	$/gal capacity	($/yr)	$/k gal	($)	($)	($/yr)	($/yr)
UW-1	$614M	$6.14	$21.6M	$1.19	$248M	$862M	$54M	$75M
CD-1	$346M	$8.65	$11.9M	$1.64	$137M	$483M	$30M	$42M
CAA-1	$289M	$7.23	$8.4M	$1.15	$96M	$385M	$25M	$34M
CAA-2	$2,888M	$5.78	$159.1M	$1.34	$1,825M	$4,713M	$252M	$411M
CAAW-1	$4,633M	$5.79	$284.0M	$1.30	$3,257M	$7,890M	$404M	$688M

Assumptions: Years (n) = 20, Rate (i) = 6%. All costs in December 2010 dollars, CCI = 8952.

8.5. Summary of VWTP Costs

A summary of the complete VWTPs in the baseline, plausible, and outer boundary scenarios is presented in Table 8-8.

Table 8-8:
Cost of VWTPs (Baseline, Plausible, and Outer Boundary)

VWTP	Scenario	Description	Capital Cost		Annual O&M Cost	
			($)	$/gal capacity	($/yr)	$/kgal
UW-1	Baseline	Conventional particulate removal, free chlorine disinfection	$93 -$200M	$0.93 -$2.00	$3.3 -$7.2M	$0.18 -$0.39
	Plausible	A- Convert to chloramines	$94 -$202M	$0.94 -$2.02	$3.4 -$7.2M	$0.18 -$0.40
		or				
		B- Add GAC, free chlorine disinfection remains	$201 -$431M	$2.01 -$4.31	$7.7 -$16.4M	$0.42 -$0.9
	Outer Boundary	Add GAC and UV disinfection, free chlorine disinfection remains	$287 -$614M	$2.87 -$6.14	$10.1 -$21.6M	$0.55 -$1.19
CD-1	Baseline	Pre-ozonation, conventional particulate removal, chloramines	$14 -$30M	$1.80 -$3.86	$2.6 -$5.7M	$0.36 -$0.78
	Plausible	Reduce ozone dose and add UV disinfection	$110 -$236M	$2.75 -$5.90	$3.5 -$7.6M	$0.48 -$1.03
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine	$161 -$346M	$4.03 -$8.65	$5.6 -$11.9M	$0.76 -$1.64
CAA-1	Baseline	Conventional particulate removal, chloramines	$46 -$98M	$1.14 -$2.45	$1 -$2.1M	$0.13 -$0.29
	Plausible*	No upgrades	$46 -$98M	$1.14 -$2.45	$1 -$2.1M	$0.13 -$0.29
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine	$135 -$289M	$3.38 -$7.23	$3.9 -$8.4M	$0.53 -$1.15
CAA-2	Baseline	Pre-ozonation, conventional particulate removal, chloramines	$577 -$1237M	$1.15 -$2.47	$32.1 -$68.7M	$0.27 -$0.58
	Plausible	Reduce ozone dose and add UV disinfection	$975 -$2089M	$1.95 -$4.18	$48.3 -$103.5M	$0.41 -$0.87
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine	$1348 -$2888M	$2.7 -$5.78	$74.3 -$159.1M	$0.63 -$1.34
CAAW-1	Baseline	Pre-ozonation, conventional particulate removal, chloramines	$923 -$1978M	$1.15 -$2.47	$59.2 -$126.8M	$0.27 -$0.58
	Plausible*	No upgrades	$923 -$1978M	$1.15 -$2.47	$59.2 -$126.8M	$0.27 -$0.58
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine	$2162 -$4633M	$2.70 -$5.79	$132.5 -$284M	$0.61 -$1.30

*No upgrades needed, baseline costs remain. All costs in December 2010 dollars, CCI = 8952.

Costs are representative of AACE Class 5 estimates. AACE Class 5 estimates are planning level costs prepared based on 0 to 2% of full project definition with accuracy ranges of -20% to -50% on the low side and +30% to +100% on the high side. Accuracy range for cost estimates presented in this project are -30% to +50%.

8.6. Extrapolation of VWTP Costs to Regional Level

VWTPs were developed to represent water treatment in each of four source water areas. Costs were estimated for each VWTP for the baseline, plausible, and outer boundary scenario. In order to expand the costs to the regional level, the added cost of each scenario was first calculated (baseline cost was subtracted from the future scenario cost) (Table 8-9).

Table 8-9:
Added Costs for VWTP Upgrades

VWTP	Scenario	Description	Added Capital Cost		Added Annual O&M Cost	
			($)	$/gal capacity	($/yr)	$/kgal
UW-1	Plausible	A- Convert to chloramines	$1 -$3M	$0.01 -$0.03	$0 -$0.1M	$0.0 -$0.0
		or				
		B- Add GAC, free chlorine disinfection remains	$108 -$231M	$1.08 -$2.31	$4.3 -$9.3M	$0.24 -$0.51
	Outer Boundary	Add GAC and UV disinfection, free chlorine disinfection remains	$193 -$414M	$1.93 -$4.14	$6.8 -$14.5M	$0.37 -$0.79
CD-1	Plausible	Reduce ozone dose and add UV disinfection	$38 -$82M	$0.95 -$2.04	$0.9 -$1.9M	$0.12 -$0.26
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine	$89 -$191M	$2.23 -$4.79	$2.9 -$6.3M	$0.4 -$0.86
CAA-1	Plausible*	No upgrades	-	-	-	-
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine	$89 -$191M	$2.23 -$4.79	$2.9 -$6.3M	$0.4 -$0.86
CAA-2	Plausible	Reduce ozone dose and add UV disinfection	$398 -$853M	$0.80 -$1.71	$16.2 -$34.8M	$0.14 -$0.29
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine	$771 -$1652M	$1.54 -$3.30	$42.2 -$90.5M	$0.36 -$0.76
CAAW-1	Plausible*	No upgrades	-	-	-	-
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine	$1239 -$2654M	$1.55 -$3.32	$73.3 -$157.2M	$0.33 -$0.72

*No upgrades needed, baseline costs remain. All costs in December 2010 dollars, CCI = 8952.

The added cost of treatment upgrades to a VWTP was expanded to represent each source water area by taking into account the area's total regional treatment capacity. The fraction of the total regional treatment capacity that was represented by the VWTP was calculated, and this factor was then applied to the VWTP costs. For example, CD-1 has 40 mgd capacity in a source water area with a total treatment capacity of 284 mgd. Dividing 284 mgd by 40 mgd gives a factor of 7.1 to be applied to the cost estimate.

Multiplying 7.1 by the added capital cost of CD-1, $142M, results in a total regional capital cost of $1012M to meet the plausible future scenario. A summary of the added costs for each source water area is presented in Table 8-10. These costs are based on current treatment capacity. Future treatment capacity is likely to increase with increasing population, so 2030 costs are likely to be higher.

Table 8-10:
Regional Added Costs for Upgrades

VWTP	VWTP Design Capacity (mgd)	Representative Regional Treatment Capacity/ VWTP Capacity	Scenario	Added Capital Cost	Added Annual O&M Cost
				($)	($/yr)
Upper Watersheds- 818 mgd Total Regional Treatment Capacity					
UW-1	100	8.18	Plausible	$10 - $21M	$0.3 - $0.6M
				or	
				$883 - $1893M	$35.3 - $118.5M
			Outer Boundary	$1581 - $3387M	$55.3 – 118.5M
Central Delta- 284 mgd Total Regional Treatment Capacity					
CD-1	40	7.1	Plausible	$270 - $579M	$6.2 - $13.4M
			Outer Boundary	$634 - $1359M	$20.8 - $44.5M
CAA- 2201 mgd Total Regional Treatment Capacity					
CAA-1	40	3.86	Plausible*	-	-
			Outer Boundary	$345 - $739M	$11.3 – $24.2M
CAA-2	500	6.78	Plausible	$2699 - $5783M	$110.0 - $235.8M
			Outer Boundary	$5226 – $11198M	$286.2 - $613.3M
CAA-West - 836 mgd Total Regional Treatment Capacity					
CAAW-1	800	1.04	Plausible*	-	-
			Outer Boundary	$1288 - $2760M	$76.3 – $163.5M
TOTAL			Plausible	$2978 - $6382M	$116.6 - $249.8M
				Or	
				$3852 – $8254M	$151.6 - $324.8M
			Outer Boundary	$9074 - $19443M	$449.8 - $963.9M

*No upgrades needed, baseline costs remain.

All costs in December 2010 dollars, CCI = 8952.

Costs are representative of AACE Class 5 estimates. AACE Class 5 estimates are planning level costs prepared based on 0 to 2% of full project definition with accuracy ranges of -20% to -50% on the low side and +30% to +100% on the high side. Accuracy range for cost estimates presented in this project are -30% to +50%.

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9. Summary

The objective of the Drinking Water Treatment Evaluation project was to determine the effects of future water quality changes at treatment plants that utilize surface water from the Central Valley of California while taking into consideration current and future regulations. This section summarizes the project findings.

9.1. Source Water Areas and Representative VWTPs

Phase I of the Drinking Water Treatment Evaluation defined the boundaries of the study by identifying areas of similar source water quality, outlining existing water treatment practices in each source water area, and defining representative VWTPs.

Four source water areas were identified:

- Upper Sacramento and Upper-Eastern San Joaquin Watersheds (Upper Watersheds)
- Central Delta including the South Bay Aqueduct (Central Delta)
- California Aqueduct – Coastal and East Branches (CAA)
- California Aqueduct – West Branch (CAA-West)

Projections of future water quality for two of the four source water areas were reviewed. It was found that the TOC, bromide, and temperature did not differ enough from historical data to result in meaningful changes to DBP modeling results. For this reason, historical water quality was used for the four source water areas for the remainder of the evaluation.

Five VWTPs were developed to represent the four source water areas. In general, three common treatment trains emerged:

- Conventional particulate removal with chlorine disinfection (primary and secondary)
- Conventional particulate removal with ozone pre-oxidation, chlorine primary disinfection, and secondary disinfection with chloramines.
- Conventional particulate removal with chlorine primary disinfection and secondary disinfection with chloramines.

9.2. Future Regulatory Scenarios

Regulatory scenarios for the year 2030 were developed based on the team's experience with the USEPA and on best professional judgment. Scenarios were divided into three categories:

- Current - includes contaminants that are currently regulated. Cost estimates were developed for this scenario and it was used as a baseline.
- Plausible - includes contaminants that are considered likely to be regulated in some form.
- Outer Boundary- includes the same contaminants; however, the requirements could be more stringent. This scenario was provided to bracket the regulatory possibilities.

9.3. Treatment Triggers

Once VWTPs and future regulatory scenarios were defined, the threshold levels (i.e., treatment triggers) where the plausible regulatory scenario creates the need for capital or operational modifications to a treatment process were developed. These threshold values, or treatment triggers, were developed for current and plausible future regulations for each VWTP. All baseline VWTPs met current regulations at the 90^{th} percentile water quality conditions. Some general observations regarding the treatment triggers for the VWTPs include:

- Bromide and TOC concentrations dictate the ability of VWTPs to comply with current and plausible future THM and HAA regulations. The plausible regulatory assumption of a single sample not to exceed is a significant driver behind bromide and TOC controlling future compliance. A matrix of varying bromide and TOC concentrations was developed for each VWTP for the purpose of this evaluation.
- Chlorate is a common contaminant associated with hypochlorite solutions. WTPs utilizing hypochlorite (on-site generation or bulk) should consider: diluting the solution upon delivery, storing the solution at lower temperatures, controlling the pH of the stored solution between 11 and 13, and using fresh solution when possible.
- All VWTPs have sufficient chlorine contact time to oxidize 10 µg/L of microcystins and some NDMA precursors.
- VWTPs utilizing pre-ozonation will also oxidize microcystins and NDMA precursors.
- It is uncertain whether additional NDMA treatment will be necessary because of the complexity of NDMA formation and low plausible regulatory levels, even though oxidation of NDMA precursor will occur.
- Nitrification will not likely form nitrate at levels approaching the MCL at the representative VWTPs considered in this study. VWTPs utilizing chloramines dose ammonia at 0.6 mg/L. At this dose, ammonia will not be present at levels above the 0.8 mg/L as N treatment trigger.
- The CCL3 is evaluating several emerging pathogens; however, none of these pathogens are more difficult to remove, oxidize, or inactivate compared to the current microbial standards for *Giardia*, virus, and *Cryptosporidium*. For this reason, no treatment triggers were developed for emerging pathogens.

9.4. Future VWTP Treatment Upgrades

Based on the ability of a VWTP to meet treatment goals (80 percent of the MCL) in the plausible regulatory scenario in combination with the treatment trigger analysis, treatment upgrades were recommended:

- UW-1 had two options:
  - A- Utilize chloramines as secondary disinfectant, or
  - B- Install GAC contactors and continued to use free chlorine as a secondary disinfectant.
- CD-1: include a reduction in ozone dose and add of UV disinfection.
- CAA-2: include a reduction in ozone dose and add of UV disinfection.

For the outer boundary future regulatory scenario, upgrades were recommended for all VWTPs, including the addition of GAC contactors and UV disinfection. A summary of VWTPs and the recommended upgrades is presented in Table 9-1.

Table 9-1:
VWTP Upgrades Needed to Meet Future Regulations

VWTP	Scenario	Description
UW-1	Current	Conventional particulate removal, free chlorine disinfection
	Plausible	Convert to chloramines or
		Add GAC, free chlorine disinfection remains
	Outer Boundary	Add GAC and UV disinfection, free chlorine disinfection remains
CD-1	Current	Pre-ozonation, conventional particulate removal, chloramines
	Plausible	Reduce ozone dose and add UV disinfection
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine
CAA-1	Current	Conventional particulate removal, chloramines
	Plausible*	No upgrades
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine
CAA-2	Current	Pre-ozonation, conventional particulate removal, chloramines
	Plausible	Reduce ozone dose and add UV disinfection
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine
CAAW-1	Current	Pre-ozonation, conventional particulate removal, chloramines
	Plausible*	No upgrades
	Outer Boundary	Add GAC and UV disinfection, eliminate chloramines and use free chlorine

*No upgrades needed, baseline costs remain.

9.5. Cost Estimates for Future VWTP Upgrades

The added cost of treatment upgrades to a VWTP was expanded to represent each source water area by taking into account the area's total regional treatment capacity. The fraction of the total regional treatment capacity that was represented by the VWTP was calculated, and this fraction was then applied to the VWTP costs. For example, CD-1 has 40 mgd capacity in a source water area with a total treatment capacity of 284 mgd. Dividing 284 mgd by 40 mgd gives a fraction of 7.1 to be applied to the cost estimate. Multiplying 7.1 by the added capital cost of CD-1, $142M, results in a total regional capital cost of $1012M to meet the plausible future scenario. A summary of the added costs for each source water area is presented in Table 8-10. These costs are based on current treatment capacity. Future treatment capacity is likely to increase with increasing population, so 2030 costs are likely to be higher.

Table 9-2:
Regional Added Costs for Upgrades

VWTP	VWTP Design Capacity (mgd)	Representative Regional Treatment Capacity/ VWTP Capacity	Scenario	Added Capital Cost ($)	Added Annual O&M Cost ($/yr)
Upper Watersheds- 818 mgd Total Regional Treatment Capacity					
UW-1	100	8.18	Plausible	$10 - $21M	$0.3 - $0.6M
				or	
				$883 - $1893M	$35.3 - $118.5M
			Outer Boundary	$1581 - $3387M	$55.3 – 118.5M
Central Delta- 284 mgd Total Regional Treatment Capacity					
CD-1	40	7.1	Plausible	$270 - $579M	$6.2 - $13.4M
			Outer Boundary	$634 - $1359M	$20.8 - $44.5M
CAA- 2201 mgd Total Regional Treatment Capacity					
CAA-1	40	3.86	Plausible*	-	-
			Outer Boundary	$345 - $739M	$11.3 – $24.2M
CAA-2	500	6.78	Plausible	$2699 - $5783M	$110.0 - $235.8M
			Outer Boundary	$5226 – $11198M	$286.2 - $613.3M
CAA-West - 836 mgd Total Regional Treatment Capacity					
CAAW-1	800	1.04	Plausible*	-	-
			Outer Boundary	$1288 - $2760M	$76.3 – $163.5M
TOTAL			Plausible	$2978 - $6382M	$116.6 - $249.8M
				Or	
				$3852 – $8254M	$151.6 - $324.8M
			Outer Boundary	$9074 - $19443M	$449.8 - $963.9M

*No upgrades needed, baseline costs remain.

All costs in December 2010 dollars, CCI = 8952.

Costs are representative of AACE Class 5 estimates. AACE Class 5 estimates are planning level costs prepared based on 0 to 2% of full project definition with accuracy ranges of -20% to -50% on the low side and +30% to +100% on the high side. Accuracy range for cost estimates presented in this project are -30% to +50%.

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Appendix A

Drinking Water Treatment Evaluation Project History

Water Treatment Evaluation Project Objective and Scope

The project objective was to identify and evaluate, at a conceptual planning level, the capital and operational costs (or cost savings) and intangible benefits (or detriments) that were projected to occur as a result of future changes in intake water quality at treatment plants that utilize surface water from the Central Valley of California. Current and projected future regulations were considered.

Project Timeline

Malcolm Pirnie initiated work on the Drinking Water Treatment Evaluation Project in March 2008, finalized the first technical memorandum that summarized the regulatory scenario, and began work on Tasks two and three. In December 2008, Malcolm Pirnie was instructed to stop work due to funding restrictions. Upon receiving a notice to proceed in January 2010, work on the Drinking Water Treatment Evaluation resumed. There have been several relevant publications completed during this time that could affect the regulatory scenarios and treatment trigger findings completed in 2008; therefore, these items were revisited to determine whether changes to the 2008 approach were justified.

The Future regulatory scenarios were described in Technical Memorandum 1, which was submitted, reviewed, and revised based on comments from the Work Group in 2008 (Appendix B). Since that time, additional research has become available on the formation, occurrence, health effects, and treatment of many priority constituents of concern. Malcolm Pirnie and the technical experts revisited, reviewed, and revised the previously developed regulatory scenarios. Any necessary updates or revisions to the previous analysis were captured in a revised Technical Memorandum 2 and in this Final Project Report.

The notice to proceed in January 2010 included project funding through the first quarter of 2010. On March 31, 2010 the decision was made to not renew project funding. As such, only initial tasks (Phase I) of the Drinking Water Treatment Evaluation were completed.

In December 2010, more funding became available through the first quarter of 2011 to complete the Drinking Water Treatment Evaluation. This Final Project Report documents the Drinking Water Treatment Evaluation in its entirety. Table A1 describes the project work completed throughout the timeline of the project.

TableA-1:
Project Work Completed

Task	Description of Work Completed
Phase I - March 2008 to December 2008 and January 2010 to March 2010	
Task 1- Define Study Boundaries	• Identified emerging drinking water quality issues. • Developed plausible and outer boundary future regulatory scenarios. • Defined areas of similar water quality and reviewed historical water quality data. • Identified WTPs in each source water area and outlined existing treatment practices at each WTP.
Task 2- Develop and Describe a Representative Virtual Water Treatment Plant (VWTP) for each Source Water Area	• Verified unit processes and design flowrates at each WTP. • Selected representative VWTPs and flowrates. • Began developing costs associated with baseline VWTPs.
Task 3- Identify Threshold Values that Trigger Treatment Changes	• Performed detail literature reviews • Identified occurrence information and formation/destruction mechanisms of contaminants. • Captured current contaminant information and treatment techniques. • Modeled DBP formation using the EPAWTPM. • Developed treatment triggers.
Phase II – January 2011 to March 2011	
Task A- Estimate Required Future Drinking Water Treatment Process and Operational Changes	• Identified many treatment strategies that could be employed. • Evaluated water quality scenarios provided by Work Group. • Determined future WTP upgrades. • Performed sensitivity analysis on water quality data • Ran upgraded VWTPs in EPAWTPM to verify treatment performance
Task B- Estimate Water Treatment Costs Associated with Different Intake Water Quality Scenarios in Each Source Water Area	• Refined initially developed costs for baseline VWTPs • Used results from Task A to estimate costs associated with WTP upgrades.
Task E- Address Additional Comments on Technical Memorandum 2	• Received and resolved additional comments on previously finalized Technical Memorandum 2 and incorporated all revisions into the Final Project Report.
Task D- Task Coordination, Meetings, and Project Report	• Developed Final Project Report

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Appendix B

Technical Memorandum 1: Definition of Study Boundaries

California Urban Water Agencies

California Urban Water Agencies

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Drinking Water Treatment Evaluation

Technical Memorandum 1: Definition of Study Boundaries

September 2008

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List of Abbreviations

AWWA	American Water Works Association
AwwaRF	American Water Works Association Research Foundation
Basin Plan	Water Quality Control Plan
Central Valley Water Board	Central Valley Regional Water Quality Control Board
CBDA	California Bay-Delta Authority
CCL3	Contaminant Candidate List
CDPH	California Department of Public Health
CUWA	California Urban Water Agencies
DBP	Disinfection By-product
Delta	Sacramento-San Joaquin Delta
DOC	Dissolved Organic Carbon
DON	Dissolved Organic Nitrogen
DWR	Department of Water Resources
EDC	Endocrine Disrupting Compounds
GAC	Granulated Activated Carbon
HAA	Haloacetic Acid
IESWTR	Interim Enhanced Surface Water Treatment Rule
LT2ESWTR	Long-Term 2 Enhanced Surface Water Treatment Rule
LRAA	Locational Running Annual Average
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MGD	Million Gallons per Day
MIOX	Mixed oxidants
NBA	North Bay Aqueduct
NCWA	Northern California Water Association
NDMA	N-Nitrosodimethylamine
OEHHA	Office of Environmental Health Hazard Assessment
PAC	Powdered Activated Carbon
PPCP	Pharmaceuticals and Personal Care Products
PHG	Public Health Goal
SDWA	Safe Drinking Water Act
SRCSD	Sacramento Regional County Sanitation District
SWP	State Water Project
SUVA	Specific Ultraviolet Absorbance
SWRCB	State Water Resources Control Board
SWTR	Surface Water Treatment Rule
TOC	Total Organic Carbon
TDS	Total Dissolved Solids
THM	Trihalomethane
THM4	Sum of four trihalomethanes
USEPA	United States Environmental Protection Agency
UV	Ultra Violet
WHO	World Health Organization
Work Group	Central Valley Drinking Water Policy Work Group
WDL	Water Data Library
WTP	Water Treatment Plant

1. Introduction and Project Background

The surface water in the Central Valley has the potential to impact more than 25 million Californians who receive a portion of their water from the Sacramento-San Joaquin Delta (Delta) and the tributaries to the Delta (CALFED Water Quality Program, 2008). The tributaries to the Sacramento and San Joaquin rivers that originate in the Sierra Nevada Mountains generally have high quality water; however, pollutants from a variety of sources (urban, industrial, agricultural, and natural) degrade the quality of water as it flows to and downstream of the Delta, creating a number of drinking water treatment challenges. A number of constituents potentially impact the water quality in the Central Valley. Table 1-1 highlights those most likely to impact present and future drinking water treatment.

Table 1-1.
Central Valley Water Quality Challenges

Water Quality Challenge	Potential Treatment Impact
High Organic Carbon and Bromide Concentrations	Treatment must balance the formation of disinfection by-products (DBPs) with the removal and inactivation of pathogens and indicator organisms.
Pathogens and Indicator Organisms	Removal and inactivation of pathogens and indicator organisms must be balanced with the formation of DBPs while achieving adequately protective disinfection of pathogens. If additional pathogens are regulated, additional treatment options may need to be considered.
High Nutrient Concentrations	High nutrient concentrations may lead to algal blooms, create taste and odor problems, and impact plant operations. If and when nitrogenous DBPs are regulated, additional treatment options may need to be considered.
High levels of Total Dissolved Solids (TDS)	High TDS levels create aesthetic problems and challenges for blending, groundwater storage, and water recycling.
Pharmaceuticals and personal care products (PPCPs) and endocrine disrupting compounds (EDCs) (Emerging Contaminants)	Potential future regulation of emerging contaminants may lead to increased monitoring and the need for additional treatment processes or process modifications.

Currently, water quality regulations applicable to the Central Valley include maximum contaminant levels (MCLs) issued by the California Department of Public Health (CDPH) and a Water Quality Control Plan (Basin Plan) for the Sacramento-San Joaquin River Basins. The Basin Plan was developed by the Central Valley Regional Water Quality Control Board (Central Valley Water Board) and designates beneficial uses, including municipal and domestic water supply, for the Sacramento and San Joaquin rivers and Delta. The Basin Plan also specifies numeric and narrative water quality objectives and implementation strategies to protect designated beneficial uses.

Current plans and policies for Central Valley surface waters do not contain numeric quality objectives for several key drinking water constituents of concern, including DBP precursors and pathogens. Additionally, the current implementation strategies do not provide source water protection at a level desired by water supply agencies. For this reason, the Central Valley Water Board is working with stakeholders to develop a comprehensive Central Valley Drinking Water Policy, as described below.

1.1. Central Valley Drinking Water Policy Development

The Drinking Water Policy will be considered as a Basin Plan amendment in 2009 or 2010. To provide the technical information needed for the development of the Drinking Water Policy, a Central Valley Drinking Water Policy Workgroup (Work Group), comprised of interested stakeholders and technical experts (listed below), was formed to develop and implement a work plan.

- California Bay-Delta Authority (CBDA)
- CDPH
- Central Valley Water Board
- State Water Resources Control Board (SWRCB)
- Sacramento Regional County Sanitation District (SRCSD)
- Northern California Water Association (NCWA)
- California Urban Water Agencies (CUWA) with representatives from Contra Costa Water District, Metropolitan Water District of Southern California, and East Bay Municipal Utility District.
- United States Environmental Protection Agency (USEPA)
- Clean Water Action
- Sacramento City Stormwater

The work plan includes:

- An assessment of the ability to control sources of key drinking water constituents in the Delta and is tributaries (source water protection approach).
- An assessment of the ability to remove key drinking water constituents in water treatment plants (water treatment approach).
- An analysis of the feasibility, costs, and risks associated with both approaches to managing key drinking water constituents (source water protection and water treatment).

This project addresses the water treatment approach for priority constituents. The drinking water constituents considered to have the highest priority by the Work Group include DBP precursors, dissolved minerals, nutrients, pathogens, and pathogen indicator organisms (Table 1-2).

Table 1-2.
Priority Constituents of Concern for Central Valley Drinking Water Policy

Constituent Class	Source Water Constituents	Treated Water Constituents
Disinfection Byproduct Precursors	Total organic carbon, dissolved organic carbon, bromide, alkalinity	Disinfection byproducts, Trihalomethanes (THMs), Haloacetic Acids (HAAs), bromate
Dissolved Minerals	Total dissolved solids, electrical conductivity (EC), and chloride	Total dissolved solids, EC, and chloride
Nutrients	Nitrogen species (total, total Kjeldahl, organic, nitrate, nitrite, ammonia) Phosphorus species (total, dissolved)	Impacts of algal growth: taste and odor, algal toxins, treatment challenges
Pathogens and Indicator Organisms	*Giardia*, *Cryptosporidium*, total coliform, fecal coliform, *Enterococcus*, *E.coli*	*Giardia*, *Cryptosporidium*, total coliform, fecal coliform, *Enterococcus*, *E.coli*

Source: Drinking Water Treatment Evaluation Scope of Work

1.2. Project Objective

The objective of this project is to identify and evaluate, at a conceptual planning level, the capital and operational costs (or cost savings) and intangible benefits (or detriments) that are projected to occur as a result of future changes in intake water quality at treatment plants that utilize surface water from the Central Valley of California. Current, improved, and degraded water quality will be evaluated. In addition, current and projected future regulations will be considered. The objective of this project will be accomplished in seven tasks:

- Task 1- Define Study Boundaries
- Task 2- Develop and Describe a Representative (Virtual) Water Treatment Plant (WTP) for each Source Water Area
- Task 3- Identify Threshold Values that Trigger Treatment Changes
- Task 4- Estimate Required Future Dinking Water Treatment Process and Operational Changes
- Task 5- Estimate Water Treatment Costs Associated with Different Intake Water Quality Scenarios in Each Source Water Area
- Task 6- Evaluate Intangible Factors in the Assessment of the Costs and Benefits of Different Raw Water Quality Scenarios
- Task 7- Task Coordination, Meetings, and Project Report

1.3. Technical Memorandum Organization

The purpose of this technical memorandum is to summarize the work completed as part of Task 1- Define Study Boundaries. This memorandum is organized into five sections:

- Section 1 provides a brief description of key water quality concerns in the Central Valley, the development of a Central Valley Drinking Water Policy, project objectives, and technical memorandum organization.
- Section 2 provides a summary of current regulations and a potential future regulatory scenario for 2030.
- Section 3 provides definitions of areas with similar source water quality and a summary of current water quality conditions for each source water area.
- Section 4 provides a description of existing water treatment practices for each source water area.

Section 5 summarizes the results from Task 1 and provides a description of and recommended approach to upcoming tasks.

2. Current and Future Drinking Water Regulations

The current drinking water regulations set contaminant limits and treatment techniques that need to be considered in subsequent tasks, and the future regulation predictions will be used to evaluate what water treatment trends may occur in the future. This section discusses the current and future regulations that are of particular interest to this project.

2.1. Current Drinking Water Regulations Summary

This section summarizes the three major categories of primary drinking water regulations that have been implemented under the Safe Drinking Water Act (SDWA) and are of interest from the perspective of this project. More detailed descriptions are provided in Appendix A. Table 2-1 summarizes selected current regulations.

Table 2-1.
Selected Current Drinking Water Regulations

Contaminant	MCL (mg/L)	Secondary MCL[1] (mg/L)	CDPH Public Health Goal (mg/L)	Removal/Inactivation Requirement
Disinfection Byproducts				
Total Trihalomethanes (THM)	0.080	-	-	-
Sum of five Haloacetic acids (HAA5)	0.060	-	-	-
Bromate	0.010	-	-	-
Chlorite	1.0	-	-	-
N-Nitrosodimethylamine (NDMA)	-	-	0.000003	-
Dissolved Minerals				
Total Dissolved Solids (TDS)	-	500 (CDPH recommended level)	-	-
Pathogens and Indicator Organisms				
Giardia	-	-	-	3-log [2]
Cryptosporidium	-	-	-	2.0-log + Bin Classification [3]

[1]CDPH Secondary MCLs are enforceable.

[2]Surface Water Treatment Rule (SWTR)

[3]Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)

2.2. Future Regulatory Scenarios

The consultant team developed possible regulatory scenarios for the year 2030. These are predictions based on our team's experience with USEPA and on best professional judgment. Federal and State regulations are continuously evolving, and the exact scenarios in the year 2030 are unknown.

The regulatory scenarios focused on the priority constituents of concern for the Central Valley Drinking Water Policy, including DBP precursors, dissolved minerals, algal toxins, and pathogens and pathogen indicators (Table 1-2). The project team also reviewed the most recent Draft of the USEPA Contaminant Candidate Lists (CCL3) to determine additional contaminants of concern that may potentially be regulated by 2030. Ultimately, a plausible and an outer boundary regulatory scenario were developed (Table 2-2). The plausible regulatory scenario in 2030 includes contaminants that are likely to be regulated in some form; this is the regulatory scenario that will be used to evaluate potential WTP modifications and cost evaluations in subsequent tasks. The outer boundary regulatory scenario includes the same contaminants; however, the regulated levels are more stringent. The outer boundary scenarios will only be evaluated qualitatively. This section describes the basis for the regulatory scenarios. Appendix B identifies the specific contaminants that could be regulated under a group of contaminants (e.g., iodinated THMs), and includes available regulatory and health risk information.

Table 2-2
Potential Future Regulatory Scenarios

Constituent	Regulatory Scenarios		
	Current	**Plausible[1]**	**Outer Boundary[2]**
Disinfection Byproduct Precursors			
Organic Carbon and Organic Nitrogen	DBPR Enhanced Coagulation Requirements	DBPR Enhanced Coagulation Requirements	Control total organic carbon (TOC) as a precursor Control dissolved organic nitrogen (DON) as a precursor
Disinfection Byproducts			
Bromate	10 µg/L*	5 or 10 µg/L*	1 to 4 µg/L*
THMs			
THM4	80 µg/L (LRAA)	80 µg/*	Regulate individual species*
Iodinated THMs	-	Regulate iodinated THMs as a group*	Regulate individual species*
HAAs			
HAA5	60 µg/L (LRAA)	60 µg/L*	Individual levels for selected species
HAA9	-	80 µg/L (LRAA[5]), additional species to current regulations	1. 80 µg/L* 2. Individual levels for selected species*
Iodinated HAAs	-	-	Regulate individual species*

Constituent	Regulatory Scenarios		
	Current	**Plausible[1]**	**Outer Boundary[2]**
Nitrogenous Organic Compounds			
Nitrosamines	PHG 3 ng/L[3], Notification Level 10 ng/L[3] (NDMA)	NDMA at 3 or 10 ng/L* [4,]	(1) Control DON as a precursor (2) Regulate select compounds*
Hydrazine	-	-	10 ng/L*
Disinfection Practices and Views			
Chloramination	Accepted technology	Other technologies preferred	Technology not accepted
View of low to no use of disinfectants	View generally not accepted in U.S	View generally not accepted in U.S.	View begins to be accepted in U.S.
Dissolved Minerals			
TDS	500 mg/L secondary MCL	500 mg/L secondary MCL	Indirect reduction requirements for recycle water TDS
Algal Toxins			
Microcystin	-	1 µg/L (WHO guideline)	-
Anatoxin-a	-	-	3 µg/L (suggested, Australia)
Saxitoxin	-	-	3 µg/L (suggested, Australia)
Pathogens and Indicators			
Total coliform (TC), Fecal coliform (FC), and *E. coli*	Monitoring based upon population. Non-acute MCL for > 5% TC positive, acute MCL for FC or *E.coli* with confirmation in repeat sample.	Monitoring based upon population. Non-acute MCL for > 5% TC positive, acute MCL for *E.coli* with confirmation in repeat sample.	-
Cryptosporidium	2-log removal credit (IESWTR[6]); Additional inactivation needed based on source water concentration (LT2ESWTR)	2-log removal credit (IESWTR); Additional inactivation needed based on source water concentration (LT2ESWTR)	Additional 1-log
Other Pathogens	-	Regulated, but less challenging to remove than SWTR and LT2ESWTR standards	-

[1]Scenario will be used in treatment selection and costing.
[2]Scenario will be discussed qualitatively, but not included in costing.
[3]CDPH regulation.
[4]NDMA is considered by the regulatory agency as an indicator of other nitrosamines' levels
[5]Locational Running Annual Average (LRAA)
[6] Interim Enhanced Surface Water Treatment Rule (IESWTR)
*Single sample not to exceed.

2.2.1. DBPs

Currently regulated DBPs include THM4, HAA5, bromate, and chlorite. There are a number of reasons that the USEPA may consider modifying the current regulations for these DBPs as well as regulating other DBPs:

- Cancer is not the only health endpoint being detected in epidemiology studies; there are new concerns about potential adverse reproduction and developmental effects (Richardson 2005).
- New human exposure studies are including inhalation and dermal absorption routes of exposure to DBPs in addition to ingestion, which is revealing increased cancer risks (Richardson 2007).
- Brominated DBPs may be more carcinogenic than their chlorinated analogs (Richardson 2005, WHO 2000, Woo et al. 2002).
- Iodinated DBPs may be more carcinogenic than their brominated analogs (Richardson 2005, Plewa et al. 2004, Woo et al. 2002)

Bromate is currently regulated at 10 µg/L, which corresponds to a cancer risk factor of 2×10^{-4} (typically, the basis for MCLs is 10^{-4} to 10^{-6}). It is anticipated that this MCL could be reduced to 5 µg/L (plausible) or lower (outer boundary) in an effort to reduce the cancer risk to 1×10^{-4} or lower. This risk has to be balanced with the fact that bromate could be present in the common disinfectant chemical, sodium hypochlorite.

THMs are regulated as a group (THM4) on a LRAA basis at 80 µg/L under the Stage 2 DBP Rule (effective from 2012). Epidemiological evidence has produced uncertain and sometimes conflicting conclusions on the reproductive effects of exposure to DBPs. For example, an extensive literature review by Reif et al. 2000 found that evidence for an increased risk of spontaneous abortion and stillbirth exists but is uncertain (Health Canada 2006). A more recent study by American Water Works Research Foundation (AwwaRF) found no association between THM exposure and pregnancy loss (Savitz et al. 2005). More research is needed; however, due to the fact that contaminant levels can significantly vary with the LRAA calculation method, it is possible that the THM regulation will change to single sample not to exceed 80 µg/L to reduce variability and limit acute or reproductive health effects (plausible). As an increasing amount of health effects data becomes available, regulations may be directed to individual species to reduce associated health risks (outer boundary).

Despite the fact that occurrence of iodinated THMs is low relative to THM4 (Krasner et al. 2006), iodinated THMs are becoming increasingly important because recent research has shown increased human health risk levels compared to chlorinated and brominated DBPs (Woo et al. 2002). Currently iodinated THMs are not regulated; however, it is possible that they will be regulated (at least as a group) on a single sample not to exceed basis (plausible). It is not possible to predict a level for regulation at this time; more human health effect research is needed. Once more data becomes available, the iodinated species may even be regulated as individual species on a single sample not to exceed basis to reduce human health risks (outer boundary).

Similar to THMs, HAAs are regulated under the Stage 2 DBP Rule as a group (HAA5) at 60 µg/L on an LRAA basis. To limit variability and reduce acute human health effects, HAA5 regulation will possibly change to a single sample not to exceed (plausible). Further, as additional human health effect data becomes available, regulations may be directed to individual species (outer boundary). It is recognized that additional regulation may be necessary to represent the entire group of HAAs that can be formed (HAA9). HAA9 is not currently regulated; however, it is possible that HAA9 will be regulated in the future and could be regulated as a group at a level of 80 µg/L LRAA (plausible). Although it is less likely, HAA9 regulation may be directed to 80 µg/L single sample not to exceed or depending on available human health affect data on an individual species basis (outer boundary).

Similar to iodinated THMs, iodinated HAAs are receiving more attention as further studies are demonstrating occurrence in finished water systems that use chloramines (Krasner et al. 2006) and increased human health risks relative to chlorinated and brominated DBPs (Richardson 2005). At this time, more occurrence and human health effect research is needed, and it is unlikely that iodinated HAAs will be regulated by 2030 (plausible). If additional data becomes available, regulation of iodinated HAAs may be directed towards individual species (outer boundary).

Another class of DBPs that may experience a change or addition to regulations are nitrogenous DBPs. NDMA, a carcinogen, has a CDPH public health goal (PHG) of 3 ng/L and a notification level of 10 ng/L. Essentially equivalent to the federal Maximum Contaminant Level Goal (MCLG), PHGs are set by California's Office of Environmental Health Hazard Assessment (OEHHA) and are based solely on scientific and public health considerations without regard to economic cost considerations. In California, PHGs are used in establishing the state's primary drinking water standards (MCLs). MCLs adopted by CDPH consider economic factors and technical feasibility, but must be set at a level that is as close as feasible to the corresponding PHG (OEHHA 2006). Currently, there is no MCL for NDMA.

It is predicted that NDMA (assuming it is representative of all nitrogenous DBPs) will pave the way for regulation of other nitrogenous DBPs. It is possible that the future regulation of NDMA will be at 3 or 10 ng/L single sample not to exceed (plausible). Although it is less likely, regulations requiring treatment for dissolved organic nitrogen (as a precursor) similar to the TOC removal requirements set forth in the Stage 1 DBP Rule could be established (outer boundary). Alternatively, if NDMA is determined to not be representative of nitrogenous DBPs, regulation of individual compounds could result (outer boundary).

Hydrazine is a probable human carcinogen that can be formed through the reaction of monochloramine and ammonia. Hydrazine is formed as a result of the addition of these chemicals, not due to source water quality. Additionally, hydrazine formation is not detectable in drinking waters with pH lower than 9.0 (Najm 2007). For this reason, regulation of hydrazine is not likely (plausible). However, the cancer risk level for hydrazine at 10 ng/L is 10^{-6}, and this risk level is within the range typically captured by an MCL. Although it is unlikely, plants using lime softening or distribution system conditions that result in pH excursions may create the need for future regulation of hydrazine at 10 ng/L single sample not to exceed (outer boundary).

2.2.2. Disinfection Practices and Views

With the increasing concern over DBPs, disinfection practices are increasingly scrutinized. The benefits of the inactivation of pathogens must continuously be balanced with the formation of compounds that adversely affect human health. For this reason, it is likely that chloramination may become the less preferred disinfection method, specifically because of potential nitrogenous DBP formation (plausible). Outside of the United States, the opinion is prevalent that residual disinfectants should minimally be used or not used at all. This viewpoint is not likely to be accepted in the United States; however, as an increasing number of studies indicate the adverse health effects associated with US disinfection practices, this view may become more accepted in the future (outer boundary).

2.2.3. Dissolved Minerals

Dissolved minerals are becoming an increasingly important issue in drinking water treatment. Currently, USEPA and CDPH have established secondary MCLs for TDS. The USEPA secondary MCL is 500 mg/L and is an unenforceable guideline. CDPH has established a secondary maximum contaminant level range for TDS. Secondary MCLs in California are enforceable limits based on a consumer acceptance contaminant level; however, the consumer acceptance contaminant level for TDS is not fixed (Table 2-3). As salinity continues to increase, adverse affects on the treatment process and the ability to recycle water may be experienced. It is likely TDS will be monitored in the future, and the regulation likely will not change (plausible). With the increasing importance of water recycling, TDS reductions may be necessary (outer boundary); however, it is unlikely that a SDWA regulation would require this.

Table 2-3.
Consumer Acceptance Contaminant Level

Constituent, Units	Recommended[1]	Upper[2]	Short Term[3]
Total Dissolved Solids, mg/L	500	1,000	1,500
Or			
Specific Conductance, µS/cm	900	1,600	2,200
Chloride, mg/L	250	500	600
Sulfate, mg/L	250	500	600

Source: CDPH, 2008.
Notes:
(1) Constituent concentrations lower than the recommended contaminant level are desirable for a higher degree of consumer acceptance.
(2) Constituent concentrations ranging to the Upper contaminant level are acceptable if it is neither reasonable nor feasible to provide more suitable waters.
(3) Constituent concentrations ranging to the short term contaminant level are acceptable only for existing community water systems on a temporary basis pending construction of treatment facilities or development of acceptable new water sources.

2.2.4. Algal Toxins

Algal toxins are toxins formed by cyanobacteria that dominate the freshwater phytoplankton communities during periods of calm, stratified conditions (AwwaRF 2008). Algal toxins are of increasing interest in the US and in other countries around the worldbecause it has been observed that increased discharges of nutrients can lead to increased algal blooms (and their toxins), which have been associated with an increased incidence of fish kills, deaths of livestock and wildlife, and human illness and death (Richardson 2007). The most common algal toxins are microcystins, anatoxins, and saxitoxins. Others have recognized the need to regulate these toxins, and it is possible that the US will follow. The World Health Organization (WHO) has a guideline value for microcystin of 1 µg/L, and it is possible that this could become an MCL by 2030 (plausible). Anatoxin-a and saxitoxin do not have WHO guidelines; however, Australia has a suggested limit for these toxins of 3 µg/L. Although it is not likely, there is a possibility that an MCL for anatoxin and saxitoxin could be established at the Australia suggested limit of 3 µg/L (outer boundary).

2.2.5. Pathogens

Currently, 2-log removal of *Cryptosporidium* is required by the IESWTR with additional inactivation required based on the bin classification outlined in the LT2ESWTR. These requirements are not likely to change by 2030, so the plausible scenario for *Cryptosporidium* inactivation will not require additional inactivation. However, future changes in source water quality could change bin classifications, triggering additional inactivation requirements. In the unlikely event that the requirements for *Cryptosporidium* removal/inactivation are increased to protect human health, it is predicted that an additional 1-log removal/inactivation will be required (outer boundary).

It is predicted that although pathogens other than *Cryptosporidium* will be regulated; none will be more challenging to remove or inactivate than *Cryptosporidium.* summarizes a number of pathogens that could possibly be regulated by 2030 based on the recommendations of expert panels from American Water Works Association (AWWA) and USEPA. Many are pathogens on the CCL3. Table 2-5 summarizes the treatment requirements that may be necessary to remove or inactive these pathogens. Based on this summary, it appears that the other pathogens that are likely to be regulated will not be more difficult to remove or inactivate compared to *Cryptosporidium.*

Table 2-4.
Recommended Pathogens for Regulation

Organism	CCL3 List	EPA Expert Recommended	AWWA Recommended
Caliciviruses (Noro Virus)	X	X	X
Campylobacter jejuni	X	X	X
Entamoeba histolytica	X	X	Exclude[1]
Escherichia coli (0157)	X	X	X
Helicobacter pylori	X	X	Exclude[1]
Hepatitis A virus	X	X	X
Legionella pneumophila	X	X	X
Naegleria fowleri	X	X	Exclude[1]
Salmonella enterica	X	X	
Shigella sonnei	X	X	
Vibrio cholerae	X	X	
Mycobacterium avium		Exclude[1]	X
Rotavirus		X	X
Enteroviruses (Coxsackieviruses and Echoviruses)		X	X
Adenovirus		X	

[1]Should not be regulated

Source: AWWA, 2008

Table 2-5.
Treatment of Pathogens

Organism	Free Chlorine	Ozone	UV
Caliciviruses	Aggregated calicicivirus required CTs greater than EPA Guidance Manual CT values. Disspersed calicicivirus required CTs less than EPA Guidance Manual CT values.[2]	<0.01 to 0.03 mg/L*min for 4-log inactivation at a pH of 7 and 5° C. [28]	29 to 36 mJ/cm2 for 4-log inactivation[3]
Campylobacter jejuni	Suseptible at doses effective for E. coli[4]	NA[1]	4.6 mJ/cm2 for 4-log inactivation[5]
Entamoeba histolytica	Similar resistance to chlorine as Giardia lamblia.6 Normal water treatment practices are able to remove Entamoeba cysts. [7]	NA[1]	NA[1]
Escherichia coli (0157)	4 log inactivation at CTs of approximately 1.1 to 1.2 mg/L*min[8]. 2-log inactivation at a CT of 0.119 mg/L* min[9]	0.09 mg/L*min for 2-log inactivation[9]	6 mJ/cm2 for 4-log inactivation[10]
Helicobacter pylori	2-log CT of 0.299 mg/L*min[9]	0.24 mg/L*min for 2-log inactivation[9]	NR[1]
Hepatitis A virus	CT table for SWTR are based on Hepatitis A	NR[1]	21 mJ/cm2 for 4-log inactivation [11]
Legionella pneumophila	2 to 13.5 mg/L*min for 2-log inactivation [12]	.5 to 1.5 mg/L*min for 2-log inactivation at a pH of 7.2 and 25° C.[12]	9.4 mJ/cm2 for 4-log inactivation [13]
Naegleria fowleri	2-log CT of 6 and 31 mg/L*min at a pH of 7.5 and 23°C for trophozoite and cyst form, respectively.[29]	NA[1]	63 mJ/cm2 for 2-log inactivation[29]
Salmonella enterica	Salmonella spp. are sensitive to chlorine and do not pose a risk when conventional drinking water treatment is applied. [14]	NA[1]	7 to 10 mJ/cm2 for 4-log of Salmonella spp. [10,15]
Shigella sonnei	Shigella spp. are sensitive to chlorine and do not pose a risk when conventional drinking water treatment is applied. [14]	0.9 to 1.4 mg/L*min for 1-log inactivation at a pH of 7.2 and 25° C. [30]	8.2 mJ/cm2 for 4-log inactivation[16]
Vibrio cholerae	Vegetative bacterium is widely known to be sensitive to chlorination and does not pose a risk when drinking water is properly disinfected.[14]	Can be inactivated by Ozone. [17]	2.9 to 21 mJ/cm2 for 4-log inactivation[18]
Mycobacterium avium	51 to 204 mg/L*min for 3-log inactivation at 23°C and a pH of 7. [19]	0.1 to 0.17 mg/L*min for 3-log inactivation at a pH of 7 and 23° C. [19]	NA[1]
Rotavirus	1.6 to 6.0 for 3-log inactivation at 4°C with pHs from 6 to 8.[20]	0.6 to 3.2 mg/L*min for 3-log inactivation with pHs from 6 to 8 at 4° C.[21]	36 mJ/cm2 for 4-log inactivation.[5]
Enteroviruses (Coxsackieviruses and Echoviruses)	0.14 to 33.66 mg/L*min for 2-log inactivation for Coxsackieviruses and 0.24 to 49.0 for Echoviruses at pHs from 6 to 10 at 5°C. [22]	0.1 mg/L*min for 3-log inactivation of unassociated coxsackievirus. 1.5 mg/L*min for 3-log inactivation of cell associated coxsackievirus at 5 NTU. [23]	32.5 to 36 mJ/cm2 for 4-log inactivation of Coxsackieviruses. 28 to 33 mJ/cm2 for 4-log inactivation of Echoviruses.[24]
Adenovirus	0.16 to 0.75 mg/L*min for 4-log inactivation at pHs from 6 to 8 and at 5° C. 36.09 mg/L*min for 4-log inactivation at pH of 8 and 15° C.[2]	0.07 to 0.6 mg/L*min for 4-log inactivation at a pH of 7 and 5° C. [25]	100 to 124 mJ/cm2 for 4-log inactivation with low pressure UV lamps. [26,27] Approximately 40 mJ/cm2 for 4-log inactivation with medium pressure UV lamps. [28]
Giardia	24 to 389 mg/L*min for 3-log inactivation depending on temperature, chlorine concentration, and pH.[32]	0.48 to 2.9 mg/L*min for 3-log inactivation depending on temperature.[32]	22 mJ/cm2 for 4-log inactivation.[31]
Cryptosporidium	Free chlorine is ineffective at inactivating Cryptosporidium. [33]	4.7 to 72 mg/L*min for 3-log inactivation depending on temperature. [31]	22 mJ/cm2 for 4-log inactivation.[31]

[1] NA = Not Available, results were not found during literature search. 2. Thurston-Enriquez et al. 2003a., 3. Thurston-Enriquez et al. 2003b., 4. Blaser et al. 1986, 5. Wilson et al. 1992, 6. Jarroll et al. 1981, 7. Karanis 2006, 8. Rice et al. 2008, 9. Baker et al. 2002 , 10. Tosa and Hirata 1999, 11. Wiedenmann et al. 1993, 12 Domingue et al 1998, 13 Oguma et al. 2004, 14 AWWA 2008., 15 Yaun et al 2003, 16 Chang et al. 1985 , 17. Burlson et al. 1975, 18. Hoyer 1998, 19. Taylor et al. 2000, 20. Vaughn et al. 1986, 21. Vaughn et al. 1987, 22. Engelbrecht et al. 1980, 23. Emerson et al. 1982, 24. Gerba et al. 2002, 25. Thurston-Enriquez et al. 2005, 26. Meng and Gerba 1996, 27. Ballester and Malley 2004, 28. Linden et al. 2007. 29. CAP 2008. 30. Lezcano et al. 1999. 31. USEPA 2006. 32. USEPA 1991. 33. Venczel et al. 1997

2.2.6. Other Contaminants of Concern

There are many contaminants of increasing concern that now are being detected in water supplies due to advances in analytical capabilities allowing for detection at the ng/L level. These contaminants include PPCPs such as antibiotics, pain killers, detergents, perfumes, disinfectants, steroids, and synthetic hormones and EDCs such as pesticides, surfactants, plasticizers, synthetic hormones, and organohalogens. Many PPCPs and EDCs are not yet regulated in the US. New regulations could be based on a common mechanism for toxicity (e.g., endocrine disruption) instead of by individual compound. Alternatively, regulations could require a specific treatment technology (e.g., granular activated carbon) for an array of chemicals, instead of setting standards for specific MCLs (Archibald Consulting, 2007; AWWARF, 2005).

The regulatory scenarios developed in this project focused primarily on the priority constituents of concern for the Central Valley Drinking Water Policy and did not address PPCPs or EDCs. These contaminants will not be considered during the treatment process selection; however, a qualitative discussion will be included as part of an intangible benefits analysis (Task 6).

3. Areas of Similar Source Water Quality

Understanding the source water quality for the existing WTPs is paramount when evaluating whether existing WTPs will meet potential future regulations and determining what treatment changes (if any) may be necessary. Accordingly, identifying areas that use Central Valley surface water that have similar water quality will simplify the necessary analyses. This section identifies the source water areas and its associated water quality that will be used in this analysis.

3.1. Determination of Source Water Areas

The Work Group identified five geographical areas that utilize water from the Delta and its tributaries, and have similar source water quality (similar levels of constituents of concern):

- Upper Sacramento and Upper-Eastern San Joaquin Watersheds (Upper Watersheds)
- North Bay Aqueduct (NBA)
- Central Delta including the South Bay Aqueduct (Central Delta)
- California Aqueduct- Coastal and East Branches (CAA)
- California Aqueduct- West Branch (CAA-West Branch)

Geographical area boundaries were not designated; the source water areas were bounded by the WTPs in each region with similar intake water quality (Figure 3-1). A total of 49 WTPs that use Delta water as a major source were considered.

3.2. Current Water Quality by Source Water Area

To characterize the water quality for each source water area, a review of available water quality data and reports was performed. Key sources of information included:

- Raw data provided by the Work Group
- Raw data from California Department of Water Resources (DWR) Water Data Library (WDL)
- California State Water Project 2006 Watershed Sanitary Survey Update (Archibald Consulting, June 2007)
- Conceptual Model for Pathogens and Pathogen Indicators in the Central Valley and Sacramento-San Joaquin Delta (Tetra Tech, August 2007)

The Work Group identified five water monitoring locations that are representative of each source water area (Table 3-1). These monitoring locations were used to summarize the water quality trends of key contaminants of concern that are discussed in the following sections. Please note that observations of water quality trends are not described in this section because additional information on current and projected source water quality will be provided by the Work Group; therefore, it is possible that any current trends shown by the data in the section below will change.

Figure 3-1: Source Water Areas[1]

[1]WTPs used to designate source water areas are described further in Section 4 and Table 4-1.

Table 3-1.
Representative Water Quality Monitoring Locations

Source Water Area	Monitoring Location	DWR Monitoring Station Number
Upper Watersheds	Sacramento River at Hood	B9D82211312
NBA	Barker Slough Pumping Plant	B9D81651476, KG000000, B9D81661478
Central Delta	Banks Pumping Plant	KA000331
CAA	Check 13	KA007089
CAA- West Branch	Castaic Lake Tower	CA002000

Source: Representative monitoring locations provided by Work Group.

3.2.1. Parameters Affecting Disinfection Byproduct Formation

Organic carbon and bromide are known as DBP precursors because they interact with chlorine during disinfection to form THMs and HAAs. Bromide can also react with ozone to form bromate, another regulated DBP. This section discusses the occurrence of organic carbon and bromide in the Delta and its tributaries and the concentrations typically found in each source water area.

Total Organic Carbon

Increased TOC concentrations can affect DBP formation in two ways: by increasing the amount of disinfectant required to achieve sufficient disinfection and by increasing DBP formation potential. TOC consists of particulate organic carbon and dissolved organic carbon (DOC).

TOC and DOC data were generally available from 1998 to 2007. These data were analyzed according to the oxidation method of analysis. The median TOC levels in the five source water areas ranged from 1.8 to 5.9 mg/L with an average of approximately 3.4 mg/L (Figure 3-2). The median DOC levels in the source water areas ranged from 1.7 to 4.2 mg/L with an average of approximately 3.6 mg/L (Figure 3-3).

Alkalinity

TOC removal can become more challenging as the alkalinity of the water increases, especially as the TOC decreases. As discussed in Appendix A, the TOC and alkalinity levels in the source water dictate treatment requirements. Based on the available data (approximately 1998 to 2007) median alkalinity values in the five source water areas ranged from 61 to 92 mg/L and had an average of approximately 78 mg/L (Figure 3-4). With these alkalinity levels, the Stage 1 DBP Rule requires the areas to remove at least 25 to 35 percent of their source water TOC (unless they meet alternative compliance criteria).

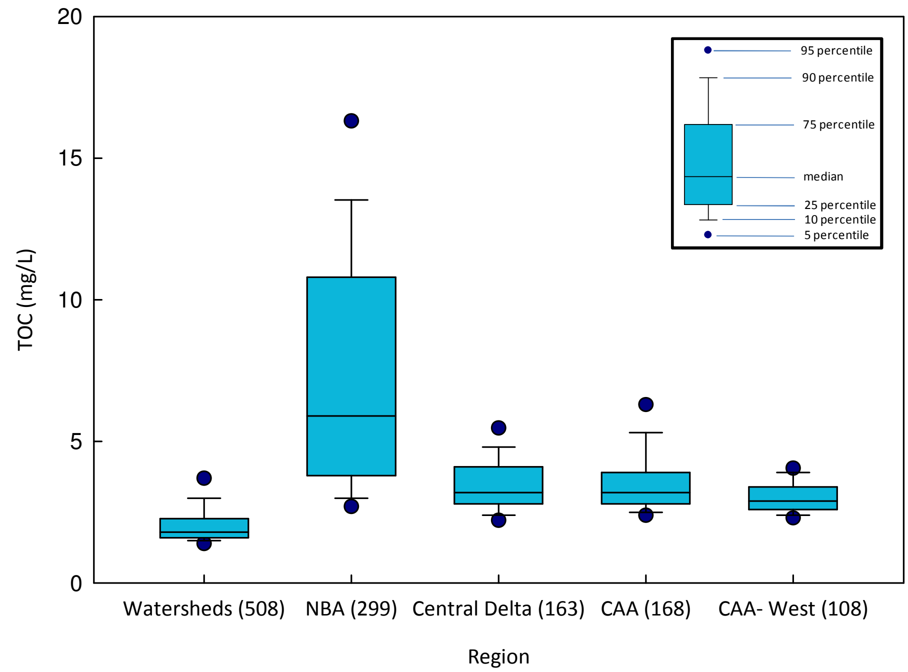

Figure 3-2: TOC Concentrations

(Number of Data Points Shown in Parenthesis)

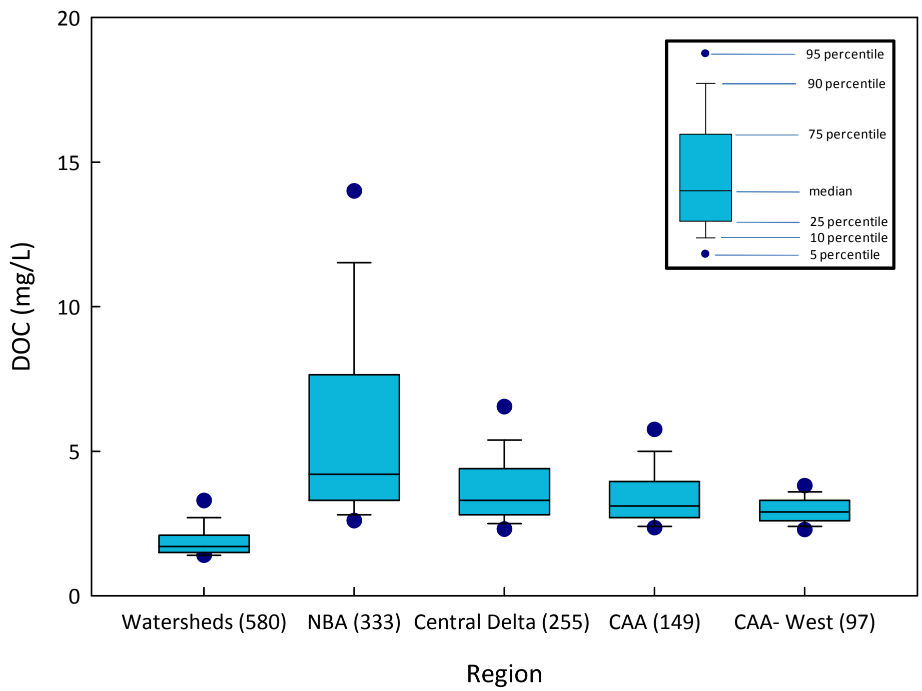

Figure 3-3: DOC Concentrations

Data obtained from California Department of Water Resources Water Quality Data Library.

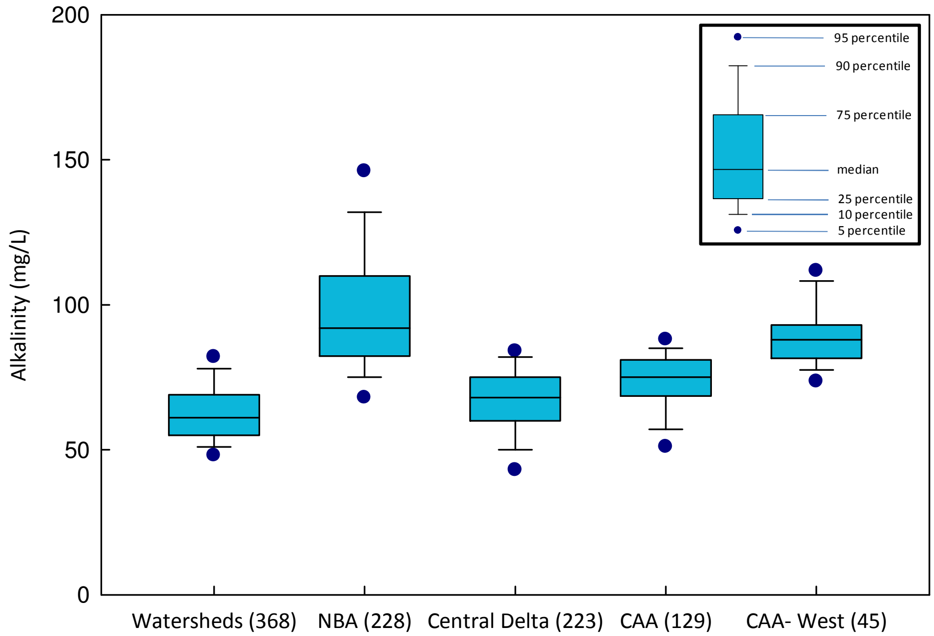

Figure 3-4: Alkalinity Concentrations

Data obtained from California Department of Water Resources Water Quality Data Library.

Specific Ultraviolet Absorbance (SUVA)

SUVA can be used to characterize the DOC, which is composed of humic and nonhumic substances. SUVA is calculated by dividing the ultraviolet absorbance at 254 nm (UV-254 measured in units of cm^{-1} and converted to m^{-1}) by the DOC concentration (mg/L), resulting in units of L/mg-m (see equation below).

$$SUVA\left(\frac{L}{mg \cdot m}\right) = \frac{UV\left(\frac{1}{cm}\right) \times 100\left(\frac{cm}{m}\right)}{DOC\left(\frac{mg}{L}\right)}$$

SUVA values less than approximately 3 L/mg-m are typical of waters containing primarily nonhumic substances. SUVA values of 4 to 5 L/mg-m are typical of waters containing primarily humic substances. SUVA can also be predictive of the organic removal capacity of water treatment practices. For instance, waters with a high SUVA result in greater reductions of TOC, and waters with low SUVA result in relatively low reductions of TOC (USEPA, 1999).

If the SUVA level is less than 2.0 L/mg-m, compliance with the TOC removal treatment technique requirements in the Stage 1 DBPR is challenging and can be achieved through the alternative compliance criteria. SUVA for four of the five source water areas was calculated (there was insufficient data to calculate values for the CAA-West source water area), and it was found that the median SUVA values ranged from 2.7 to 3.3 L/mg-m and averaged of 3.1 L/mg-m. This indicates that the water in these source water areas is composed of primarily nonhumic substances. SUVA values in this range are not particularly low, which indicates that conventional treatment processes should be able reduce TOC concentrations in accordance with Stage 1 DBPR.

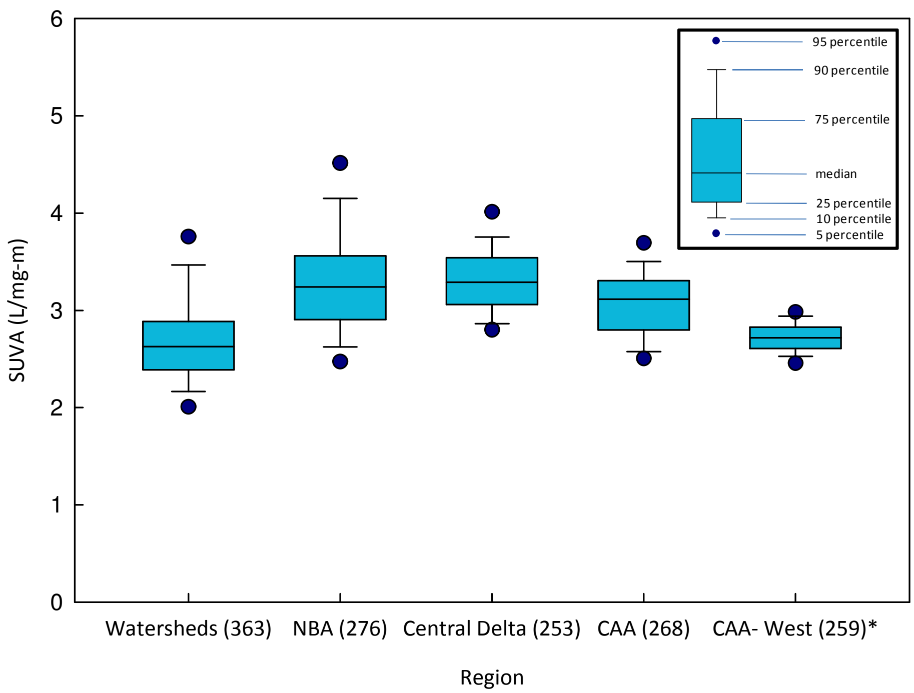

Figure 3-5: SUVA Levels

*CAA-West SUVA levels were calculated from MWD provided Jensen WTP Influent data (2000 to 2007). Castaic Lake Monitoring Station data from the WDL were not available.

Bromide

Three of the four regulated THMs and two of the five regulated HAAs contain bromide. Bromide can also react with ozone to form bromate, another regulated DBP. Median bromide levels in the Delta and its tributaries ranged from 0.01 to 0.19 mg/L with an average of 0.14 mg/L (Figure 3-6).

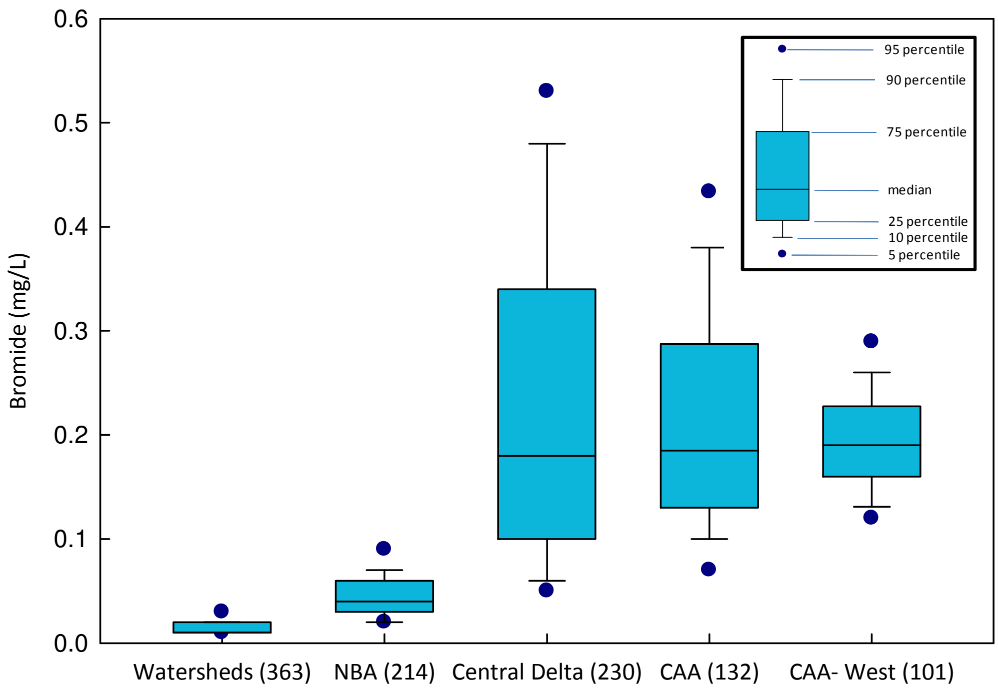

Figure 3-6: Bromide Concentrations

The regulatory scenarios projected for 2030 contain regulations for a number of DBPs including THMs, iodinated THMs, HAAs, iodinated HAAs, NDMA, and hydrazine. DBP formation will affect whether additional treatment may be necessary at existing WTPs in each source water area. Table 3-2 summarizes the key water quality parameters that affect DBP formation.

Table 3-2.
Summary of DBP Precursor Levels by Source Water Area

	Upper Watersheds	NBA	Central Delta	CAA	CAA-West
TOC (mg/L)					
Median	1.8	5.9	3.2	3.2	2.9
95 Percentile	3.67	16.2	5.3	6.3	4.0
DOC (mg/L)					
Median	1.7	4.2	3.3	3.1	2.9
95 Percentile	3.2	13.9	6.3	5.5	3.8
Alkalinity (mg/L)					
Median	61	92	68	75	88
95 Percentile	82	145	84	88	111
Stage 1 DBPR TOC Removal Requirement (percent)[1]	25	35	35	25	25
SUVA (L/mg-m)					
Median	2.6	3.2	3.3	3.1	2.7
95 Percentile	3.7	4.5	4.0	3.7	3.0
Bromide (mg/L)					
Median	0.01	0.04	0.18	0.19	0.19
95 Percentile	0.03	0.09	0.53	0.43	0.28

[1]If alternative compliance criteria are not met.

3.2.2. Dissolved Minerals

Dissolved minerals can be measured as either TDS or electrical conductivity (conductivity). The USEPA has established a secondary MCL (non-enforceable) of 500 mg/L for TDS and CDPH has secondary MCLs (enforceable) of 500 mg/L for TDS and 900 µS/cm for conductivity (CDPH 2008). The salinity in the tributaries to the Delta is influenced by natural, urban, and agricultural sources. As the tributaries flow through the Delta, they (along with urban discharges and seawater intrusion) contribute to the Delta salinity. Ultimately, the salinity in the Delta is variable and is affected by the hydraulic conditions and releases from upstream reservoirs, which influence seawater intrusion.

A review of conductivity and TDS data from approximately 1998 to 2007 revealed that salinity in the source water area are variable. Median conductivity ranged from 156 to 483 µS/cm, with an average of 383 µS/cm (Figure 3-7). Median TDS ranged from 97 to 283 mg/L, with an average of 202 mg/L.

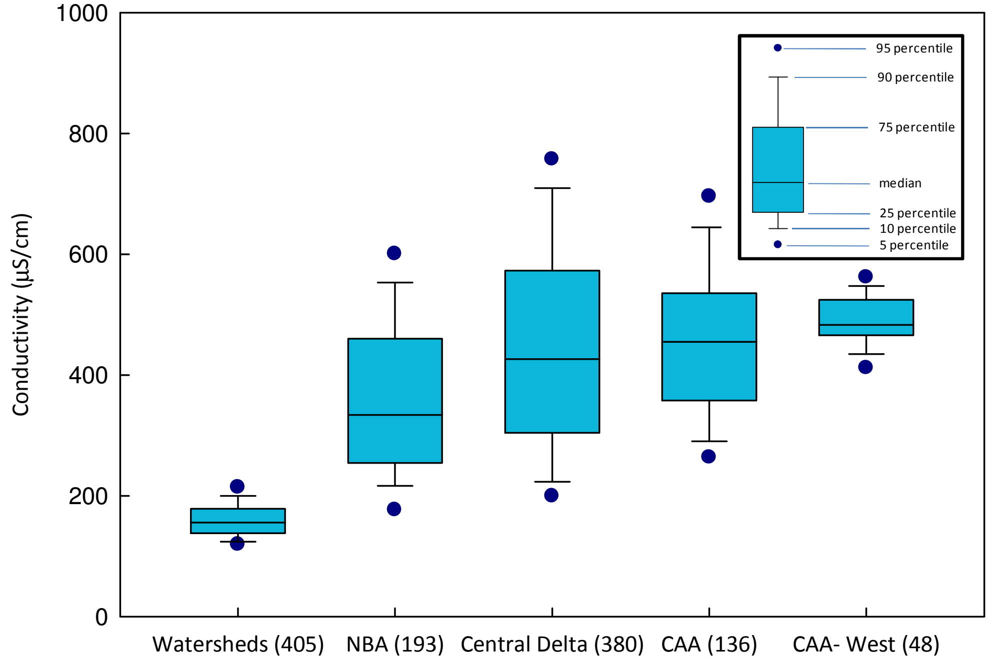

Figure 3-7: Conductivity

Data obtained from California Department of Water Resources Water Quality Data Library.

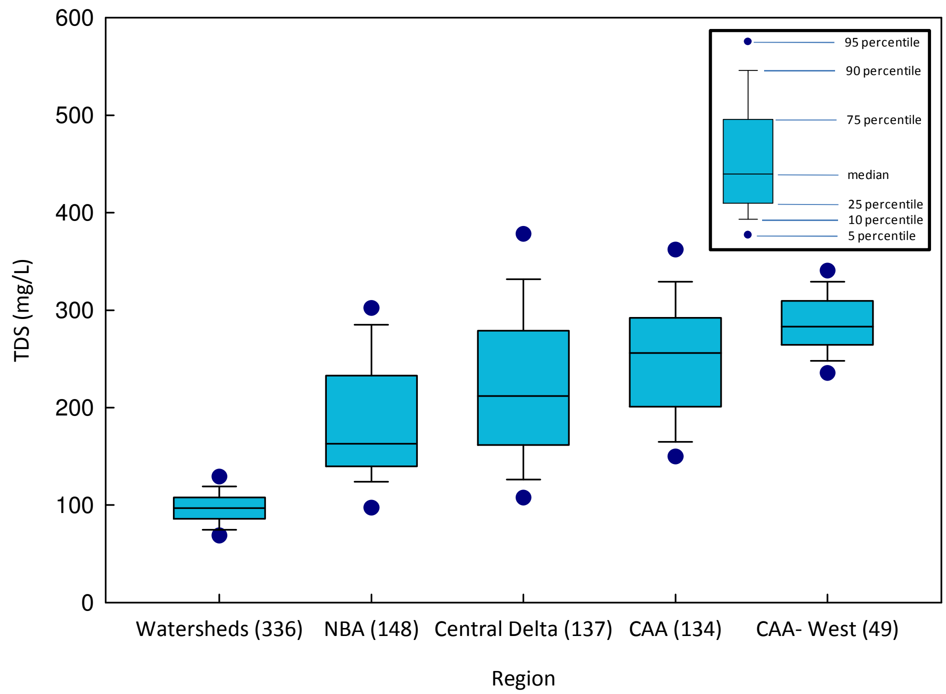

Figure 3-8: Total Dissolved Solids

Data obtained from California Department of Water Resources Water Quality Data Library.

3.2.3. Nutrients

Increased levels of nutrients such as nitrogen and phosphorus can lead to algal and vascular plant growth. Associated treatment concerns include taste and odor problems, increased levels of organic carbon, filtration impacts, and potentially higher levels of nitrogenous DBPs (e.g., NDMA) and algal toxins. The USEPA established nitrogen and phosphorus reference conditions in a 2001 Ambient Water Quality Criteria Recommendations Report to assist states in developing nutrient water quality standards for receiving waters. These values are guidelines and are not enforceable. The state of California is considering the adoption of nutrient water quality standards, but has not released an official proposal to date. The nitrogen and phosphorus reference conditions generally represent nutrient levels that protect against the adverse effects of nutrient over enrichment and generally apply to the source water areas in this analysis. The reference concentration for total nitrogen is 0.31 mg/L and total phosphorus is 0.047 mg/L (USEPA 2001a). Total nitrogen includes nitrate, nitrite, ammonia, and organic nitrogen. Total phosphorus includes particulate and dissolved phosphorus. The particulate phosphorus includes organic phosphorus incorporated in planktonic organisms, inorganic mineral phosphorus in suspended sediments, and phosphate adsorbed to inorganic particles. The dissolved phosphorus includes dissolved organic phosphorus, orthophosphate, and polyphosphates.

Data from approximately 1998 to 2007 indicated that total nitrogen and total phosphorus concentrations in the Delta and its tributaries are significantly higher than USEPA's total nitrogen and total phosphorus reference concentrations (USEPA 2001a). Median total nitrogen concentrations ranged from 0.67 to 0.96 mg/L and averaged 0.87 mg/L (Figure 3-9). Median total phosphorus concentrations ranged from 0.04 to 0.19 mg/L and averaged 0.12 mg/L (Figure 3-10).

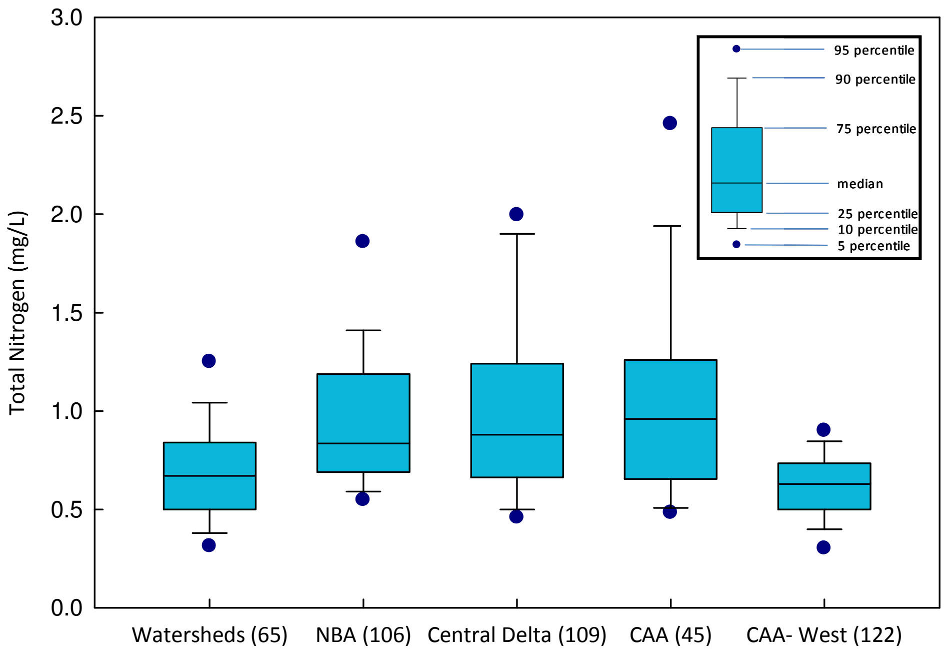

Figure 3-9: Total Nitrogen

Data obtained from California Department of Water Resources Water Quality Data Library.

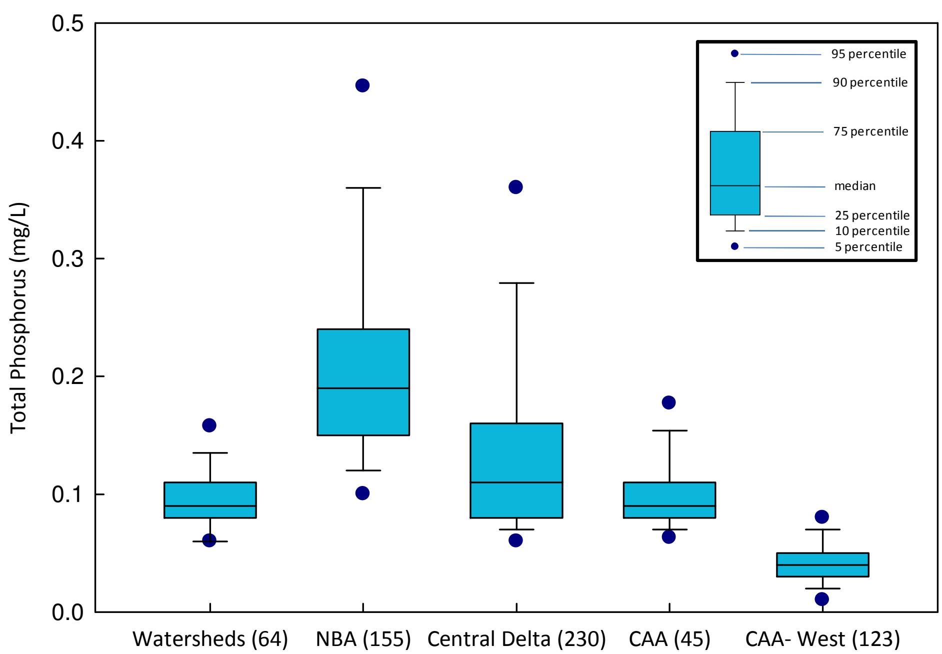

Figure 3-10: Total Phosphorus

Data obtained from California Department of Water Resources Water Quality Data Library.

In addition to considering total nitrogen levels, DON was estimated. DON is a precursor to nitrogenous DBP formation and could be used to assess the potential for increased NDMA formation. DON was not directly measured for each source water area; instead, DON was estimated as the difference between Total Kjeldahl Nitrogen (TKN) and ammonia value, assuming that the TKN sample was filtered and represents DON instead of total organic nitrogen. DON was calculated from TKN and ammonia data from approximately 1998 to 2007. Median DON values ranged from 0.22 to 0.57 mg/L and averaged

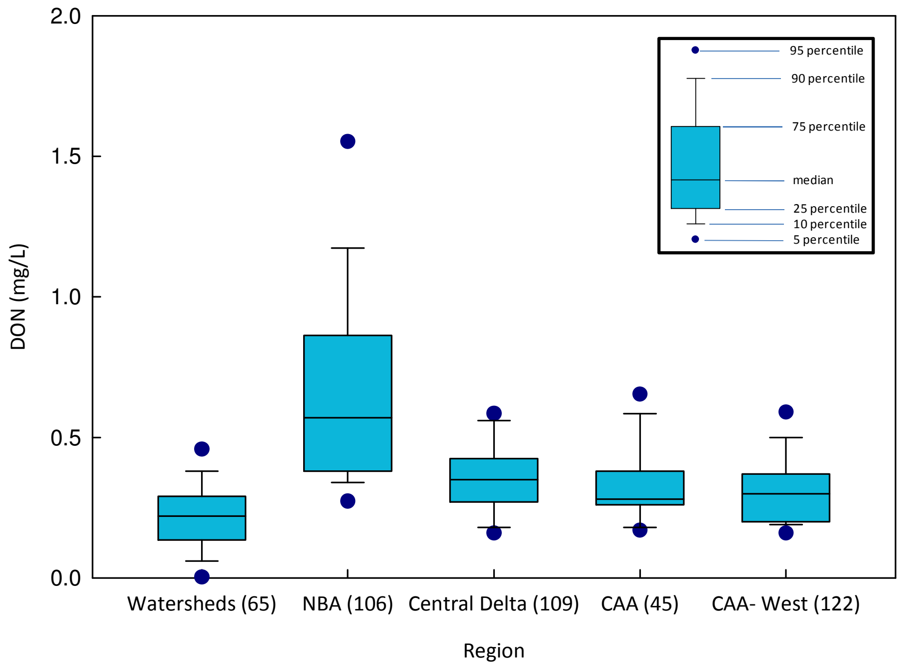

Figure 3-11: Estimated DON Levels[1]

[1]DON estimated as TKN minus ammonia. TKN and ammonia data obtained from California Department of Water Resources Water Quality Data Library.

3.2.4. Algal Toxins

With the emergence of toxic algal blooms and cyanobacteria, California DWR has recognized the importance of monitoring for algal toxins such as microcystins. California DWR monitors for microcystins from June to October, which is the time of year that the toxin is most likely to occur. Data from 2004 to 2007 in various locations throughout the Delta and the State Water Project (SWP) show that microcystins are present but at concentrations less than 1 µg/l.

3.2.5. Pathogens and Indicator Organisms

The SWTR, IESWTR, and LT2ESWTR (discussed in detail in Appendix A) set treatment requirements to protect the public from pathogenic bacteria, viruses, and protozoans.

Monitoring for all pathogens is impossible, so most monitoring is directed towards *Giardia* and *Cryptosporidium* (pathogenic protozoan). Additionally, fecal coliform, total coliform, and *Escherichia coli* (*E. coli*) are used as indicators of the microbiological quality of water. To assess the microbiological profile of the five source water areas, data from the 2006 Watershed Sanitary Survey Update, the Conceptual Model for Pathogens and Pathogen Indicators in the Central Valley and Sacramento-San Joaquin Delta (Tetra Tech 2007), and the Sacramento River Water Treatment Plant were reviewed. The data that were available were variable (varying sampling frequencies, different methods for determining bacteria densities, different periods of record) and as noted did not always correlate with the monitoring locations used previously in this water quality analysis. Table 3-3 summarizes the number and range of *Giardia* and *Cryptosporidium* detects, and Table 3-4 summarizes the fecal coliform, total coliform, and *E. coli* ranges for the source water areas (data sources and monitoring locations noted on tables).

Table 3-3.
Source Water *Giardia* and *Cryptosporidium* Detections

Source Water Area	Data Period	Number of *Giardia* Detections	Range of *Giardia* Detections (cysts/L)	Number of *Crypto* Detections	Range of *Crypto* Detections (oocysts/L)
Upper Watersheds[1]	2001 to 2004	1	0.09	0	-
NBA[2]	2000 to 2005	8	0.1 to < 0.4	5	0.1 to 0.8
Central Delta[3]	2005 to 2005	1	0.1	0	-
CAA[4]	2003 to 2005	1	0.6	0	-
CAA- West Branch[5]	2000 to 2005	0	-	1	0.1

Source: [1]Sacramento River Water Treatment Plant Presumed *Crypto* and *Giardia* detects (raw data provided to project team by Work Group).

[2]2006 Watershed Sanitary Survey Update- DWR data at Barker Slough

[3]2006 Watershed Sanitary Survey Update- Patterson Pass, Del Valle, and Penitencia WTP data

[4]2006 Watershed Sanitary Survey Update- Central Coast Water Authority Polonio Pass WTP data

[5]2006 Watershed Sanitary Survey Update- Metropolitan Water District of Southern California Jensen WTP data

Table 3-4.
Source Water Fecal Coliform, Total Coliform, and *E. coli* Detections

Source Water Area	Data Period	Range of Fecal Coliforms (MPN/100 mL)	Range of Total Coliforms (MPN/100 mL)	Range of E. coli (MPN/100 mL)
Upper Watersheds[1]	2000 to 2004	-	80 to > 16000	2 to 16000
NBA[2]	2000 to 2005	25 to 230[a]	200 to 2400	30 to 3000[b]
Central Delta[3]	2005 to 2005	-	2 to 11000	2 to 240
CAA[4]	2005 to 2006	-	10 to 320	2 to 26
CAA- West Branch[5]	2000 to 2005	2 to 300	2 to 510	-

Source: [1]Sacramento River Water Treatment Plant total coliform and *E.coli* data(raw data provided to project team by Work Group).

[2]2006 Watershed Sanitary Survey Update- monthly median total and fecal coliforms at the North Bay Regional WTP Intake.

[a]Data period was 2003 to 2005.

[b]E.coli counts associated with pathogen and indicator bacteria detection at Barker Slough (see Table 3-3)

[3]2006 Watershed Sanitary Survey Update- Patterson Pass, Del Valle, and Penitencia WTP data

[4]2006 Watershed Sanitary Survey Update- Central Coast Water Authority Polonio Pass WTP data

[5]2006 Watershed Sanitary Survey Update- Metropolitan Water District of Southern California Jensen WTP data

4. Current Water Treatment Practices

The current WTPs in each source water area are evaluated to determine the effect of the future source water quality changes and the 2030 regulatory scenario. This section summarizes the WTPs and identifies water treatment trends in each source water area.

4.1. Water Treatment Plants in Each Source Water Area

Existing WTPs in each of the five source water areas were identified. The number, size, and treatment processes of the WTPs vary within and across each source water area. Table 4-1 summarizes the WTPs that are included in each source water area and the size of each plant.

Table 4-1.
Water Treatment Plants in each Source Water Area

Source Water Area	System Name	Facility	Size (mgd)
Upper Watersheds	City of Sacramento	American River WTP (Fairbairn)	200
	Carmichael Water District	Bajamont SWTP	17
	City of Redding	Sacramento River @ Foothill WTP	28
	Yuba County	WTP	24
	City of West Sacramento	Bryte Bend WTP	160
	City of Sacramento	Sacramento River WTP	160
	East Bay MUD	Layfayette WTP	25
		Orinda WTP	175
		Walnut Creek WTP	91
	Modesto Irrigation District	Modesto Reservoir	45
	Stockton East Water District	WTP	45
	Calaveras County Water District	West Point WTP	1
		Bear Creek	*
		Mokelumne River	*
NBA	City of Fairfield and Vacaville	North Bay Regional WTP	40
	City of Fairfield	Waterman WTP	22.5
	City of Benicia	Benicia WTP	12
	City of Vallejo	Fleming Hill WTP	42

*Data not available

Table 4-1 Continued.

Source Water Area	System Name	Facility	Size (mgd)
NBA	City of Vallejo	Travis WTP	7.5
	City of American Canyon	American Canyon WTP (2 plants w/matching flow systems, 1 conventional and 1 membrane)	2.2
Central Delta	Contra Costa Water District	Bollman WTP	75
	Contra Costa Water District	Randall Bold WTP	40
	City of Antioch	Antioch WTP	26
	Zone 7 Water Agency	Del Valle	44
		Patterson Pass	21
	Alameda County Water District	WTP #2	28
		Mission San Jose WTP	8
	Santa Clara Water District	Penitencia WTP	42
CAA	Santa Clara Water District	Santa Teresa WTP	100
		Rinconada WTP	80
	City of Dos Palos	Dos Palos WTP	3
	City of Coalinga	Coalinga WTP	12
	City of Huron	Huron WTP #2	*
	City of Avenal	Avenal WTP #2	3.1
		Avenal WTP #1	2.2
	Central Coast Water Authority	Polonio Pass WTP	43
	Antelope Valley East Kern Water Agency	Rosamund WTP	14
		Quartz Hill WTP	65
		Acton WTP	4
		Eastside WTP	10
	Palmdale	Palmdale Filter Plant	30
	CLAWA	Lake Silverwood WTP	5
	Metropolitan Water Dist. Of So. Cal	Mills WTP	160
		Diemer WTP	520
		Skinner WTP	630
		Weymouth WTP	520
CAA-West Branch	Metropolitan Water District of So. Cal	Jensen WTP	750
	Castaic Lake Water Agency	Earl Schmidt WTP	56
	Castaic Lake Water Agency	Rio Vista WTP	30

*Data not available

4.2. Current Water Treatment Practices in Each Source Water Area

The treatment processes used in each source water area were evaluated to determine trends in water treatment practices. Conventional coagulation/flocculation/sedimentation is a common treatment in all source water areas. However, the filtration, disinfection, and additional treatment processes vary in each source water area. Table 4-2 describes the types of water treatment unit processes that were considered. The following sections summarize the water treatment practices in each source water area.

Table 4-2.
Water Treatment Unit Processes

Item	Purpose
Coagulation/Flocculation/Sedimentation	
Rapid Mix	Uniform coagulant dispersion
Coagulation	Particle destabilization
Flocculation	Particle agglomeration
Sedimentation	Particulate removal
Filtration	
Multi-Media/Rapid Sand/Pressure Sand*	Particulate removal
Pressure Sand	Particulate removal
Slow Sand	Particulate removal
Membranes	Particulate removal
Primary Disinfection	
Chlorine	Disinfection credit
Mixed oxidants (MIOX)	Disinfection credit
Ozone	Disinfection credit
Secondary Disinfection	
Chlorine	Maintain residual chlorine in distribution system
Chloramines	Maintain residual chlorine in distribution system
Other	
Granular Activated Carbon (GAC) (T&O)	Taste and Odor (T&O) control
Fluoridation	Public dental health
Lime-Soda Ash	Corrosion control or softening
Permanganate	T&O control, iron and manganese oxidation
GAC (DBP)	DBP control
Powdered Activated Carbon (PAC)	T&O control
Aeration	T&O control, iron and manganese oxidation
Pre- pH Adj.	Enhanced coagulation for DBP control or
Post- pH Adj.	Corrosion control
Orthophosphate	Corrosion control

*Displayed in figures as "Multi-Media"

4.2.1. Upper Watersheds Source Water Area

The Upper Watersheds source water area contains 14 WTPs with flow rates ranging from 1 million gallons per day (MGD) to 200 MGD. Approximately 93 percent of the WTPs in the Upper Watersheds source water area have media filtration with the majority also having coagulation/ flocculation/ sedimentation (Figure 4-1). This source water area also has a membrane filtration plant. The majority of the WTPs use free chlorine for primary disinfection; however, one WTP uses ozone. The WTPs use both free chlorine (79 percent) and chloramines (21 percent) for secondary disinfection. Additional treatment processes include PAC/ GAC, softening, aeration, and pH adjustment. However, the number of plants that use these technologies is limited.

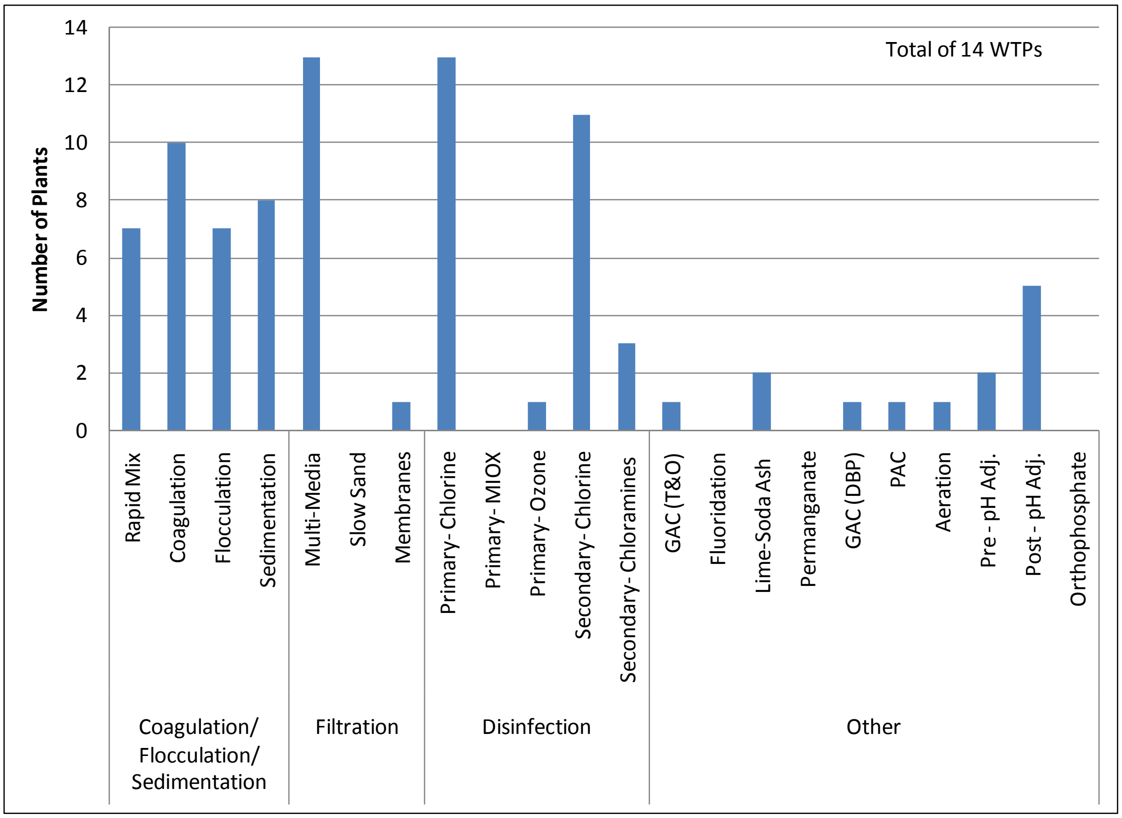

Figure 4-1: Water Treatment Plant Unit Processes in the Upper Watersheds Source Water Area

4.2.2. North Bay Aqueduct Source Water Area

The North Bay Aqueduct source water area contains 6 WTPs with flow rates ranging from 3 MGD to 40 MGD. The majority of the WTPs use coagulation/ flocculation/ sedimentation followed by media filtration (Figure 4-2). The majority of the WTPs use free chlorine for primary disinfection; only one WTP utilizes ozone. All of the WTPs use free chlorine for secondary disinfection.

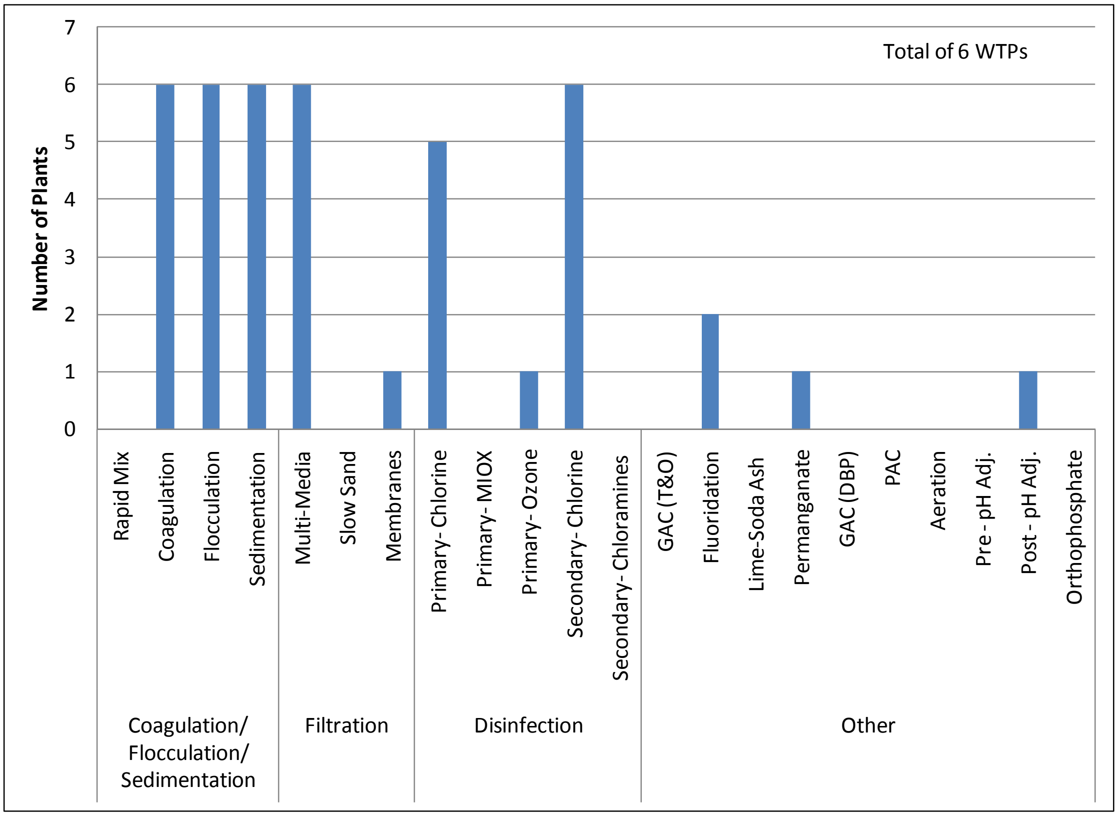

Figure 4-2: Water Treatment Plant Unit Processes in the NBA Source Water Area

4.2.3. Central Delta Source Water Area

The Central Delta source water area contains 8 WTPs with flow rates ranging from 8 MGD to 75 MGD. The majority of the WTPs in this source water area utilize media filtration (Figure 4-3). The source water area also has two slow sand filtration plants and two membrane filtration plants. One of the membrane filtration plants includes slow sand filtration as pretreatment. All WTPs use free chlorine for primary disinfection with half of the WTPs also using ozone in addition to free chlorine. The majority of the WTPs use chloramines for secondary disinfection; only one WTP uses free chlorine. Corrosion control is accomplished with pH adjustments at 5 of the 8 WTPs.

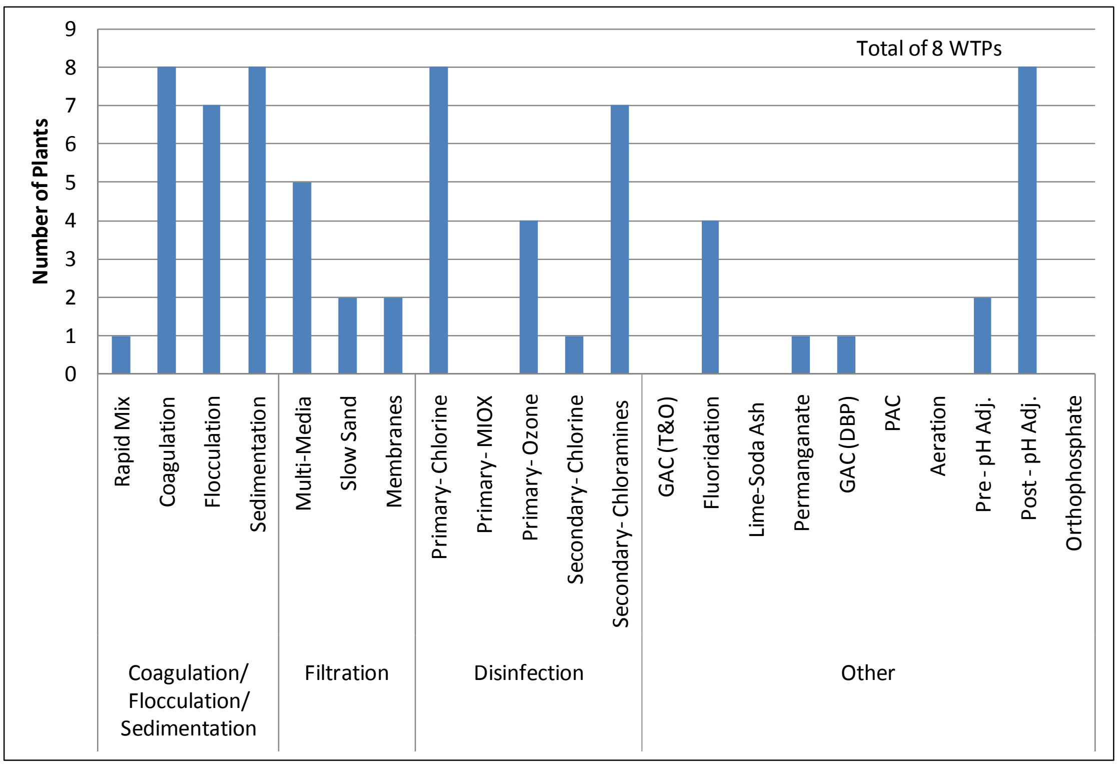

Figure 4-3: Water Treatment Plant Unit Processes in the Central Delta Source Water Area

4.2.4. California Aqueduct Source Water Area

The California Aqueduct source water area contains 18 WTPs with flow rates ranging from 3 MGD to 630 MGD. The majority of the WTPs use coagulation/ flocculation/ sedimentation followed by media filtration (Figure 4-4). Approximately 89 percent of the WTPs use free chlorine for primary disinfection, although some WTPs use MIOX (1 WTP) and ozone (2 WTPs). Approximately half of the water treatment plants use free chlorine and half utilize chloramines for secondary disinfection. Approximately 22 percent of the WTPs in this source water area also use GAC for disinfection byproduct control.

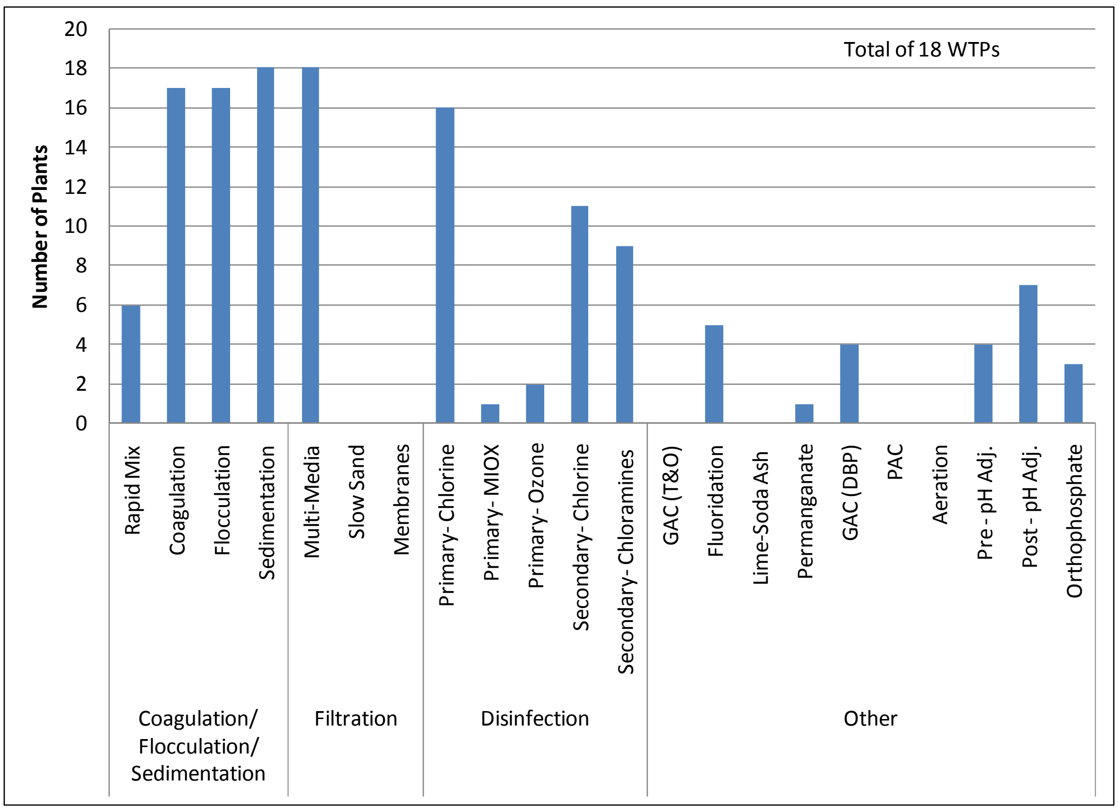

Figure 4-4: Water Treatment Plant Unit Processes in the CAA Source Water Area

4.2.5. California Aqueduct West Branch Source Water Area

The California Aqueduct West Branch source water area contains 3 WTPs with flow rates ranging from 30 MGD to 750 MGD. All of the WTPs in this source water area utilize the same treatment train that includes conventional coagulation/ flocculation/ sedimentation followed by media filtration with ozone for primary disinfection and chloramines for secondary disinfection (Figure 4-5)

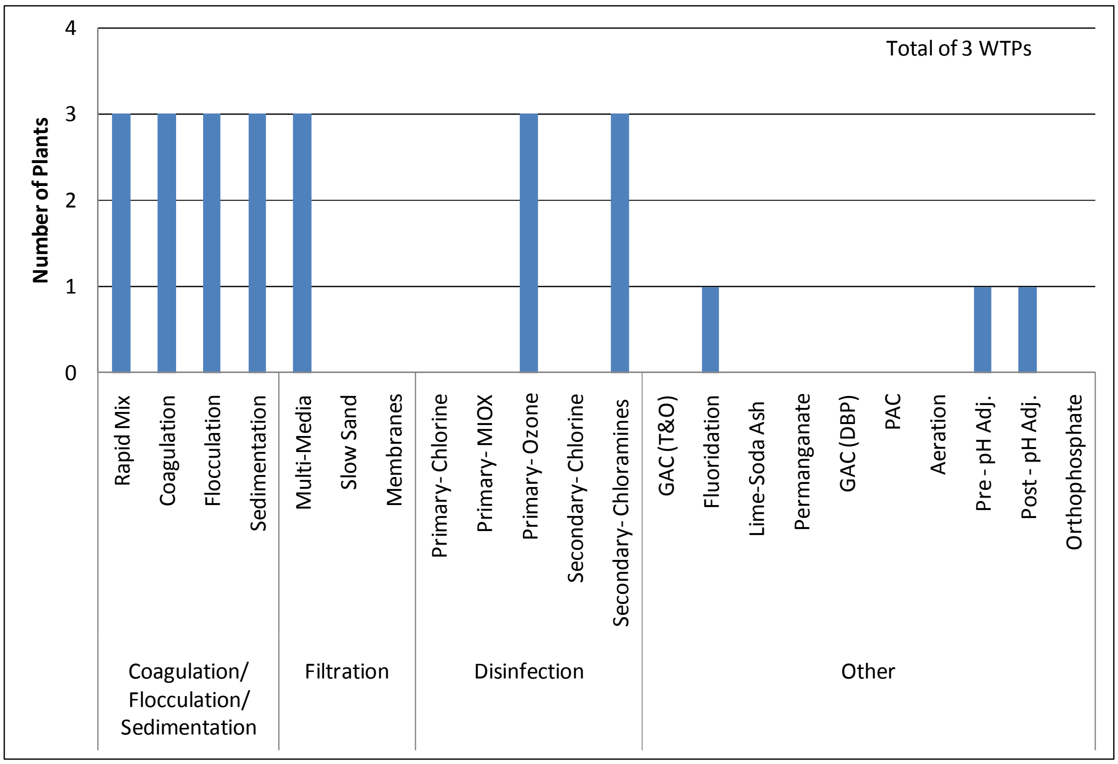

Figure 4-5: Water Treatment Plant Unit Processes in CAA West Branch Source Water Area

5. Summary and Next Steps

The purpose of the Water Treatment Plant Evaluation's Task 1 was to determine the study boundaries with respect to future regulations, source water area and associated water quality data, and water treatment technologies used in each source water area. This section summarizes the study boundary evaluation and next steps for the project.

5.1. Summary of Task 1: Definition of Study Boundaries

The Water Treatment Plant Evaluation Study boundaries were developed as summarized below.

- Malcolm Pirnie staff and technical advisors identified emerging drinking water quality issues and developed two regulatory scenarios for 2030: "plausible" and "outside boundary." The 2030 plausible regulatory scenario includes a reduction or modification to the current regulations for bromate, THM4, and HAA5. In addition, the plausible scenario identified possible regulation of iodinated THMs, HAA9, iodinated HAAs, nitrogenous DBPs (e.g., NDMA), other pathogens (not as challenging as currently regulated pathogens), and algal toxins (specifically microcystins). The plausible regulatory scenario will be used to evaluate the WTPs in each source water area to determine treatment upgrades and associated costs. The outside boundary 2030 regulatory scenario is more stringent than the plausible scenario and is provided to bracket the range of possible regulations.
- Five geographical areas of similar source water quality were identified by the Work Group: Upper Watersheds, NBA, Central Delta, CAA, and CAA-West. Source water quality for each region was compared with respect to DBP precursors, dissolved minerals, nutrients, and pathogens and indicator organisms to confirm these five source water areas were appropriate for the Study.
- The WTPs in each source water area were identified and evaluated to determine the existing water treatment practices. The results from the water treatment practice evaluation will be used in the development of virtual WTPs and threshold values.

5.2. Next Steps: Virtual Water Treatment Plants (Task 2)

The evaluation process to be used for developing the virtual WTPs is as follows:

- Identify WTPs in each source water area.
- Identify unit processes and design flowrates at each WTP.
- Identify trends is each source water area based on similar combination of unit processes.

- Select representative virtual WTPs for each source water area.
- Select representative flowrates for each virtual WTP.
- Develop conceptual level capital and O&M costs for each virtual WTP.

5.3. Next Steps: Threshold Values Development (Task 3)

The virtual water treatment plants developed in Task 2 will be used to develop threshold values for the water quality parameters identified in the plausible future regulatory summary (Table 2-2). The threshold values will be the WTP influent concentration that triggers an evaluation of adding additional treatment. Each virtual WTP will be entered into the Water Treatment Plant Model (USEPA, 2001b) to determine the removal efficiencies of each unit process. The influent threshold value will be determined based on the removal efficiencies of each virtual WTP and the target effluent concentration based on the plausible future regulatory scenarios. The effluent concentration will be set at 80 percent of the regulatory limit to prevent regulatory violations.

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Summary of Current Drinking Water Regulations

This appendix contains information on several of the primary drinking water regulations that have been proposed or implemented under the Safe Drinking Water Act (SDWA). Current federal regulations include:

- Surface Water Treatment Rule (SWTR)
- Total Coliform Rule (TCR)
- Lead and Copper Rule (LCR)
- Regulations for Inorganic Chemicals (IOCs), Synthetic Organic Chemicals (SOCs), and Volatile Organic Chemicals (VOCs) (Phases I, IIA, II, and V)
- Radionuclides Rule
- Filter Backwash Recycle Rule (FBWR)
- Stage 1 Disinfectant/Disinfection By-Products Rule (D/DBPR)
- Stage 2 Disinfectant/Disinfection By-Products Rule (D/DBPR)
- Interim Enhanced Surface Water Treatment Rule (IESWTR)
- Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)
- Arsenic Rule

Surface Water Treatment Rule (SWTR)

The SWTR requires that surface water and groundwater under the direct influence of surface water (GWUDI) be treated to achieve at least 3-log (99.9 percent) inactivation and/or removal of *Giardia* cysts and 4-log (99.99 percent) inactivation and/or removal of enteric viruses. Filtered water turbidity must never exceed 5 Nephelometric Turbidity Units (NTU), and 95 percent of the measurements taken must not exceed 0.5 NTU. If utilities did not meet the filtration avoidance criteria set in the SWTR, they were required to implement filtration treatment. The SWTR also requires that the secondary disinfectant residual entering the distribution system cannot be less than 0.2 mg/L for more than four consecutive hours, as demonstrated by continuous monitoring.

Total Coliform Rule (TCR)

Similar to the SWTR, the primary goal of the TCR is also to maintain microbiological quality in finished and distributed drinking water supplies. The TCR specifies a maximum contaminant level goal (MCLG) for total coliforms of zero (including both fecal coliforms and *E. coli*). Compliance is based upon the presence or absence of total coliforms rather than coliform densities. The TCR requires 95 percent of the samples in a month to be negative.

Lead and Copper Rule (LCR)

The intent of the LCR is to minimize exposure to lead and copper from drinking water. If lead or copper exceeds a specified trigger value at the consumer tap (action level), treatment is required. The action levels for lead and copper are 15 and 1,300 µg/L, respectively. This rule includes extensive requirements for sampling and, if necessary, demonstration studies. In general, systems that comply with the lead action level will also comply with the copper action level.

Compliance is based on implementation of optimal corrosion control treatment. EPA's intent was to require all systems to install optimal corrosion control regardless of the lead and copper concentrations at consumers' taps. Optimal corrosion control treatment is defined as the technology that minimizes lead and copper levels at consumers' taps. It must be demonstrated on the basis of data from distribution system monitoring as well as results of corrosion control studies. Currently, the State is responsible for conducting all lead and copper enforcement actions and reviews of corrosion control studies.

Inorganic Chemicals (IOCs), Synthetic Organic Chemicals (SOCs), and Volatile Organic Chemicals (VOCs)

The majority of the drinking water contaminants regulated under the SDWA amendments fall into the categories of inorganic chemicals (IOCs), synthetic organic chemicals (SOCs), and volatile organic chemicals (VOCs). In total, there are 135 contaminants regulated by this rule. The rules regulating these groups of contaminants include:

- Phase I -VOCs;
- Phase IIA – Fluoride;
- Phase II - SOCs and IOCs; and
- Phase V - Additional SOCs and IOCs.

The names "Phase III" and Phase IV" were not used in the rulemaking process.

Radionuclides Rule

Radionuclides are radiological material that can enter the water supply naturally from soil or from leakage of radioactive wastes. Previously radionuclides were regulated by a rule from 1976. Of all of the changes to the old rule, the most significant is probably the sample location. According to the 1976 Rule, samples could be taken within the distribution system, which provided the "average customer" with water meeting the requirements. With the 2000 Rule, all samples must be taken at each entry point to the distribution system. Radium 226/228, gross alpha, and uranium should be monitored four times a year. Only vulnerable utilities (*i.e.,* water contaminated by nuclear facilities) are required to monitor for beta emitters.

After community water systems (CWSs) have determined a baseline through the four consecutive quarterly samples or have been approved by the State based on grandfathered data, they may proceed with reduced monitoring based on their initial baseline.

Filter Backwash Recycling Rule (FBWR)

The FBRR requires public water systems to review their backwash water recycling practices to ensure that they do not compromise microbial control. Under the FBRR, recycled filter backwash water, sludge thickener supernatant, and liquids from dewatering processes must be returned to a location such that the recycled water is subject to all the processes in a system's conventional or direct filtration treatment train including coagulation, flocculation, sedimentation (conventional filtration only) and filtration. Systems may apply to the State for approval to recycle at an alternate location.

Stage 1 Disinfectant/Disinfection Byproducts Rule (D/DBPR)

The D/DBPR has been implemented in two stages. EPA promulgated the Stage 1 D/DBPR to reduce the levels of disinfectants and disinfection byproducts in drinking water supplies. The Stage 1 D/DBPR revised the MCLs for total trihalomethanes (TTHMs), reducing it from 0.10 to 0.08 mg/L, and included a new MCL of 0.06 mg/L for the sum of five haloacetic acids (HAA5). Additionally, MCLs for chlorite (1.0 mg/L) and bromate (0.010 mg/L) were established.

The rule designated monitoring requirements and best available technologies (BATs) for compliance and specified treatment techniques to reduce DBP precursors. This requires systems using surface water to remove specific amounts of total organic carbon (TOC) prior to adding disinfectants by implementing a treatment technique, either enhanced coagulation or enhanced softening. The percent removal required depends on the source water TOC and alkalinity (Table A-1). TOC removal compliance is based on the running annual average (RAA) of quarterly averages of monthly removal ratios. The removal ratio is the ratio of the removal achieved divided by the removal required. The RAA of the removal ratios needs to equal or exceed 1.0.

Table A-1.
TOC Removal Requirements

Source Water TOC (mg/L)	Source Water Alkalinity (mg/L as $CaCO_3$)		
	0 to 60	**>60 to 120**	**>120**
>2.0 to 4.0	35.0%	25.0%	15.0%
>4.0 to 8.0	45.0%	35.0%	25.0%
>8.0	50.0%	40.0%	30.0%

Source: USEPA 1999.

The USEPA also established alternative compliance criteria. If any of the conditions summarized below are met, the system is not required to achieve the specified TOC removal.

- Source water TOC is less than 2.0 mg/L.
- Treated water TOC is less than 2.0 mg/L.
- Source water TOC is less than 4.0 mg/L, source water alkalinity is greater than 60 mg/L, and distribution system TTHM is less than 0.04 mg/L and HAA5 is less than 0.03 mg/L.
- Distribution system TTHM is less than 0.04 mg/L and HAA5 is less than 0.03 mg/L and only chlorine is used for primary disinfection and distribution system residual.
- Source water specific ultraviolet absorbance (SUVA), prior to any treatment, is less than or equal to 2.0 L/mg-m.
- Treated water SUVA is less than or equal to 2.0 L/mg-m.

Stage 2 D/DBPR

The Stage 2 D/DBPR does not change the MCL for any of the DBPs; however, it changes how the compliance levels for TTHMs and HAA5 are calculated. Rather than determining compliance by averaging DBP concentrations throughout the distribution system, the Stage 2 D/DBPR requires each sampling point in the distribution system to comply on an average annual basis, which is referred to as a Locational Running Annual Average (LRAA).

The Stage 2 D/DBPR applies to public water systems that are community water systems or non-transient non-community water systems that add a primary or residual disinfectant other than ultraviolet light or deliver water that has been treated with a primary or residual disinfectant other than ultraviolet light.

Interim Enhanced Surface Water Treatment Rule (IESWTR)

The IESWTR and the LT2ESWTR (discussed below in Section 0) build on the requirements of the SWTR in relation to improving control of microbial pathogens, specifically *Cryptosporidium*, in drinking water. To assist with the development of these rules, the Information Collection Rule (ICR) was implemented. The ICR gathered data from over 400 utilities to assess microbial risk and DBP formation. The IESWTR was finalized in December 1998 and implemented in conjunction with the Stage 1 D/DBPR. An important element of the IESWTR was to safeguard against significant increases in microbial risk that might occur when systems implement the Stage 1 Disinfectants/Disinfection Byproducts Rule.

The IESWTR applies to public water systems that use surface water or GWUDI of surface water, and serve more than 10,000 people. The IESWTR sets the MCLG for *Cryptosporidium* oocysts in water at zero. The IESWTR also has the following requirements, which are revisions to the SWTR:

- Inclusion of *Cryptosporidium* in list of microbial contaminants that determine whether or not a particular ground water source is under the direct influence of surface water.
- Extension of watershed control requirements to include the control of *Cryptosporidium* in the source water in a manner analogous to the existing requirements for *Giardia* cysts and viruses.
- All systems that use surface water and GWUDI have a periodic sanitary survey, regardless of whether or not they filter their supplies.
- All surface water and GWUDI systems serving 10,000 or more people cover all new treated water reservoirs for which construction began after February 1999.
- Monitoring of individual filter turbidities and lowering the combined filtered water turbidity MCL from 0.5 to 0.3 NTU.
- Cross-connection control "in the context of a broad range of issues." Issues include system pressure requirements, backflow prevention programs, categorizing service connections with respect to potential backflow, periodic review of backflow prevention devices, and the utility backflow prevention program.
- Requirement for filter backwash and other waste streams to be regulated.

Long Term 2 Enhanced Surface Water Treatment Rule (LTSESWTR)

The LT2ESWTR building on the IESWTR and requires systems to provide addition protection against *Cryptosporidium* based on monitoring results. Systems must monitor for *Cryptosporidium* for 2 years following finalization of the LT2ESWTR with the exception of systems that already provide 2.5-log removal/inactivation of *Cryptosporidium*. Based on the levels of *Cryptosporidium* in the source water, a WTP is given a bin classification (Table A-2). Based on the bin classification, a WTP may be required to implement additional treatment to achieve a certain level of removal/inactivation of *Cryptosporidium* using the components from the Microbial Toolbox. Systems currently using ozone, chlorine dioxide, UV disinfection, or membranes in addition to conventional treatment may receive credit for those technologies toward bin requirements.

Table A-2.
Bin Classification and Action Requirements

Bin Classification	Maximum Running Annual Average (oocysts/L)	Action Required (log)
1	< 0.075	none
2	0.075 to < 1.0	1
3	1.0 to < 3.0	2
4	≥ 3.0	2.5

Depending on the *Cryptosporidium* concentration in the source water and the resulting removal/inactivation requirements (i.e., bin classification), the utility can use the treatment technique(s) listed in the microbial toolbox to achieve the required *Cryptosporidium* removal/inactivation. Meeting the removal/inactivation treatment requirements identified for each "Action Bin" may necessitate one or more actions from an array of management strategies which include watershed control, reducing influent *Cryptosporidium* concentrations, improved system performance, and additional treatment barriers.

Arsenic Rule

An MCL of 50 µg/L for arsenic was established by EPA in 1975 based on the standard set by the Public Health Service in 1943. The 1996 SDWA Amendments required EPA to revise the arsenic MCL and take into consideration peer-reviewed health effects research, treatment studies, analytical methods, occurrence, cost-benefit tradeoffs, and affordable small-system treatment technologies. The Arsenic Rule was finalized at an MCL of 10 µg/L. Surface water supplies are required to monitor and report arsenic levels once every year, and groundwater supplies are required to monitor and report arsenic levels once every three years. If the arsenic level is above the MCL, then the utility will need to monitor that location quarterly until the location is reliably and consistently below the MCL. If quarterly monitoring is performed, compliance is based on the running annual average of the quarterly samples.

List of Relevant Disinfection By-Products

Appendix B lists disinfection by-products (DBPs) that are currently regulated or could potentially regulated in the future. Classes of DBPs include trihalomethanes (THMs), haloacetic acids (HAAs), iodinated DBPs, brominated DBPs, and nitrogenous DBPs. Current state (California Department of Public Health, CDPH) and federal (USEPA) regulations are listed, as well as any available health risk information. Abbreviations, notes, and references are summarized at the end of the appendix.

All concentrations are μg/L.

Constituent	CDPH Primary MCL	USEPA Primary MCL	USEPA MCLG	CDPH PHG	CDPH Notification Level/ Response Level	One in a Million Cancer Risk for DW USEPA IRIS	USEPA SNARL	References
THMs								
Bromodichloromethane (BDCM)	80 [1]	80 [1]	0	-	-	0.6	21	1
Bromoform (CHBr3)	80 [1]	80 [1]	0	-	-	4	210	1
Chloroform (CHCl3)	80 [1]	80 [1]	70	-	-	-	70	1
Dibromochloromethane (DBCM)	80 [1]	80 [1]	60	-	-	0.4	60	1
HAA5s								
Dibromoacetic acid (DBAA)	60 [2]	60 [2]	-	-	-	-	-	1
Dichloroacetic acid (DCAA)	60 [2]	60 [2]	0	-	-	0.7	0	1
Monobromoacetic acid (MBAA)	60 [2]	60 [2]	-	-	-	-	-	1
Monochloroacetic acid (MCAA)	60 [2]	60 [2]	30	-	-	-	70	1
Trichloroacetic acid (TCAA)	60 [2]	60 [2]	20	-	-	-	20	1
HAA9								
Includes all HAA5s	-	-	-	-	-	-	-	
Bromochloroacetic acid (BCAA)	-	-	-	-	-	-	-	1

All concentrations are $\mu g/L$.

Constituent	CDPH Primary MCL	USEPA Primary MCL	USEPA MCLG	CDPH PHG	CDPH Notification Level/ Response Level	One in a Million Cancer Risk for DW USEPA IRIS	USEPA SNARL	References
-		-	-	-	-	-	-	1
Chlorodibromoacetic acid (CDBAA)	-	-	-	-	-	-	-	1
Tribromoacetic acid (TBAA)	-	-	-	-	-	-	-	1
Iodinated DBPs								
Iodate (IO3-)	-	-	-	-	-	-	-	2
Iodo acids	-	-	-	-	-	-	-	2
Bromoiodoacetic acid	-	-	-	-	-	-	-	2
(Z)-3-bromo-3-iodopropenoic acid	-	-	-	-	-	-	-	2
(E)-3-bromo-3-iodopropenoic acid	-	-	-	-	-	-	-	2, 3
(E)-2-iodo-3-methylbutenedioic acid	-	-	-	-	-	-	-	2
Iodinated THMs								
Halonitromethanes	-	-	-	-	-	-	-	2
Bromochloroiodomethane	-	-	-	-	-	-	-	2
Dichloroiodomethane	-	-	-	-	-	-	-	3
Iodinated HAAs								3
Iodoacetic acid	-	-	-	-	-	-	-	2
Bromoioacetic acid	-	-	-	-	-	-	-	3
Iodated haloaldehydes	-	-	-	-	-	-	-	3
Iodated haloamides	-	-	-	-	-	-	-	2
Brominated DBPs								
Bromate	10	10	0	0.1	-	0.05	200	
Bromoform	80	80	0	-	-	4	210	3
Dibromoacetic Acid	-	-	-	-	-	-	-	3
Bromonitromethanes	-	-	-	-	-	-	-	3
Dibromonitromethane	-	-	-	-	-	-	-	2

All concentrations are $\mu g/L$.

Constituent	CDPH Primary MCL	USEPA Primary MCL	USEPA MCLG	CDPH PHG	CDPH Notification Level/ Response Level	One in a Million Cancer Risk for DW USEPA IRIS	USEPA SNARL	References
Tribromonitromethane	-	-	-	-	-	-	-	2
Bromonitromethane	-	-	-	-	-	-	-	2
Brominated forms of MX (3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone)	-	-	-	-	-	-	-	2
Bromonated haloaldehydes	-	-	-	-	-	-	-	2
Bromonated haloamides	-	-	-	-	-	-	-	2
Monobromoacetic acid	-	-	-	-	-	-	-	2
Nitrogenous DBPs								
Halogenated N-DBPs	-	-	-	-	-	-	-	
Halonitromethanes (HNMs)	-	-	-	-	-	-	-	3
Chloronitromethane	-	-	-	-	-	-	-	3
Bromonitromethane	-	-	-	-	-	-	-	3
Dichloronitromethane	-	-	-	-	-	-	-	3
Bromochloronitromethane	-	-	-	-	-	-	-	3
Dibromononitromethane	-	-	-	-	-	-	-	3
DHNMs	-	-	-	-	-	-	-	3
TCNM	-	-	-	-	-	-	-	3
Bromodichloronitromethane	-	-	-	-	-	-	-	3
Dibromochloronitromethane	-	-	-	-	-	-	-	3
Bromopicrin	-	-	-	-	-	-	-	3
THMs	-	-	-	-	-	-	-	
Haloacetamides	-	-	-	-	-	-	-	3
Non-Halogenated N-DBPs	-	-	-	-	-	-	-	
Nitrosamines	-	-	-	-	-	-	-	

All concentrations are μg/L.

Constituent	CDPH Primary MCL	USEPA Primary MCL	USEPA MCLG	CDPH PHG	CDPH Notification Level/ Response Level	One in a Million Cancer Risk for DW USEPA IRIS	USEPA SNARL	References
N-Nitrosodimethylamine (NDMA)	-	-	-	0.003	0.01/0.3	0.0007	-	1, 4
N-Nitrosodiethylamine (NDEA)	-	-	-	-	0.01/0.1	0.0002	-	1, 4
N-Nitrosodi-n-propylamine (NDPA)	-	-	-	-	0.01/0.5	0.005	-	1, 4
N-Nitrosodiphenylamine	-	-	-	-	-	7	-	1, 4
N-nitrosopyrrolidine (NPYR)	-	-	-	-	-	0.02	-	1, 4
N-nitrosodi-n-butylamine (NDBA)	-	-	-	-	-	0.006	-	1, 4
N-nitrosomethylethylamine (NMEA)	-	-	-	-	-	0.002	-	1, 2
Hydrazine	-	-	-	-	-	0.01	-	1, 2

Abbreviations:

CDPH	California Department of Public Health
DBP	Disinfection By-products
DW	Drinking Water
HAA	Haloacetic Acid
IRIS	Integrated Risk Information System
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
PHG	Public Health Goal
SNARL	Suggested No-Adverse-Response Levels (from toxicity other than cancer risk)
THM	Trihalomethane
USEPA	United States Environmental Protection Agency

Notes:

[1] For total trihalomethanes (sum of bromoform, bromodichloromethane, chlororform, and dibromochloromethane); based largely on technology and economics.

[2] For five haloacetic acids (sum of monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid.

References:

1. California Regional Water Quality Control Board Central Valley Region. 2008. A Compilation of Water Quality Goals. Rancho Cordova, CA.
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3. Amy, Gary. 2008. Disinfection By-Products (DBPs): Formation, Occurrence, and Control. Presentation to Malcolm Pirnie, Inc, May, 2008.
4. USEPA. 2008. Drinking Water Contaminant Candidate List 3-Draft; Notice. Federal Register. Vol. 73, No. 35, p. 9628, February 21, 2008.

Appendix C

Future Water Quality Scenarios Provided by the Work Group

Scenario	Current Condition	Future Condition Planned	Future Condition Plausible	Future Condition Outer Boundary
Output Location	CLIFTON_COURT	CLIFTON_COURT	CLIFTON_COURT	CLIFTON_COURT
Constituent	DOC	DOC	DOC	DOC
Model_Output Type	EXISTING_CUWA+FROM-ALL	EXISTING_CUWA+FROM-ALL	EXISTING_CUWA+FROM-ALL	EXISTING_CUWA+FROM-ALL
Unit of measurement	MG/L	MG/L	MG/L	MG/L
Type - Average or Instantaneous	PER-AVER	PER-AVER	PER-AVER	PER-AVER
Average	**3.59**	**3.51**	**3.46**	**3.43**
90th Percentile	**5.26**	**5.16**	**5.13**	**5.09**
Oct-75	2.38	2.34	2.33	2.32
Nov-75	2.43	2.37	2.34	2.32
Dec-75	2.32	2.24	2.19	2.16
Jan-76	2.70	2.61	2.56	2.53
Feb-76	3.61	3.50	3.44	3.40
Mar-76	3.83	3.71	3.65	3.62
Apr-76	3.75	3.66	3.60	3.55
May-76	3.75	3.69	3.64	3.58
Jun-76	4.24	4.18	4.12	4.08
Jul-76	3.22	3.10	3.04	3.03
Aug-76	2.45	2.36	2.31	2.30
Sep-76	2.36	2.23	2.17	2.16
Oct-76	2.53	2.40	2.34	2.32
Nov-76	2.68	2.57	2.50	2.48
Dec-76	2.67	2.51	2.43	2.40
Jan-77	2.93	2.77	2.69	2.65
Feb-77	4.48	4.35	4.27	4.22
Mar-77	5.07	4.94	4.87	4.82
Apr-77	5.21	5.07	5.00	4.95
May-77	4.83	4.70	4.63	4.58
Jun-77	4.56	4.42	4.34	4.31
Jul-77	4.25	4.09	4.01	3.99
Aug-77	3.87	3.70	3.62	3.61
Sep-77	3.20	3.02	2.95	2.94
Oct-77	2.82	2.68	2.59	2.58
Nov-77	2.96	2.82	2.74	2.72
Dec-77	2.87	2.69	2.60	2.56
Jan-78	4.96	4.83	4.76	4.74
Feb-78	7.28	7.20	7.19	7.19
Mar-78	7.17	7.12	7.18	7.09
Apr-78	5.96	5.93	5.93	5.84
May-78	4.80	4.78	4.75	4.71
Jun-78	4.24	4.23	4.20	4.17
Jul-78	3.05	3.02	2.99	2.99
Aug-78	2.51	2.45	2.42	2.42
Sep-78	2.30	2.24	2.20	2.19
Oct-78	2.47	2.41	2.37	2.35
Nov-78	2.62	2.55	2.50	2.47
Dec-78	2.35	2.24	2.18	2.15
Jan-79	3.60	3.49	3.43	3.40
Feb-79	5.25	5.16	5.13	5.11
Mar-79	5.26	5.19	5.22	5.15
Apr-79	4.32	4.28	4.25	4.18
May-79	3.07	3.06	3.03	2.97
Jun-79	3.39	3.38	3.35	3.31
Jul-79	2.86	2.82	2.78	2.78
Aug-79	2.40	2.34	2.30	2.30
Sep-79	2.31	2.23	2.18	2.18
Oct-79	2.48	2.39	2.33	2.32
Nov-79	2.28	2.16	2.10	2.08
Dec-79	2.28	2.18	2.12	2.10
Jan-80	4.11	4.06	4.03	4.00
Feb-80	4.60	4.58	4.56	4.52
Mar-80	5.07	5.05	5.03	4.99
Apr-80	4.47	4.45	4.41	4.35
May-80	3.42	3.40	3.36	3.30
Jun-80	3.42	3.40	3.38	3.34
Jul-80	3.02	2.98	2.95	2.95
Aug-80	2.64	2.57	2.53	2.53
Sep-80	2.57	2.49	2.45	2.44
Oct-80	2.83	2.77	2.72	2.70
Nov-80	2.78	2.70	2.65	2.63
Dec-80	2.33	2.22	2.16	2.14
Jan-81	2.85	2.76	2.69	2.67
Feb-81	4.19	4.11	4.05	4.04
Mar-81	4.78	4.70	4.64	4.62
Apr-81	4.49	4.42	4.36	4.29
May-81	3.39	3.35	3.30	3.21
Jun-81	3.82	3.78	3.73	3.68
Jul-81	2.86	2.76	2.72	2.72
Aug-81	2.35	2.27	2.23	2.23
Sep-81	2.22	2.13	2.08	2.08
Oct-81	2.37	2.27	2.21	2.20
Nov-81	2.27	2.16	2.11	2.08
Dec-81	3.15	3.08	3.05	3.06
Jan-82	5.81	5.76	5.81	5.78
Feb-82	5.14	5.12	5.17	5.09
Mar-82	4.49	4.45	4.43	4.37
Apr-82	4.45	4.42	4.41	4.35
May-82	3.63	3.62	3.60	3.58
Jun-82	3.53	3.52	3.50	3.49
Jul-82	3.12	3.09	3.07	3.06
Aug-82	2.75	2.68	2.64	2.64
Sep-82	2.47	2.42	2.38	2.37
Oct-82	2.54	2.51	2.49	2.47
Nov-82	2.97	2.94	2.92	2.90
Dec-82	3.22	3.20	3.18	3.14
Jan-83	4.02	4.00	3.99	3.95
Feb-83	4.87	4.86	4.84	4.82
Mar-83	4.84	4.81	4.80	4.77
Apr-83	4.85	4.84	4.82	4.78
May-83	4.10	4.09	4.07	4.03
Jun-83	3.57	3.57	3.56	3.55
Jul-83	3.14	3.14	3.13	3.12
Aug-83	3.18	3.17	3.15	3.14

Sep-83	2.76	2.75	2.73	2.71
Oct-83	2.73	2.71	2.68	2.67
Nov-83	2.74	2.71	2.69	2.66
Dec-83	2.83	2.81	2.79	2.76
Jan-84	3.70	3.68	3.66	3.63
Feb-84	4.19	4.17	4.15	4.11
Mar-84	3.93	3.90	3.87	3.84
Apr-84	3.54	3.51	3.47	3.43
May-84	2.92	2.91	2.87	2.82
Jun-84	3.41	3.39	3.35	3.32
Jul-84	2.86	2.79	2.76	2.76
Aug-84	2.37	2.30	2.27	2.27
Sep-84	2.29	2.23	2.19	2.18
Oct-84	2.65	2.61	2.57	2.56
Nov-84	2.66	2.57	2.50	2.49
Dec-84	3.11	3.01	2.94	2.98
Jan-85	3.80	3.72	3.66	3.67
Feb-85	4.40	4.31	4.24	4.23
Mar-85	4.73	4.63	4.57	4.55
Apr-85	4.46	4.39	4.33	4.24
May-85	3.50	3.48	3.43	3.31
Jun-85	3.96	3.92	3.88	3.81
Jul-85	2.93	2.83	2.79	2.78
Aug-85	2.39	2.31	2.26	2.26
Sep-85	2.23	2.14	2.09	2.08
Oct-85	2.39	2.30	2.24	2.22
Nov-85	2.45	2.32	2.26	2.23
Dec-85	2.55	2.39	2.32	2.29
Jan-86	3.54	3.45	3.38	3.36
Feb-86	6.16	6.11	6.19	6.04
Mar-86	5.18	5.15	5.14	5.10
Apr-86	4.62	4.60	4.57	4.51
May-86	4.11	4.10	4.06	4.00
Jun-86	3.88	3.87	3.84	3.80
Jul-86	3.01	2.95	2.92	2.91
Aug-86	2.60	2.53	2.49	2.48
Sep-86	2.80	2.74	2.69	2.67
Oct-86	3.01	2.97	2.92	2.89
Nov-86	3.12	3.06	3.02	2.98
Dec-86	2.60	2.51	2.45	2.40
Jan-87	3.01	2.90	2.84	2.81
Feb-87	4.20	4.10	4.03	3.99
Mar-87	5.27	5.17	5.10	5.05
Apr-87	4.75	4.68	4.62	4.55
May-87	3.23	3.20	3.16	3.08
Jun-87	3.78	3.73	3.69	3.65
Jul-87	2.79	2.69	2.64	2.65
Aug-87	2.36	2.27	2.23	2.23
Sep-87	2.41	2.32	2.27	2.26
Oct-87	2.77	2.66	2.59	2.57
Nov-87	2.91	2.78	2.70	2.67
Dec-87	2.71	2.53	2.45	2.41
Jan-88	3.82	3.68	3.59	3.60
Feb-88	5.86	5.75	5.67	5.68
Mar-88	5.80	5.69	5.61	5.59
Apr-88	5.84	5.73	5.66	5.60
May-88	5.49	5.40	5.33	5.26
Jun-88	4.84	4.74	4.67	4.63
Jul-88	3.19	3.07	3.01	3.02
Aug-88	2.70	2.60	2.55	2.56
Sep-88	2.92	2.81	2.75	2.75
Oct-88	2.91	2.77	2.70	2.68
Nov-88	2.88	2.73	2.64	2.61
Dec-88	2.55	2.38	2.28	2.24
Jan-89	2.95	2.78	2.69	2.67
Feb-89	3.82	3.67	3.58	3.56
Mar-89	5.26	5.13	5.04	4.99
Apr-89	6.39	6.27	6.21	6.17
May-89	5.87	5.79	5.74	5.76
Jun-89	4.24	4.17	4.12	4.15
Jul-89	2.82	2.73	2.69	2.71
Aug-89	2.36	2.29	2.25	2.25
Sep-89	2.31	2.23	2.18	2.17
Oct-89	2.41	2.28	2.20	2.19
Nov-89	2.43	2.29	2.21	2.18
Dec-89	2.46	2.32	2.24	2.21
Jan-90	3.05	2.91	2.84	2.82
Feb-90	4.26	4.13	4.05	4.05
Mar-90	5.41	5.28	5.20	5.18
Apr-90	5.87	5.75	5.68	5.66
May-90	5.44	5.34	5.27	5.25
Jun-90	4.75	4.65	4.58	4.56
Jul-90	3.37	3.23	3.17	3.18
Aug-90	2.59	2.50	2.45	2.46
Sep-90	2.55	2.46	2.41	2.40
Oct-90	2.79	2.64	2.57	2.55
Nov-90	3.02	2.86	2.79	2.76
Dec-90	3.18	3.02	2.94	2.89
Jan-91	3.21	3.03	2.94	2.90
Feb-91	4.44	4.26	4.17	4.12
Mar-91	5.36	5.17	5.08	5.02
Apr-91	6.36	6.20	6.13	6.07
May-91	6.25	6.10	6.05	6.04
Jun-91	4.95	4.78	4.71	4.75
Jul-91	3.01	2.87	2.80	2.82
Aug-91	2.56	2.48	2.43	2.44

Scenario	Current Condition	Future Condition Planned	Future Condition Plausible	Future Condition Outer Boundary
Output Location	CLIFTON_COURT	CLIFTON_COURT	CLIFTON_COURT	CLIFTON_COURT
Constituent	Bromide	Bromide	Bromide	Bromide
Model_Output Type	CALCULATED	CALCULATED	CALCULATED	CALCULATED
Unit of measurement	MG/L	MG/L	MG/L	MG/L
Type - Average or Instantaneous	PER-AVER	PER-AVER	PER-AVER	PER-AVER
Average	**0.25**	**0.26**	**0.26**	**0.25**
90th Percentile	**0.41**	**0.41**	**0.41**	**0.41**
Oct-75	0.08	0.08	0.08	0.08
Nov-75	0.07	0.09	0.09	0.08
Dec-75	0.07	0.08	0.08	0.08
Jan-76	0.24	0.25	0.25	0.24
Feb-76	0.28	0.30	0.30	0.29
Mar-76	0.21	0.24	0.24	0.24
Apr-76	0.13	0.18	0.18	0.17
May-76	0.14	0.20	0.20	0.19
Jun-76	0.15	0.19	0.19	0.18
Jul-76	0.28	0.28	0.28	0.28
Aug-76	0.39	0.39	0.39	0.39
Sep-76	0.35	0.34	0.34	0.34
Oct-76	0.37	0.38	0.38	0.37
Nov-76	0.32	0.33	0.33	0.33
Dec-76	0.32	0.34	0.34	0.33
Jan-77	0.45	0.46	0.46	0.46
Feb-77	0.41	0.45	0.45	0.44
Mar-77	0.31	0.36	0.36	0.35
Apr-77	0.20	0.24	0.24	0.23
May-77	0.18	0.22	0.22	0.21
Jun-77	0.17	0.21	0.21	0.20
Jul-77	0.27	0.30	0.30	0.30
Aug-77	0.29	0.30	0.30	0.30
Sep-77	0.28	0.28	0.28	0.28
Oct-77	0.34	0.33	0.33	0.33
Nov-77	0.37	0.37	0.37	0.36
Dec-77	0.36	0.35	0.36	0.35
Jan-78	0.43	0.45	0.45	0.45
Feb-78	0.36	0.42	0.42	0.41
Mar-78	0.38	0.45	0.44	0.43
Apr-78	0.43	0.50	0.50	0.50
May-78	0.41	0.49	0.48	0.48
Jun-78	0.26	0.32	0.32	0.31
Jul-78	0.09	0.11	0.11	0.11
Aug-78	0.12	0.14	0.14	0.14
Sep-78	0.18	0.21	0.21	0.20
Oct-78	0.07	0.10	0.10	0.09
Nov-78	0.08	0.11	0.12	0.11
Dec-78	0.08	0.11	0.11	0.10
Jan-79	0.33	0.35	0.35	0.35
Feb-79	0.20	0.24	0.24	0.23
Mar-79	0.22	0.26	0.26	0.25
Apr-79	0.23	0.29	0.29	0.28
May-79	0.15	0.20	0.20	0.19
Jun-79	0.12	0.15	0.15	0.15
Jul-79	0.07	0.08	0.08	0.08
Aug-79	0.18	0.19	0.19	0.19
Sep-79	0.33	0.33	0.33	0.33
Oct-79	0.39	0.40	0.40	0.39
Nov-79	0.42	0.42	0.42	0.41
Dec-79	0.43	0.43	0.43	0.43
Jan-80	0.37	0.39	0.39	0.38
Feb-80	0.23	0.25	0.25	0.25
Mar-80	0.30	0.33	0.33	0.33
Apr-80	0.29	0.33	0.33	0.32
May-80	0.22	0.26	0.26	0.25
Jun-80	0.15	0.18	0.18	0.17
Jul-80	0.08	0.10	0.10	0.09
Aug-80	0.07	0.07	0.07	0.07
Sep-80	0.16	0.17	0.17	0.17
Oct-80	0.09	0.11	0.11	0.10
Nov-80	0.08	0.09	0.10	0.09
Dec-80	0.15	0.17	0.17	0.16
Jan-81	0.32	0.33	0.33	0.33
Feb-81	0.24	0.26	0.26	0.26
Mar-81	0.17	0.19	0.19	0.19
Apr-81	0.24	0.27	0.27	0.26
May-81	0.21	0.23	0.23	0.22
Jun-81	0.17	0.19	0.19	0.18
Jul-81	0.16	0.17	0.17	0.17
Aug-81	0.31	0.30	0.30	0.30
Sep-81	0.40	0.39	0.39	0.39
Oct-81	0.39	0.38	0.39	0.38
Nov-81	0.29	0.29	0.29	0.28
Dec-81	0.09	0.10	0.10	0.09
Jan-82	0.21	0.22	0.22	0.21
Feb-82	0.25	0.26	0.26	0.25
Mar-82	0.24	0.25	0.25	0.25
Apr-82	0.23	0.24	0.24	0.24
May-82	0.22	0.24	0.24	0.24
Jun-82	0.18	0.19	0.19	0.19
Jul-82	0.11	0.12	0.12	0.11
Aug-82	0.08	0.08	0.08	0.08
Sep-82	0.09	0.09	0.09	0.09
Oct-82	0.06	0.07	0.07	0.06
Nov-82	0.15	0.15	0.15	0.15
Dec-82	0.31	0.32	0.32	0.31
Jan-83	0.27	0.27	0.27	0.27
Feb-83	0.26	0.27	0.27	0.27
Mar-83	0.21	0.23	0.22	0.22
Apr-83	0.29	0.31	0.31	0.31
May-83	0.27	0.28	0.28	0.28
Jun-83	0.20	0.21	0.21	0.20
Jul-83	0.17	0.18	0.18	0.18
Aug-83	0.14	0.15	0.15	0.15

Sep-83	0.08	0.09	0.09	0.09
Oct-83	0.07	0.08	0.08	0.08
Nov-83	0.16	0.17	0.17	0.17
Dec-83	0.22	0.22	0.22	0.22
Jan-84	0.26	0.26	0.26	0.26
Feb-84	0.19	0.19	0.19	0.19
Mar-84	0.14	0.15	0.15	0.14
Apr-84	0.14	0.15	0.15	0.14
May-84	0.11	0.12	0.12	0.12
Jun-84	0.11	0.12	0.12	0.12
Jul-84	0.06	0.06	0.06	0.06
Aug-84	0.09	0.09	0.09	0.09
Sep-84	0.22	0.22	0.22	0.21
Oct-84	0.12	0.09	0.09	0.09
Nov-84	0.07	0.07	0.08	0.07
Dec-84	0.08	0.08	0.08	0.08
Jan-85	0.11	0.12	0.12	0.11
Feb-85	0.15	0.15	0.15	0.15
Mar-85	0.16	0.16	0.16	0.16
Apr-85	0.20	0.21	0.21	0.20
May-85	0.18	0.18	0.18	0.17
Jun-85	0.15	0.16	0.16	0.15
Jul-85	0.14	0.15	0.15	0.15
Aug-85	0.29	0.28	0.28	0.28
Sep-85	0.38	0.37	0.37	0.37
Oct-85	0.36	0.35	0.35	0.35
Nov-85	0.32	0.31	0.31	0.31
Dec-85	0.48	0.46	0.46	0.46
Jan-86	0.46	0.45	0.45	0.44
Feb-86	0.26	0.26	0.26	0.25
Mar-86	0.12	0.13	0.13	0.12
Apr-86	0.14	0.16	0.15	0.15
May-86	0.15	0.16	0.16	0.15
Jun-86	0.14	0.15	0.15	0.15
Jul-86	0.08	0.08	0.08	0.08
Aug-86	0.13	0.13	0.13	0.13
Sep-86	0.22	0.22	0.22	0.22
Oct-86	0.12	0.12	0.12	0.12
Nov-86	0.10	0.11	0.11	0.11
Dec-86	0.11	0.11	0.11	0.11
Jan-87	0.28	0.28	0.28	0.28
Feb-87	0.28	0.28	0.28	0.28
Mar-87	0.21	0.21	0.21	0.20
Apr-87	0.23	0.23	0.23	0.23
May-87	0.15	0.16	0.16	0.15
Jun-87	0.13	0.14	0.14	0.14
Jul-87	0.14	0.14	0.14	0.14
Aug-87	0.29	0.28	0.28	0.28
Sep-87	0.36	0.35	0.35	0.35
Oct-87	0.39	0.38	0.38	0.37
Nov-87	0.36	0.35	0.35	0.35
Dec-87	0.40	0.38	0.38	0.38
Jan-88	0.35	0.35	0.35	0.34
Feb-88	0.23	0.23	0.23	0.22
Mar-88	0.25	0.25	0.25	0.25
Apr-88	0.29	0.29	0.29	0.29
May-88	0.28	0.29	0.29	0.28
Jun-88	0.23	0.24	0.24	0.23
Jul-88	0.18	0.18	0.18	0.18
Aug-88	0.31	0.30	0.30	0.30
Sep-88	0.33	0.33	0.33	0.33
Oct-88	0.36	0.35	0.35	0.35
Nov-88	0.40	0.39	0.39	0.38
Dec-88	0.35	0.34	0.34	0.33
Jan-89	0.63	0.61	0.61	0.61
Feb-89	0.61	0.59	0.59	0.58
Mar-89	0.59	0.58	0.58	0.57
Apr-89	0.52	0.52	0.52	0.50
May-89	0.26	0.26	0.26	0.25
Jun-89	0.13	0.13	0.13	0.13
Jul-89	0.16	0.15	0.15	0.15
Aug-89	0.34	0.33	0.33	0.33
Sep-89	0.38	0.36	0.37	0.37
Oct-89	0.38	0.36	0.36	0.36
Nov-89	0.38	0.36	0.36	0.35
Dec-89	0.48	0.46	0.45	0.45
Jan-90	0.47	0.45	0.45	0.45
Feb-90	0.34	0.33	0.33	0.33
Mar-90	0.25	0.25	0.25	0.25
Apr-90	0.27	0.27	0.27	0.26
May-90	0.25	0.26	0.26	0.25
Jun-90	0.21	0.22	0.22	0.21
Jul-90	0.28	0.28	0.28	0.27
Aug-90	0.42	0.40	0.40	0.40
Sep-90	0.37	0.35	0.35	0.35
Oct-90	0.42	0.41	0.41	0.41
Nov-90	0.43	0.42	0.42	0.41
Dec-90	0.36	0.35	0.35	0.34
Jan-91	0.35	0.34	0.34	0.33
Feb-91	0.40	0.40	0.39	0.39
Mar-91	0.44	0.44	0.44	0.43
Apr-91	0.35	0.35	0.35	0.34
May-91	0.32	0.32	0.33	0.31
Jun-91	0.24	0.24	0.24	0.23
Jul-91	0.31	0.30	0.30	0.30
Aug-91	0.41	0.40	0.40	0.40

Scenario	Current Condition	Future Condition
Output Location	CLIFTON_COURT	CLIFTON_COURT
Constituent	TEMP	TEMP
Model_Output Type	EXISTING_CUWA+FROM-ALL	EXISTING_CUWA+FROM-ALL
Unit of measurement	DEG C	DEG C
Type - Average or Instantaneous	PER-AVER	PER-AVER
Average	**16.58**	**16.58**
99th Percentile	**23.97**	**23.97**
Oct-75	18.68	18.69
Nov-75	14.24	14.25
Dec-75	10.08	10.09
Jan-76	8.99	9.01
Feb-76	12.04	12.05
Mar-76	15.42	15.42
Apr-76	15.42	15.42
May-76	20.39	20.39
Jun-76	21.30	21.30
Jul-76	23.48	23.48
Aug-76	22.11	22.11
Sep-76	21.23	21.24
Oct-76	18.42	18.42
Nov-76	15.57	15.58
Dec-76	9.80	9.80
Jan-77	8.01	8.03
Feb-77	11.96	11.97
Mar-77	14.21	14.21
Apr-77	16.50	16.50
May-77	16.58	16.59
Jun-77	21.25	21.25
Jul-77	22.85	22.85
Aug-77	22.30	22.30
Sep-77	20.45	20.46
Oct-77	17.18	17.18
Nov-77	14.02	14.03
Dec-77	11.11	11.12
Jan-78	11.72	11.73
Feb-78	12.33	12.34
Mar-78	16.08	16.09
Apr-78	15.27	15.27
May-78	19.65	19.65
Jun-78	21.04	21.04
Jul-78	22.29	22.29
Aug-78	22.61	22.61
Sep-78	19.54	19.55
Oct-78	18.63	18.64
Nov-78	12.96	12.97
Dec-78	8.29	8.30
Jan-79	9.05	9.06
Feb-79	11.30	11.31
Mar-79	14.69	14.69
Apr-79	14.55	14.55
May-79	18.67	18.67
Jun-79	20.95	20.95
Jul-79	22.52	22.53
Aug-79	22.23	22.23
Sep-79	21.30	21.30
Oct-79	17.75	17.76
Nov-79	12.88	12.89
Dec-79	10.12	10.13
Jan-80	10.23	10.24
Feb-80	12.14	12.14
Mar-80	14.42	14.42
Apr-80	16.18	16.18
May-80	18.02	18.02
Jun-80	19.39	19.39
Jul-80	22.35	22.35
Aug-80	21.86	21.87
Sep-80	19.73	19.74

Oct-80	18.09	18.10
Nov-80	13.72	13.73
Dec-80	9.71	9.72
Jan-81	9.33	9.34
Feb-81	11.52	11.54
Mar-81	14.04	14.04
Apr-81	14.53	14.53
May-81	18.12	18.12
Jun-81	21.91	21.92
Jul-81	22.96	22.96
Aug-81	22.23	22.23
Sep-81	20.49	20.49
Oct-81	17.45	17.45
Nov-81	15.60	15.61
Dec-81	10.43	10.44
Jan-82	8.83	8.84
Feb-82	11.40	11.41
Mar-82	13.95	13.95
Apr-82	15.17	15.17
May-82	18.75	18.75
Jun-82	19.09	19.10
Jul-82	21.69	21.69
Aug-82	21.73	21.73
Sep-82	20.06	20.07
Oct-82	16.39	16.40
Nov-82	12.31	12.32
Dec-82	9.16	9.17
Jan-83	9.13	9.13
Feb-83	11.96	11.96
Mar-83	14.49	14.49
Apr-83	15.02	15.02
May-83	18.13	18.13
Jun-83	21.36	21.36
Jul-83	22.51	22.51
Aug-83	23.31	23.31
Sep-83	21.90	21.90
Oct-83	18.80	18.80
Nov-83	13.94	13.95
Dec-83	10.38	10.39
Jan-84	10.03	10.04
Feb-84	11.88	11.89
Mar-84	15.33	15.33
Apr-84	15.09	15.09
May-84	19.66	19.66
Jun-84	21.61	21.61
Jul-84	24.03	24.03
Aug-84	22.87	22.87
Sep-84	22.28	22.29
Oct-84	17.69	17.70
Nov-84	13.96	13.97
Dec-84	9.62	9.63
Jan-85	7.60	7.62
Feb-85	10.65	10.67
Mar-85	14.33	14.33
Apr-85	16.86	16.86
May-85	17.79	17.79
Jun-85	21.16	21.16
Jul-85	23.96	23.96
Aug-85	21.50	21.50
Sep-85	20.23	20.23
Oct-85	17.21	17.22
Nov-85	13.23	13.25
Dec-85	8.23	8.25
Jan-86	10.47	10.48
Feb-86	13.37	13.38
Mar-86	15.53	15.53
Apr-86	15.52	15.52
May-86	18.26	18.26

Jun-86	20.99	20.99
Jul-86	22.50	22.50
Aug-86	22.64	22.64
Sep-86	19.49	19.50
Oct-86	17.50	17.51
Nov-86	15.40	15.41
Dec-86	10.21	10.22
Jan-87	8.67	8.68
Feb-87	12.29	12.31
Mar-87	14.82	14.82
Apr-87	17.05	17.05
May-87	19.69	19.69
Jun-87	21.04	21.05
Jul-87	21.55	21.55
Aug-87	22.14	22.14
Sep-87	20.98	20.98
Oct-87	19.08	19.09
Nov-87	15.05	15.05
Dec-87	10.71	10.72
Jan-88	9.40	9.41
Feb-88	12.56	12.57
Mar-88	16.57	16.57
Apr-88	17.37	17.37
May-88	18.35	18.35
Jun-88	21.32	21.32
Jul-88	24.17	24.17
Aug-88	22.77	22.77
Sep-88	21.71	21.71
Oct-88	18.55	18.55
Nov-88	14.84	14.85
Dec-88	10.05	10.06
Jan-89	7.90	7.92
Feb-89	10.79	10.81
Mar-89	15.52	15.52
Apr-89	17.60	17.60
May-89	18.46	18.46
Jun-89	20.93	20.93
Jul-89	22.99	22.99
Aug-89	22.50	22.51
Sep-89	20.55	20.56
Oct-89	17.83	17.83
Nov-89	13.67	13.69
Dec-89	9.26	9.27
Jan-90	9.95	9.97
Feb-90	10.46	10.47
Mar-90	14.82	14.82
Apr-90	16.64	16.64
May-90	18.63	18.63
Jun-90	20.87	20.88
Jul-90	23.55	23.55
Aug-90	23.08	23.08
Sep-90	21.48	21.48
Oct-90	18.47	18.48
Nov-90	13.93	13.93
Dec-90	8.42	8.43
Jan-91	8.78	8.79
Feb-91	12.84	12.85
Mar-91	14.33	14.34
Apr-91	15.22	15.22
May-91	17.97	17.97
Jun-91	20.89	20.89
Jul-91	23.06	23.06
Aug-91	21.84	21.84

Appendix D

Virtual Water Treatment Plant Selection

California Urban Water Agencies Drinking Water Treatment Evaluation

California Urban Water Agencies

APPENDIX D

Development of Virtual Water Treatment Plants (VWTPs)

INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

49 WTPs Were Used to Define 5 WQ Regions

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California Urban Water Agencies

INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

Context for VWTP Development

- VWTPs are being developed to represent the central tendencies of treatment in each region.
- To accomplish project objectives, the project needs to be a high level planning effort; therefore, some VWTP design details are difficult to include.
- Important to come to consensus on VWTP approach and resulting VWTPs
- VWTPs are a vital piece of the project that needs to be established and not changed subsequent to Work Group agreement

Approach for Developing VWTPs

1 Consider the WTPs that treat > 70% Delta water.
2 Consider the treatment trains that are > 10% of the region's treatment capacity or WTPs that are greater than 20 mgd.
3 Consider the treatment processes that are used at least twice in the remaining WTPs in the region.
4 Consolidate treatment trains.
5 Select flows representative of remaining treatment trains.

CAA-West Branch

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A	30	3.6%	80–100*		x	x			x				x			x			
B	56	6.7%	80–100*		x	x			x				x			x			
C	750	89.7%	100	x	x	x			x				x			x			
	836	Total Regional Treatment Capacity																	

*Temporary Approximate Value

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

California Urban Water Agencies

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INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

CAA-West Branch

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A	30	3.6%	80–100*		x	x			x				x			x			
B	56	6.7%	80–100*		x	x			x				x			x			
C	750	89.7%	100	x	x	x			x				x			x			
	836	Total Regional Treatment Capacity																	

*Temporary Approximate Value

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

California Urban Water Agencies

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INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

CAA-West Branch

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A	30	3.6%	80–100*		x	x			x				x			x			
B	56	6.7%	80–100*		x	x			x				x			x			
C	750	89.7%	100	x	x	x			x				x			x			
	836	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

Step 3 is not applicable to this region (there are only a total of 3 WTPs).

California Urban Water Agencies

CAA-West Branch

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A	30	3.6%	80–100*		x	x			x				x			x			
B	56	6.7%	80–100*		x	x			x				x			x			
C	750	89.7%	100	x	x	x			x				x			x			
	836	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

A, B, C → 4 → A, B, C: Conventional + Pre-ozonation + Chloramines +pH adjustment (56, 30, 750 mgd)

California Urban Water Agencies

CAA-West Branch

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Particulate Removal: Rapid Mix	Particulate Removal: Conventional	Particulate Removal: Direct Filtration	Particulate Removal: Filtration: Slow Sand	Particulate Removal: Filtration: Rapid Sand, Multi-media	Particulate Removal: Filtration: Pressure Sand	Particulate Removal: Membranes	Disinfection: Pre - Chlorination	Disinfection: Pre-Ozonation	Disinfection: Post-Ozonation	Disinfection: Post-chlorination	Disinfection: Chloramines	Disinfection: MIOX	DBP Control: GAC	DBP Control: PAC
A	30	3.6%	80–100*		x	x			x				x			x			
B	56	6.7%	80–100*		x	x			x				x			x			
C	750	89.7%	100	x	x	x			x				x			x			
	836	Total Regional Treatment Capacity																	

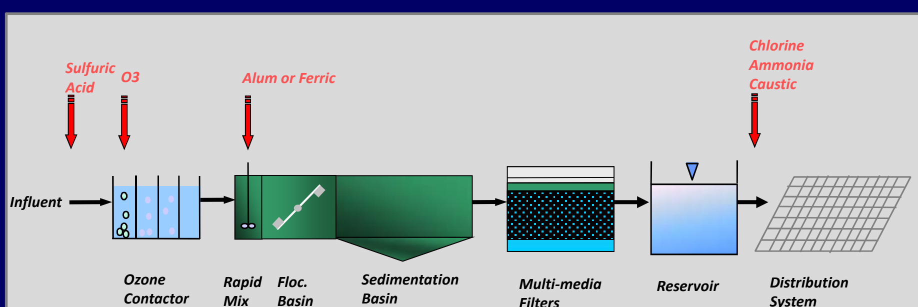
1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

A, B, C: Conventional + Pre-ozonation + Chloramines + pH adjustment (56, 30, 720 mgd) → 5 → CAAW-1: 800 mgd Conventional + Pre-ozonation + Chloramines+ pH adjustment

California Urban Water Agencies

MALCOLM PIRNIE — INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

CAAW-1



- Size- 800 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- ozone
- Secondary Disinfection- chloramines
- pH adjustment

California Urban Water Agencies

MALCOLM PIRNIE — INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

Central Delta

				Particulate Removal								Disinfection						DBP Control	
	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A	8	2.8%	0-100		x	x					x	x			x	x			
B	21	7.4%	100			x		x			x					x			
C	26	9.2%	100*			x			x							x			
D	28	9.9%	0-100	x	x	x			x				x		x	x			
E	40	14.1%	100	x	x	x			x				x	x	x	x			
F	42	14.8%	0-100		x	x			x			x	x		x	x			
G	44	15.5%	0-100			x		x								x			
H	75	26.4%	100	x		x			x						x				
	284	Total Regional Treatment Capacity																	

**Temporary Approximate Value*

1 Treat >70% Delta water.

2 >10% Regional Contribution or >20 mgd Capacity.

3 Treatment process used at least twice in the region.

4 Consolidate treatment trains.

5 Select flows representative of selected treatment trains.

California Urban Water Agencies

MALCOLM PIRNIE

INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

Central Delta

				Particulate Removal								Disinfection						DBP Control	
	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A	8	2.8%	0-100		x	x					x	x			x	x			
B	21	7.4%	100			x		x			x					x			
C	26	9.2%	100*			x			x							x			
D	28	9.9%	0-100	x	x	x			x				x		x	x			
E	40	14.1%	100	x	x	x			x				x	x	x	x			
F	42	14.8%	0-100		x	x			x			x	x		x	x			
G	44	15.5%	0-100			x		x								x			
H	75	26.4%	100	x		x			x						x				
	284	Total Regional Treatment Capacity																	

**Temporary Approximate Value*

1 Treat >70% Delta water.

2 >10% Regional Contribution or >20 mgd Capacity.

3 Treatment process used at least twice in the region.

4 Consolidate treatment trains.

5 Select flows representative of selected treatment trains.

California Urban Water Agencies

MALCOLM PIRNIE

INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

Central Delta

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal								Disinfection						DBP Control	
				Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A	8	2.8%	0-100		x	x					x	x			x	x			
B	21	7.4%	100			x		x			x					x			
C	26	9.2%	100*			x			x							x			
D	28	9.9%	0-100	x	x	x			x				x		x	x			
E	40	14.1%	100	x	x	x			x				x	x	x	x			
F	42	14.8%	0-100		x	x			x			x	x		x	x			
G	44	15.5%	0-100			x		x								x			
H	75	26.4%	100	x		x			x						x				
	284	Total Regional Treatment Capacity																	

**Temporary Approximate Value*

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

California Urban Water Agencies

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INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

Central Delta

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal								Disinfection						DBP Control	
				Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A	8	2.8%	0-100		x	x					x	x			x	x			
B	21	7.4%	100			x		x			x					x			
C	26	9.2%	100*			x			x							x			
D	28	9.9%	0-100	x	x	x			x				x		x	x			
E	40	14.1%	100	x	x	x			x				x	x	x	x			
F	42	14.8%	0-100		x	x			x			x	x		x	x			
G	44	15.5%	0-100			x		x								x			
H	75	26.4%	100	x		x			x						x				
	284	Total Regional Treatment Capacity																	

**Temporary Approximate Value*

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

C, D, E, F → 4 → Conventional + ozone + chlorine+ chloramines + pH adjustment (26, 28, 40, 42 mgd)

California Urban Water Agencies

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INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

Central Delta

				Particulate Removal								Disinfection						DBP Control	
x	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A	8	2.8%	0-100		x	x					x	x			x	x			
B	21	7.4%	100			x		x			x					x			
C	26	9.2%	100*			x			x							x			
D	28	9.9%	0-100	x	x	x			x				x		x	x			
E	40	14.1%	100	x	x	x			x				x	x	x	x			
F	42	14.8%	0-100		x	x			x			x	x		x	x			
G	44	15.5%	0-100			x		x								x			
H	75	26.4%	100	x		x			x						x				
	284	Total Regional Treatment Capacity																	

*Temporary Approximate Value

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

Conventional + ozone + chlorine+ chloramines + pH adjustment (26, 28, 40, 42 mgd) → 5 → CD-1: 40 mgd Conventional + ozone + chlorine+ chloramines + pH adjustment

California Urban Water Agencies

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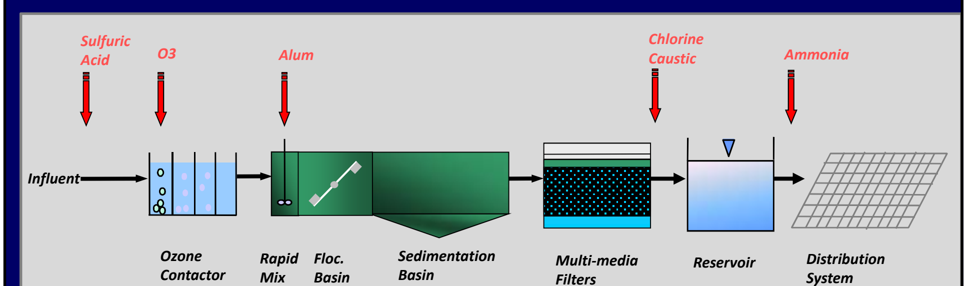
INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

CD-1



- Size- 40 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- ozone + chlorine
- Secondary Disinfection- chloramines
- pH adjustment

California Urban Water Agencies

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INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

NBA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal								Disinfection						DBP Control	
				Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A	5.2	4.0%	40*			x			x		x				x				
B	7.5	5.8%	80-100*			x			x						x				
C	12	9.3%	80-100*			x			x			x			x				
D	22.5	17.4%	70*			x			x				x	x	x				
E	40	31.0%	50-80*			x			x				x	x	x				
F	42	32.5%	25-50*			x			x						x				
	122	Total Regional Treatment Capacity																	

Temporary Approximate Value

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

California Urban Water Agencies

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INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

NBA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal								Disinfection						DBP Control	
				Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A	5.2	4.0%	40*			x			x		x				x				
B	7.5	5.8%	80-100*			x			x						x				
C	12	9.3%	80-100*			x			x			x			x				
D	22.5	17.4%	70*			x			x				x	x	x				
E	40	31.0%	50-80*			x			x				x	x	x				
F	42	32.5%	25-50*			x			x						x				
	122	Total Regional Treatment Capacity																	

Temporary Approximate Value

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

California Urban Water Agencies

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INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

NBA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
B	7.5	5.8%	80-100*			x			x						x				
C	12	9.3%	80-100*			x			x			x			x				
	122	Total Regional Treatment Capacity																	

Temporary Approximate Value

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

B & C → 4 → Conventional + chlorine (7.5 and 12 mgd)

NBA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
D	22.5	17.4%	70*			x			x				x	x	x				
E	40	31.0%	50-80*			x			x				x	x	x				
	122	Total Regional Treatment Capacity																	

Temporary Approximate Value

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

D & E → 4 → Conventional + ozone + chlorine (22.5 and 40 mgd)

NBA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
				Particulate Removal								Disinfection						DBP Control	
A	5.2	4.0%	40*			x			x		x				x				
B	7.5	5.8%	80-100*			x			x						x				
C	12	9.3%	80-100*			x			x			x			x				
D	22.5	17.4%	70*			x			x				x	x	x				
E	40	31.0%	50-80*			x			x				x	x	x				
F	42	32.5%	25-50*			x			x						x				
	122	Total Regional Treatment Capacity																	

**Temporary Approximate Value*

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

B & C
D & E
4 →
B&C: Conventional + chlorine (7.5 and 12 mgd)
D&E: Conventional + ozone + chlorine (22.5 and 40 mgd)

California Urban Water Agencies

INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

NBA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
				Particulate Removal								Disinfection						DBP Control	
A		4.0%	40*			x			x		x				x				
B	7.5	5.8%	80-100*			x			x						x				
C	12	9.3%	80-100*			x			x			x			x				
D		17.4%	70*			x			x				x	x	x				
E		31.0%	50-80*			x			x				x	x	x				
F		32.5%	25-50*			x			x						x				
	122	Total Regional Treatment Capacity																	

**Temporary Approximate Value*

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

Conventional + chlorine (7.5 and 12 mgd)
5 →
NBA-1: 10 mgd Conventional + chlorine

California Urban Water Agencies

INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

NBA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A		4.0%	40*			x			x		x				x				
B		5.8%	80-100*			x			x						x				
C		9.3%	80-100*			x			x			x			x				
D	22.5	17.4%	70*			x			x				x	x	x				
E	40	31.0%	50-80*			x			x				x	x	x				
F		32.5%	25-50*			x			x						x				
	122	Total Regional Treatment Capacity																	

**Temporary Approximate Value*

Conventional + ozone + chlorine (22.5 and 40 mgd) → 5 → NBA-2: 20 mgd Conventional + ozone + chlorine

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

California Urban Water Agencies

NBA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A	5.2	4.0%	40*			x			x		x				x				
B	7.5	5.8%	80-100*			x			x						x				
C	12	9.3%	80-100*			x			x			x			x				
D	22.5	17.4%	70*			x			x				x	x	x				
E	40	31.0%	50-80*			x			x				x	x	x				
F	42	32.5%	25-50*			x			x						x				
	122	Total Regional Treatment Capacity																	

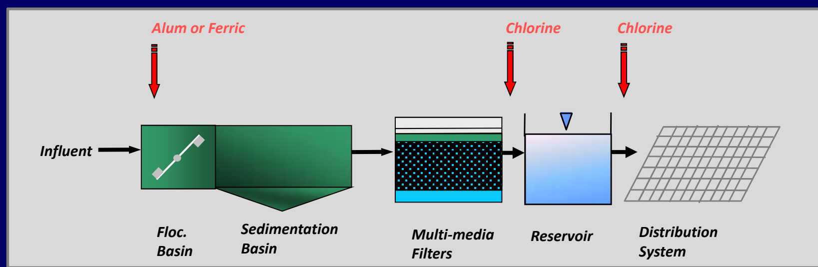
**Temporary Approximate Value*

Conventional + chlorine (7.5 and 12 mgd)
Conventional + ozone + chlorine (22.5 and 40 mgd)
→ 5 →
NBA-1: 10 mgd Conventional + chlorine
NBA-2: 20 mgd Conventional + ozone + chlorine

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

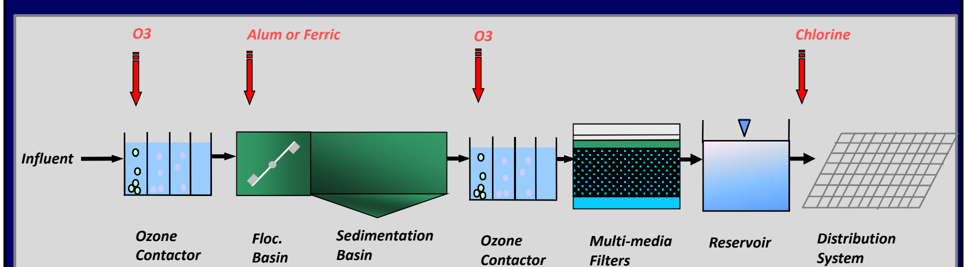
California Urban Water Agencies

NBA-1



- Size- 10 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- chlorine
- Secondary Disinfection- chlorine

NBA-2



- Size- 20 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- ozone
- Secondary Disinfection- chlorine

Upper Watersheds

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A	-	-			x	x			x			x			x				
B	-	-			x	x			x			x			x				
C	1	0.1%			x	x			x			x			x				
D	7	0.9%							x						x				
E	17	2.1%									x				x				
F	24	2.9%				x			x			x			x				
G	25	3.1%					x		x							x			
H	28	3.4%				x			x			x			x				
I	45	5.5%			x	x			x				x		x				
J	45	5.5%			x		x		x						x			x	
K	91	11.1%					x		x							x			
L	160	19.6%		x	x	x			x			x			x				
M	175	21.4%					x		x							x			
N	200	24.4%		x	x	x			x			x			x				
	818	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

California Urban Water Agencies

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INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

Upper Watersheds

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A	-	-			x	x			x			x			x				
B	-	-			x	x			x			x			x				
C	1	0.1%			x	x			x			x			x				
D	7	0.9%							x						x				
E	17	2.1%									x				x				
F	24	2.9%				x			x			x			x				
G	25	3.1%					x		x							x			
H	28	3.4%				x			x			x			x				
I	45	5.5%			x	x			x				x		x				
J	45	5.5%			x		x		x						x			x	
K	91	11.1%					x		x							x			
L	160	19.6%		x	x	x			x			x			x				
M	175	21.4%					x		x							x			
N	200	24.4%		x	x	x			x			x			x				
	818	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

California Urban Water Agencies

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INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

Upper Watersheds

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A	-	-			x	x			x			x			x				
B	-	-			x	x			x			x			x				
C	1	0.1%			x	x			x			x			x				
D	7	0.9%							x						x				
E	17	2.1%									x				x				
F	24	2.9%				x			x			x			x				
G	25	3.1%					x		x							x			
H	28	3.4%				x			x			x			x				
I	45	5.5%			x	x			x				x (red)		x				
J	45	5.5%			x		x		x						x			x (red)	
K	91	11.1%					x		x							x			
L	160	19.6%		x	x	x			x			x			x				
M	175	21.4%					x		x							x			
N	200	24.4%		x	x	x			x			x			x				
	818	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

California Urban Water Agencies

Upper Watersheds

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A	-	-			x	x			x			x			x				
B	-	-			x	x			x			x			x				
C	1	0.1%			x	x			x			x			x				
D	7	0.9%							x						x				
F	24	2.9%				x			x			x			x				
H	28	3.4%				x			x			x			x				
L	160	19.6%		x	x	x			x			x			x				
N	200	24.4%		x	x	x			x			x			x				
	818	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

A, B, C, D, F, H, L, N → 4 → Conventional + Chlorine + pH adjustment (1, 7, 24, 28, 160, 200 mgd)

California Urban Water Agencies

Upper Watersheds

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
G	25	3.1%					x		x							x			
K	91	11.1%					x		x							x			
M	175	21.4%					x		x							x			
	818	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

G, K, M → 4 → Direct Filtration + Chloramines (25, 91, 175 mgd)

California Urban Water Agencies

INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

Upper Watersheds

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A	-	-			x	x			x			x			x				
B	-	-			x	x			x			x			x				
C	1	0.1%			x	x			x			x			x				
D	7	0.9%							x						x				
E	17	2.1%									x				x				
F	24	2.9%				x			x			x			x				
G	25	3.1%					x		x							x			
H	28	3.4%				x			x			x			x				
I	45	5.5%			x	x			x				x		x				
J	45	5.5%			x		x		x						x			x	
K	91	11.1%					x		x							x			
L	160	19.6%		x	x	x			x			x			x				
M	175	21.4%					x		x							x			
N	200	24.4%		x	x	x			x			x			x				
	818	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

A, B, C, D, F, H, L, N / G, K, M → 4 →
A, B, C, D, F, H, L, N: Conventional + Chlorine + pH adjustment (1, 7, 24, 28, 160, 200 mgd)
G, K, M: Direct Filtration + Chloramines (25, 91, 175 mgd)

California Urban Water Agencies

INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

MALCOLM PIRNIE

Upper Watersheds

				Particulate Removal								Disinfection						DBP Control	
	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A	-	-			x	x			x			x			x				
B	-	-			x	x			x			x			x				
C	1	0.1%			x	x			x			x			x				
D	7	0.9%							x						x				
E		2.1%									x				x				
F	24	2.9%				x			x			x			x				
G		3.1%					x		x							x			
H	28	3.4%				x			x			x			x				
I		5.5%			x	x			x				x		x				
J		5.5%			x		x		x						x			x	
K		11.1%					x		x							x			
L	160	19.6%		x	x	x			x			x			x				
M		21.4%					x		x							x			
N	200	24.4%		x	x	x			x			x			x				
	818	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.

A, B, C, D, F, H, L, N: Conventional + Chlorine + pH adjustment (1, 7, 24, 28, 160, 200 mgd)

5 UW-1: 100 mgd Conventional + Chlorine + pH adjustment

5 Select flows representative of selected treatment trains.

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California Urban Water Agencies

MALCOLM PIRNIE

INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

Upper Watersheds

				Particulate Removal								Disinfection						DBP Control	
	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A		-			x	x			x			x			x				
B		-			x	x			x			x			x				
C		0.1%			x	x			x			x			x				
D		0.9%							x						x				
E		2.1%									x				x				
F		2.9%				x			x			x			x				
G	25	3.1%					x		x							x			
H		3.4%				x			x			x			x				
I		5.5%			x	x			x				x		x				
J		5.5%			x		x		x						x			x	
K	91	11.1%					x		x							x			
L		19.6%		x	x	x			x			x			x				
M	175	21.4%					x		x							x			
N		24.4%		x	x	x			x			x			x				
	818	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.

G, K, M: Direct Filtration + Chloramines (25, 91, 175 mgd)

5 UW-2: 100 mgd Direct Filtration + Chloramines

5 Select flows representative of selected treatment trains.

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California Urban Water Agencies

MALCOLM PIRNIE

INDEPENDENT ENVIRONMENTAL ENGINEERS, SCIENTISTS AND CONSULTANTS

Upper Watersheds

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A	-	-			x	x			x			x			x				
B	-	-			x	x			x			x			x				
C	1	0.1%			x	x			x			x			x				
D	7	0.9%							x						x				
E	17	2.1%									x				x				
F	24	2.9%				x			x			x			x				
G	25	3.1%					x		x							x			
H	28	3.4%				x			x			x			x				
I	45	5.5%			x	x			x				x		x				
J	45	5.5%			x		x		x						x			x	
K	91	11.1%					x		x							x			
L	160	19.6%		x	x	x			x			x			x				
M	175	21.4%					x		x							x			
N	200	24.4%		x	x	x			x			x			x				
	818	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.

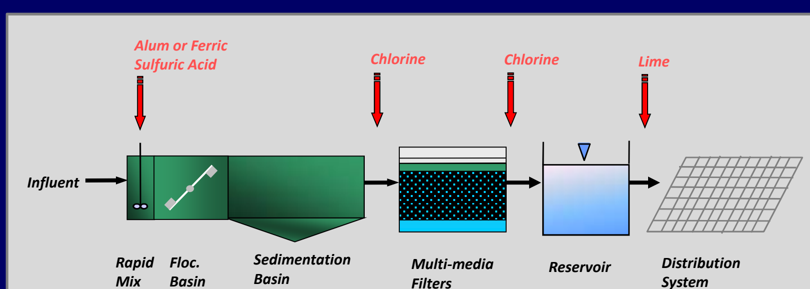
A, B, C, D, F, H, L, N: Conventional + Chlorine + pH adjustment (1, 7, 24, 28, 160, 200 mgd)
G, K, M: Direct Filtration + Chloramines (25, 91, 175 mgd)

5

UW-1: 100 mgd Conventional + Chlorine + pH adjustment
UW-2: 100 mgd Direct Filtration + Chloramines

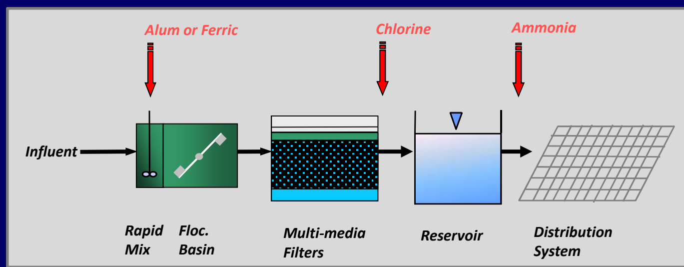
5 Select flows representative of selected treatment trains.

UW-1



- Size- 100 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- chlorine
- Secondary Disinfection- chlorine
- pH adjustment

UW-2



- Size- 100 mgd
- Particulate Removal- direct filtration (multi-media)
- Primary Disinfection- chlorine
- Secondary Disinfection- chloramines

CAA

				Particulate Removal								Disinfection						DBP Control	
	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A	-	-	*		x	x			x			x							
B	2.2	0.1%	*			x				x					x				
C	3	0.1%	*			x			x							x		x	
D	3.1	0.1%	*		x	x			x						x				
E	4	0.2%	100*			x			x						x				
F	5	0.2%	*			x			x								x	x	
G	10	0.5%	100*			x			x						x				
H	12	0.5%	*		x	x			x						x	x			
I	14	0.6%	100*						x			x			x				
J	30	1.4%	80-100*			x			x						x			x	
K	43	2.0%	80-100*		x	x			x			x			x	x		x	
L	65	3.0%	100*			x			x							x			
M	80	3.6%	0-100		x	x			x			x			x	x			
N	100	4.5%	0-100		x	x			x				x		x	x			
O	160	7.3%	100	x	x	x			x				x			x			
P	520	23.6%	45-86	x	x	x			x			x	x			x			
Q	520	23.6%	39-75	x	x	x			x			x	x			x			
R	630	28.6%	32-55	x	x	x	x		x			x	x			x			
	2201	Total Regional Treatment Capacity																	

*Temporary Approximate Value

1 Treat >70% Delta water.

2 >10% Regional Contribution or >20 mgd Capacity.

3 Treatment process used at least twice in the region.

4 Consolidate treatment trains.

5 Select flows representative of selected treatment trains.

CAA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A	-	-	*		x	x			x			x							
B	2.2	0.1%	*			x				x					x				
C	3	0.1%	*			x			x							x		x	
D	3.1	0.1%	*		x	x			x						x				
E	4	0.2%	100*			x			x						x				
F	5	0.2%	*			x			x								x	x	
G	10	0.5%	100*			x			x						x				
H	12	0.5%	*		x	x			x						x	x			
I	14	0.6%	100*						x			x			x				
J	30	1.4%	80-100*			x			x						x			x	
K	43	2.0%	80-100*		x	x			x			x			x	x		x	
L	65	3.0%	100*			x			x							x			
M	80	3.6%	0-100		x	x			x			x			x	x			
N	100	4.5%	0-100		x	x			x				x		x	x			
O	160	7.3%	100	x	x	x			x				x			x			
P	520	23.6%	45-86	x	x	x			x			x	x			x			
Q	520	23.6%	39-75	x	x	x			x			x	x			x			
R	630	28.6%	32-55	x	x	x	x		x			x	x			x			
	2201	Total Regional Treatment Capacity																	

*Temporary Approximate Value

1 Treat >70% Delta water.

2 >10% Regional Contribution or >20 mgd Capacity.

3 Treatment process used at least twice in the region.

4 Consolidate treatment trains.

5 Select flows representative of selected treatment trains.

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California Urban Water Agencies

CAA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal: Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Disinfection: Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	DBP Control: GAC	PAC
A	-	-	*		x	x			x			x							
B	2.2	0.1%	*			x				x					x				
C	3	0.1%	*			x			x							x		x	
D	3.1	0.1%	*		x	x			x						x				
E	4	0.2%	100*			x			x						x				
F	5	0.2%	*			x			x								x	x	
G	10	0.5%	100*			x			x						x				
H	12	0.5%	*		x	x			x						x	x			
I	14	0.6%	100*						x			x			x				
J	30	1.4%	80-100*			x			x						x			x	
K	43	2.0%	80-100*		x	x			x			x			x	x		x	
L	65	3.0%	100*			x			x							x			
M	80	3.6%	0-100		x	x			x			x			x	x			
N	100	4.5%	0-100		x	x			x				x		x	x			
O	160	7.3%	100	x	x	x			x				x			x			
P	520	23.6%	45-86	x	x	x			x			x	x			x			
Q	520	23.6%	39-75	x	x	x			x			x	x			x			
R	630	28.6%	32-55	x		x			x			x	x			x			
	2201	Total Regional Treatment Capacity																	

*Temporary Approximate Value

1 Treat >70% Delta water.

2 >10% Regional Contribution or >20 mgd Capacity.

3 Treatment process used at least twice in the region.

4 Consolidate treatment trains.

5 Select flows representative of selected treatment trains.

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California Urban Water Agencies

CAA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal								Disinfection						DBP Control	
				Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
K	43	2.0%	80-100*		x	x			x			x			x	x		x	
L	65	3.0%	100*			x			x							x			
M	80	3.6%	0-100		x	x			x			x			x	x			
	2201	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

K, L, M → 4 → Conventional + chloramines (43, 65, 80 mgd)

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MALCOLM PIRNIE

CAA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal								Disinfection						DBP Control	
				Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
N	100	4.5%	0-100		x	x			x				x		x	x			
O	160	7.3%	100	x	x	x			x				x			x			
P	520	23.6%	45-86	x	x	x			x			x	x			x			
Q	520	23.6%	39-75	x	x	x			x			x	x			x			
	2201	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

N, O, P, Q → 4 → Conventional + ozone + chloramines + pH adjustment (100, 160, 520, 520 mgd)

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MALCOLM PIRNIE

CAA

				Particulate Removal								Disinfection						DBP Control	
	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A	-	-	*		x	x			x			x							
B	2.2	0.1%	*			x				x					x				
C	3	0.1%	*			x			x							x		x	
D	3.1	0.1%	*		x	x			x						x				
E	4	0.2%	100*			x			x						x				
F	5	0.2%	*			x			x								x	x	
G	10	0.5%	100*			x			x						x				
H	12	0.5%	*		x	x			x						x	x			
I	14	0.6%	100*						x			x			x				
J	30	1.4%	80-100*			x			x						x			x	
K	43	2.0%	80-100*		x	x			x			x			x	x		x	
L	65	3.0%	100*			x			x							x			
M	80	3.6%	0-100		x	x			x			x			x	x			
N	100	4.5%	0-100		x	x			x				x		x	x			
O	160	7.3%	100	x	x	x			x				x			x			
P	520	23.6%	45-86	x	x	x			x			x	x			x			
Q	520	23.6%	39-75	x	x	x			x			x	x			x			
R	630	28.6%	32-55	x	x	x			x			x	x			x			
	2201	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

K, L, M
N, O, P, Q

4

K, L, M: Conventional + chloramines (43, 65, 80,mgd)
N, O, P, Q: Conventional + ozone + chloramines +pH adjustment (100, 160, 520, 520 mgd)

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MALCOLM PIRNIE

CAA

				Particulate Removal								Disinfection						DBP Control	
	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
		-	*		x	x			x			x							
		0.1%	*			x				x					x				
		0.1%	*			x			x							x		x	
		0.1%	*		x	x			x						x				
		0.2%	100*			x			x						x				
		0.2%	*			x			x								x	x	
		0.5%	100*			x			x						x				
		0.5%	*		x	x			x						x	x			
		0.6%	100*						x			x			x				
		1.4%	80-100*			x			x						x			x	
K	43	2.0%	80-100*		x	x			x			x			x	x		x	
L	65	3.0%	100*			x			x							x			
M	80	3.6%	0-100		x	x			x			x			x	x			
...	....	4.5%	0-100		x	x			x				x		x	x			
		7.3%	100	x	x	x			x				x			x			
		23.6%	45-86	x	x	x			x			x	x			x			
		23.6%	39-75	x	x	x			x			x	x			x			
		28.6%	32-55	x	x	x			x			x	x			x			
	2201	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

K, L, M: Conventional + chloramines (43, 65, 80 mgd)

5

CA-1: 40 mgd Conventional + chloramines

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California Urban Water Agencies

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MALCOLM PIRNIE

CAA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal								Disinfection						DBP Control	
				Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
		-	*		x	x			x			x							
		0.1%	*			x				x					x				
		0.1%	*			x			x							x		x	
		0.1%	*		x	x			x						x				
		0.2%	100*			x			x						x				
		0.2%	*			x			x								x	x	
		0.5%	100*			x			x						x				
		0.5%	*		x	x			x						x	x			
		0.6%	100*						x			x			x				
		1.4%	80-100*			x			x						x			x	
		2.0%	80-100*		x	x			x			x			x	x		x	
		3.0%	100*			x			x							x			
		3.6%	0-100		x	x			x			x			x	x			
N	100	4.5%	0-100		x	x			x				x		x	x			
O	160	7.3%	100	x	x	x			x				x			x			
P	520	23.6%	45-86	x	x	x			x			x	x			x			
Q	520	23.6%	39-75	x	x	x			x			x	x			x			
		28.6%	32-55	x	x	x			x			x	x			x			
	2201	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of selected treatment trains.

N, O, P, Q: Conventional + ozone + chloramines+ pH adjustment (100, 160, 520, 520 mgd)

5

CA-2: 500 mgd Conventional + ozone + chloramines + pH adjustment

California Urban Water Agencies

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MALCOLM PIRNIE

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CAA

	Size (MGD)	% Regional Treatment Capacity	% Delta Water	Particulate Removal								Disinfection						DBP Control	
				Pre-pH Adjustment	Rapid Mix	Conventional	Direct Filtration	Filtration: Slow Sand	Filtration: Rapid Sand, Multi-media	Filtration: Pressure Sand	Membranes	Pre - Chlorination	Pre-Ozonation	Post-Ozonation	Post-chlorination	Chloramines	MIOX	GAC	PAC
A	-	-	*		x	x			x			x							
B	2.2	0.1%	*			x				x					x				
C	3	0.1%	*			x			x							x		x	
D	3.1	0.1%	*		x	x			x						x				
E	4	0.2%	100*			x			x						x				
F	5	0.2%	*			x			x								x	x	
G	10	0.5%	100*			x			x						x				
H	12	0.5%	*		x	x			x						x	x			
I	14	0.6%	100*						x			x			x				
J	30	1.4%	80-100*			x			x						x			x	
K	43	2.0%	80-100*		x	x			x			x			x	x		x	
L	65	3.0%	100*			x			x							x			
M	80	3.6%	0-100		x	x			x			x			x	x			
N	100	4.5%	0-100		x	x			x				x		x	x			
O	160	7.3%	100	x	x	x			x				x			x			
P	520	23.6%	45-86	x	x	x			x			x	x			x			
Q	520	23.6%	39-75	x	x	x			x			x	x			x			
R	630	28.6%	32-55	x	x	x			x			x	x			x			
	2201	Total Regional Treatment Capacity																	

1 Treat >70% Delta water.
2 >10% Regional Contribution or >20 mgd Capacity.
3 Treatment process used at least twice in the region.
4 Consolidate treatment trains.
5 Select flows representative of select

K, M: Conventional + chloramines (43, 80, mgd)

N, O, P, Q: Conventional + ozone + chloramines (100, 160, 520, 520 mgd)

5

CA-1: 40 mgd Conventional + chloramines

CA-2: 500 mgd Conventional + ozone + chloramines + pH adjustment

California Urban Water Agencies

PIRNIE

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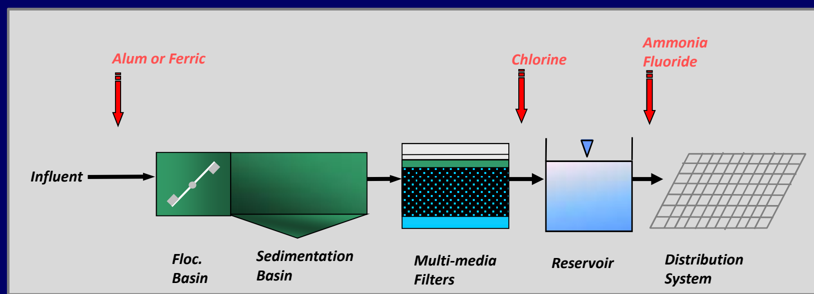
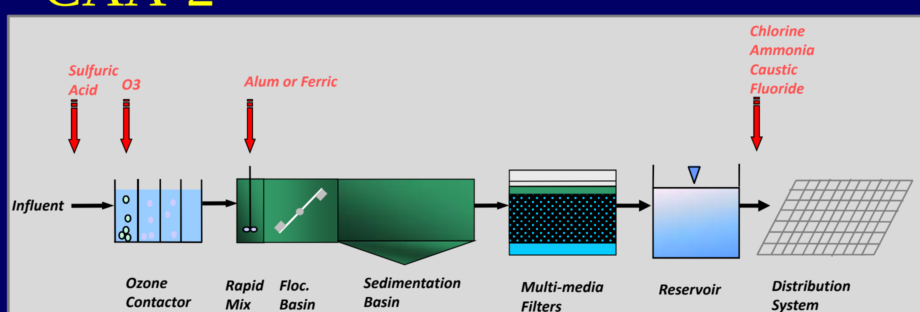
CAA-1



- Size- 40 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- chlorine
- Secondary Disinfection- chloramines

CAA-2



- Size- 500 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- ozone
- Secondary Disinfection- chloramines
- pH adjustment
- Fluoridation

VWTP Summary

Region	Identifier	Size (MGD)	Particulate Removal: Pre-pH Adjustment	Particulate Removal: Rapid Mix	Particulate Removal: Conventional	Particulate Removal: Direct Filtration	Particulate Removal: Filtration: Slow Sand	Particulate Removal: Filtration: Rapid Sand, Multi-media	Particulate Removal: Filtration: Pressure Sand	Particulate Removal: Membranes	Disinfection: Pre - Chlorination	Disinfection: Pre-Ozonation	Disinfection: Post-Ozonation	Disinfection: Post-chlorination	Disinfection: Chloramines	Disinfection: MIOX	DBP Control: GAC	DBP Control: PAC
Upper Watersheds	UW-1	100	x	x	x			x			x			x				
	UW-2	100				x		x							x			
NBA	NBA-1	20			x			x				x	x	x				
	NBA-2	10			x			x						x				
Central Delta	CD-1	40	x	x	x			x				x		x	x			
CAA	CAA-1	40			x			x			x				x			
	CAA-2	500	x	x	x			x				x			x			
CAA- West Branch	CAAW-1	800	x	x	x			x				x			x			

California Urban Water Agencies

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MALCOLM PIRNIE

VWTP Summary

UW-1
- Size- 100 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- chlorine
- Secondary Disinfection- chlorine
- pH adjustment

UW-2
- Size- 100 mgd
- Particulate Removal- direct filtration (multi-media)
- Primary Disinfection- chlorine
- Secondary Disinfection- chloramines

NBA-1
- Size- 20 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- ozone
- Secondary Disinfection- chlorine

NBA-1
- Size- 10 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- chlorine
- Secondary Disinfection- chlorine

CD-1
- Size- 40 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- ozone + chlorine
- Secondary Disinfection- chloramines
- pH adjustment

CAA-1
- Size- 40 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- chlorine
- Secondary Disinfection- chloramines

CAA-2
- Size- 500 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- ozone
- Secondary Disinfection- chloramines
- pH adjustment

CAAW-1
- Size- 800 mgd
- Particulate Removal- conventional + multi-media filtration
- Primary Disinfection- ozone
- Secondary Disinfection- chloramines
- pH adjustment

California Urban Water Agencies

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MALCOLM PIRNIE

Regional Treatment Summary

Region	Total Regional Treatment Capacity (MGD)	Identifier	Size (MGD)	Predominant Process Trains/ VWTPs
Upper Watersheds	818	UW-1	100	Conventional + chlorine + pH adjustment
		UW-2	100	Direct Filtration + chlorine + chloramines
NBA	122	NBA-1	20	Conventional + ozone + chlorine
		NBA-2	10	Conventional + chlorine
Central Delta	284	CD-1	40	Conventional + ozone + chlorine + chloramines + pH adjustment
CAA	2201	CAA-1	40	Conventional + chlorine + chloramines
		CAA-2	500	Conventional + ozone + chloramines + pH adjustment
CAA- West Branch	836	CAAW-1	800	Conventional + ozone + chloramines + pH adjustment

California Urban Water Agencies

MALCOLM PIRNIE

California Urban Water Agencies Drinking Water Treatment Evaluation

California Urban Water Agencies

END APPENDIX D

Development of Virtual Water Treatment Plants (VWTPs)

MALCOLM PIRNIE

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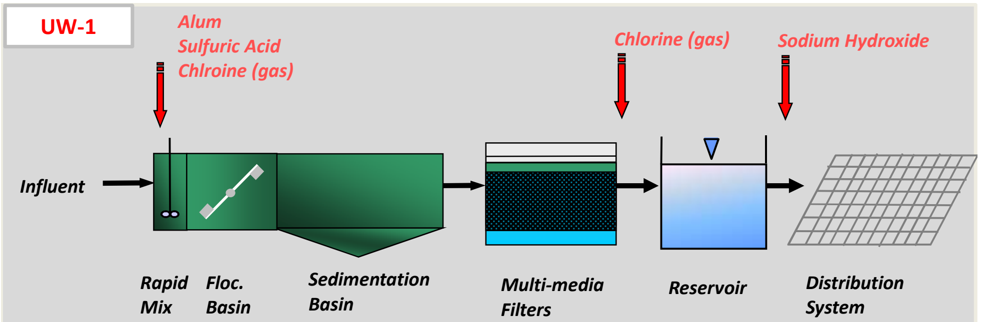
Appendix E

Baseline Virtual Water Treatment Plants in EPAWTPM

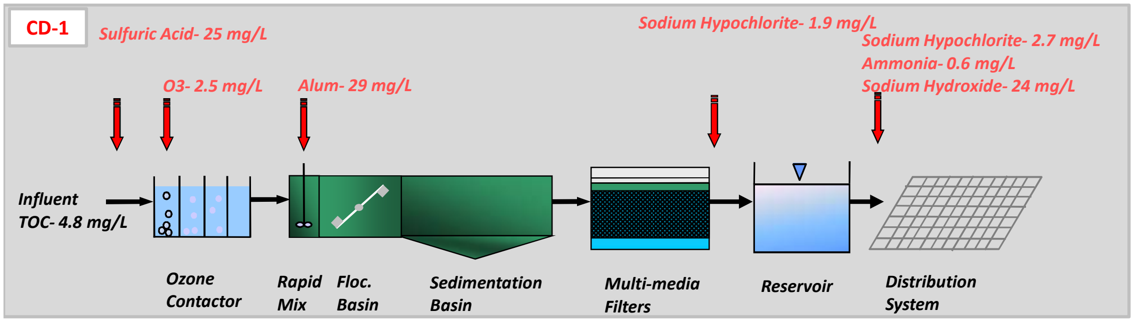


WTPM v.2.0 Inputs

Baseline Inputs

Input Parameter	Value	Units	Basis	Source
Influent			(median to 90th percentile)	
pH	7.7	pH	7.1 to 7.7	WDL
Influent Temperature	20	°C	20	default
Minimum Temperature	5	°C	5	default
TOC	3	mg/L	1.8 to 3.0	TM1/WDL
UV254	0.091	1/cm	0.046 to 0.091	WDL
Bromide	0.02	mg/L	0.01 to 0.02	TM1/WDL
Alkalinity	78	mg/L as $CaCO_3$	61 to 78	WDL
Calcium Hardness	35	mg/L as $CaCO_3$	30 to 35	WDL
Total Hardness	68	mg/L as $CaCO_3$	55 to 68	WDL
Ammonia	0.63	mg/L as N	0.3 to 0.63	WDL
Turbidity	31	NTU	11 to 31	WDL
Crypto Removal + Inactivation	3	logs		default
Multiplier for Crypto CT by ClO_2	7.5			default
Peak Flow	100	mgd	VWTP Development	Task 2
Alum				
Dose	35	mg/L as $Al_2(SO_4)_3{\cdot}14H_2O$		
Sulfuric Acid				
Dose	5.8	mg/L as H_2SO_4		
Chlorine (Gas)				
Dose	4.9	mg/L as Cl_2		
Rapid Mix				
Volume	0.035	MG	30-sec detention time	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.1	ratio		
Flocculation				
Volume	2.08	MG	30-min detention time	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.1	ratio		
Sedimentation				
Volume	5.98	MG	1500 gpd/ft^2 overflow rate, 12 ft depth	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.5	ratio		
Filtration				
Liquid Volume	1.39	MG	6 gpm/ft2, 16 ft total depth, media depth 2-3 ft	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.7	ratio		
Chlorinated Backwash Water	FALSE	true/false		
Filter Media (Antracite/Sand or GAC)	S	S or G		
Crypto Log Removal by Filters	2	logs		
Chlorine (Gas)				
Dose	0.8	mg/L as Cl_2		
Reservoir				
Volume of Basin	15	MG	15% of Design Flow rate	Kawamura 2000
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.5	ratio		
Chlorine (Gas)				
Dose	2	mg/L as Cl_2		
Sodium Hydroxide				
Dose	20	mg/L as NaOH		
WTP Effluent				
-				
Additional Point				
Residence Time for Avg. Flow	3	days		

WDL = Water Data Library

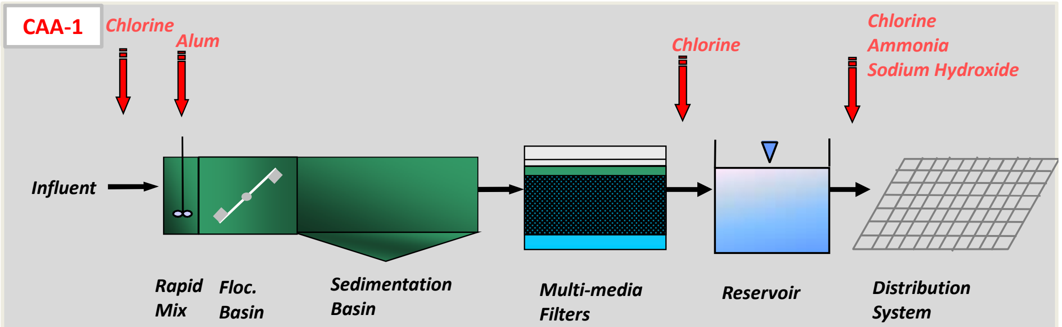


WTPM v.2.0 Inputs

Baseline Inputs

Input Parameter	Value	Units	Basis	Source
Influent			(median to 90th percentile)	
pH	7.9	pH	7.4 to 7.9	WDL
Influent Temperature	20	°C	20	
Minimum Temperature	5	°C	5	
TOC	4.8	mg/L	3.2 to 4.8	TM1/WDL
UV254	0.193	1/cm	0.108 to 0.1934	WDL
Bromide	0.48	mg/L	0.18 to 0.48	TM1/WDL
Alkalinity	82	mg/L as $CaCO_3$	68 to 82	WDL
Calcium Hardness	55	mg/L as $CaCO_3$	43 to 55	WDL
Total Hardness	113	mg/L as $CaCO_3$	86 to 113	WDL
Ammonia	0.11	mg/L as N	0.05 to 0.11	WDL
Turbidity	23	NTU	11 to 23	WDL
Crypto Removal + Inactivation	3	logs	default	
Multiplier for Crypto CT by ClO_2	7.5		default	
Peak Flow	40	mgd	VWTP Development	Task 2
Sulfuric Acid				
Dose	25	mg/L as H_2SO_4	Bromate control	
Ozone				
Dose	2.5	mg/L as O_3		
Ozone Chamber				
Volume	0.333	MG	12 minute detention time	LT2ESWTR T&C Doc
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.6	ratio		
Alum				
Dose	29	mg/L as $Al_2(SO_4)_3{\cdot}14H_2O$	Step 1 Enhanced Coag. Rmvl Rqmts	
Rapid Mix				
Volume	0.014	MG	30-sec detention time	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.1	ratio		
Flocculation				
Volume	0.833	MG	30-min detention time	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.1	ratio		
Sedimentation				
Volume	2	MG	1500 gpd/ft^2 overflow rate, 12 ft depth	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.5	ratio		
Filtration				
Liquid Volume	0.554	MG	6 gpm/ft2, 16 ft total depth, media depth 2-3 ft	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.7	ratio		
Chlorinated Backwash Water		true/false		
Filter Media (Antracite/Sand or GAC)	S	S or G		
Crypto Log Removal by Filters	2	logs		
Sodium Hypochlorite				
Dose	1.9	mg/L as Cl_2	1.5 CT Ratio at 5 degrees Celcius	
Reservoir				
Volume of Basin	6	MG	15% of Design Flow rate	Kawamura 2000
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.5	ratio		
Sodium Hypochlorite				
Dose	2.7	mg/L as Cl_2	3 mg/L finished water chloramine residual	
Ammonia				
Dose	0.6	mg/L as N	3 mg/L finished water chloramine residual	
Sodium Hydroxide				
Dose	24	mg/L as NaOH	Finished water pH 8.1	
WTP Effluent				
-				
Additional Point				
Residence Time for Avg. Flow	3	days		

WDL = Water Data Library

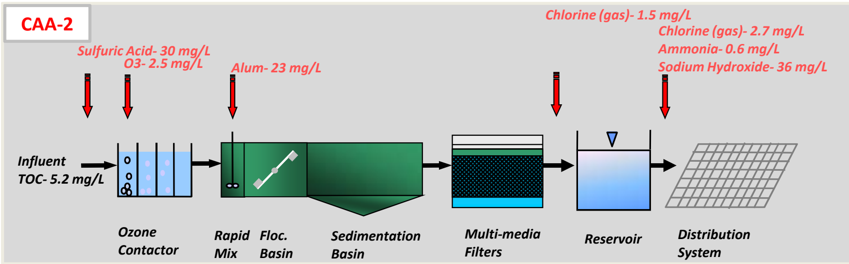


WTPM v.2.0 Inputs

Baseline Inputs

Input Parameter	Value	Units	Basis	Source
Influent			(median to 90th percentile)	
pH	8	pH	7.6 to 8.0	WDL
Influent Temperature	20	°C		
Minimum Temperature	5	°C		
TOC	5.2	mg/L	3.2 to 5.2	TM1/WDL
UV254	0.1722	1/cm	0.103 to 0.1722	WDL
Bromide	0.38	mg/L	0.19 to 0.38	TM1/WDL
Alkalinity	84	mg/L as $CaCO_3$	75 to 84	WDL
Calcium Hardness	60	mg/L as $CaCO_3$	48 to 60	WDL
Total Hardness	118	mg/L as $CaCO_3$	99 to 118	WDL
Ammonia	0.06	mg/L as N	0.02 to 0.06	WDL
Turbidity	16	NTU	6 to 16	WDL
Crypto Removal + Inactivation	3	logs		
Multiplier for Crypto CT by ClO_2	7.8			
Peak Flow	40	mgd	VWTP Development	Task 2
Chlorine (gas)				
Dose	0.5	mg/L as Cl_2		
Alum				
Dose	37	mg/L as $Al_2(SO_4)_3 \cdot 14H_2O$		
Rapid Mix				
Volume	0.014	MG	30-sec detention time	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.1	ratio		
Flocculation				
Volume	0.83	MG	30-min detention time	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.1	ratio		
Sedimentation				
Volume	2.39	MG	1500 gpd/ft^2 overflow rate, 12 ft depth	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.5	ratio		
Filtration				
Liquid Volume	0.55	MG	6 gpm/ft2, 16 ft total depth, media depth 2-3 ft	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.7	ratio		
Chlorinated Backwash Water		true/false		
Filter Media (Antracite/Sand or GAC)	S	S or G		
Crypto Log Removal by Filters		logs		
Chlorine (Gas)				
Dose	1	mg/L as Cl_2		
Reservoir				
Volume of Basin	6	MG	15% of Design Flow rate	Kawamura 2000
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.5	ratio		
Chlorine (Gas)				
Dose	2.7	mg/L as Cl_2		
Ammonia				
Dose	0.6	mg/L as N		
Sodium Hydroxide				
Dose	17	mg/l as NaOH		
WTP Effluent				
-				
Additional Point				
Residence Time for Avg. Flow	3	days		

WDL = Water Data Library

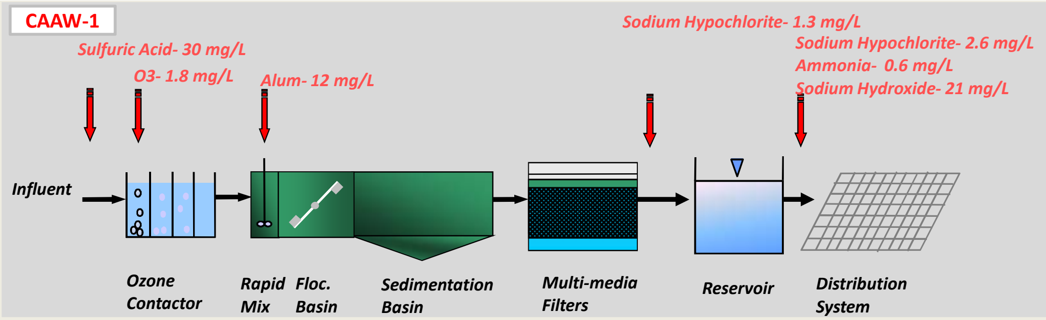


WTPM v.2.0 Inputs

Baseline Inputs

Input Parameter	Value	Units	Basis	Source
Influent			(median to 90th percentile)	
pH	8	pH	7.6 to 8.0	WDL
Influent Temperature	20	°C		
Minimum Temperature	5	°C		
TOC	5.2	mg/L	3.2 to 5.2	TM1/WDL
UV254	0.1722	1/cm	0.103 to 0.1722	WDL
Bromide	0.38	mg/L	0.19 to 0.38	TM1/WDL
Alkalinity	84	mg/L as $CaCO_3$	75 to 84	WDL
Calcium Hardness	60	mg/L as $CaCO_3$	48 to 60	WDL
Total Hardness	118	mg/L as $CaCO_3$	99 to 118	WDL
Ammonia	0.06	mg/L as N	0.02 to 0.06	WDL
Turbidity	16	NTU	6 to 16	WDL
Crypto Removal + Inactivation	3	logs		
Multiplier for Crypto CT by ClO_2	7.5			
Peak Flow	500	mgd	VWTP Development	Task 2
Sulfuric Acid				
Dose	30	mg/L as H_2SO_4		
Ozone				
Dose	2.5	mg/L as O_3		
Ozone Chamber				
Volume	4.167	MG	12 minute detention time	LT2ESWTR T&C Doc
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.6	ratio		
Alum				
Dose	23	mg/L as $Al_2(SO_4)_3{\cdot}14H_2O$		
Rapid Mix				
Volume	0.174	MG	30-sec detention time	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.1	ratio		
Flocculation				
Volume	10.42	MG	30-min detention time	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.1	ratio		
Sedimentation				
Volume	29.92	MG	1500 gpd/ft^2 overflow rate, 12 ft depth	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.5	ratio		
Chlorine (Gas)				
Dose	1.5	mg/L as Cl_2		
Filtration				
Liquid Volume	6.93	MG	6 gpm/ft2, 16 ft total depth, media depth 2-3 ft	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.7	ratio		
Chlorinated Backwash Water		true/false		
Filter Media (Antracite/Sand or GAC)	S	S or G		
Crypto Log Removal by Filters		logs		
Chlorine (Gas)				
Dose	2.7	mg/L as Cl_2		
Ammonia				
Dose	0.6	mg/L as N		
Reservoir				
Volume of Basin	75	MG	15% of Design Flow rate	Kawamura 2000
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.5	ratio		
Sodium Hydroxide				
Dose	36	mg/L as NaOH		
WTP Effluent				
-				
Additional Point				
Residence Time for Avg. Flow	3	days		

WDL = Water Data Library



WTPM v.2.0 Inputs

Baseline Inputs

Input Parameter	Value	Units	Basis	Source
Influent			(median to 90th percentile)	
pH	8.8	pH	8 to 8.8	WDL
Influent Temperature	20	°C		
Minimum Temperature	5	°C		
TOC	3.8	mg/L	2.9 to 3.8	TM1/WDL
UV254	0.1	1/cm	0.077 to 0.10	WDL
Bromide	0.26	mg/L	0.19 to 0.26	TM1/WDL
Alkalinity	106	mg/L as $CaCO_3$	88 to 106	WDL
Calcium Hardness	94	mg/L as $CaCO_3$	65 to 94	WDL
Total Hardness	158	mg/L as $CaCO_3$	120 to 158	WDL
Ammonia	0.041	mg/L as N	0.02 to 0.041	WDL
Turbidity	3	NTU	2 to 3.0	WDL
Crypto Removal + Inactivation	3	logs		
Multiplier for Crypto CT by ClO_2	7.5			
Peak Flow	800	mgd	VWTP Development	Task 2
Sulfuric Acid				
Dose	30	mg/L as H_2SO_4		
Ozone				
Dose	1.8	mg/L as O_3		
Ozone Chamber				
Volume	6.667	MG	12 minute detention time	LT2ESWTR T&C Doc
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.6	ratio		
Alum				
Dose	12	mg/L as $Al_2(SO_4)_3{\cdot}14H_2O$		
Rapid Mix				
Volume	0.278	MG	30-sec detention time	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.1	ratio		
Flocculation				
Volume	17	MG	30-min detention time	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.1	ratio		
Sedimentation				
Volume	48	MG	1500 gpd/ft^2 overflow rate, 12 ft depth	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.5	ratio		
Filtration				
Liquid Volume	11.082	MG	6 gpm/ft2, 16 ft total depth, media depth 2-3 ft	
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.7	ratio		
Chlorinated Backwash Water	FALSE	true/false		
Filter Media (Antracite/Sand or GAC)	S	S or G		
Crypto Log Removal by Filters	2	logs		
Sodium Hypochlorite				
Dose	1.3	mg/L as Cl_2		
Reservoir				
Volume of Basin	120	MG	15% of Design Flow rate	Kawamura 2000
Ratio of T50/Detention Time	1	ratio		
Ratio of T10/Detention Time	0.5	ratio		
Sodium Hypochlorite				
Dose	2.6	mg/L as Cl_2		
Ammonia				
Dose	0.6	mg/L as N		
Sodium Hydroxide				
Dose	21	mg/L as NaOH		
WTP Effluent				
-				
Additional Point				
Residence Time for Avg. Flow	3	days		

WDL = Water Data Library

References

Water Data Library (WDL)- http://www.water.ca.gov/waterdatalibrary/waterquality/station_county/index.cfm
Drinking Water Treatment Evaluation Technical Memorandum 1- Definition of Study Boundaries
Kawamura, S. Integrated Design and Operation of Water Treatment Facilities. 2000

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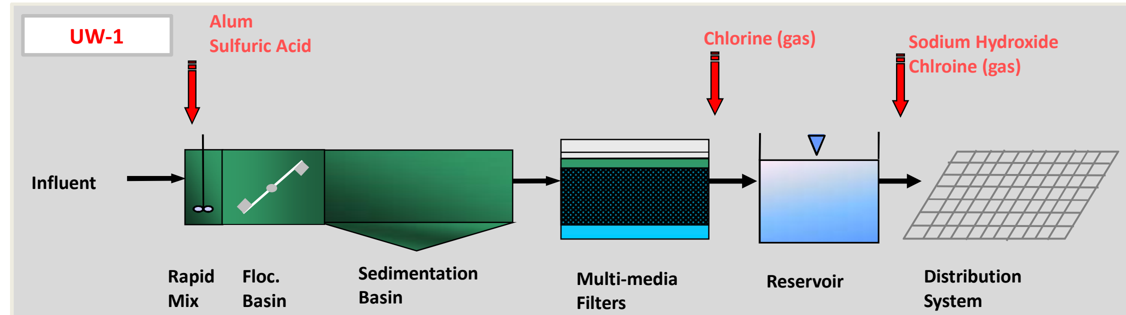
Appendix F

EPAWTPM Inputs for VWTP Treatment Trigger Analysis

UW-1 Current Regulatory Scenario

Input Parameter	Value	Units
	90th Percentil e Water Quality	
pH	7.7	pH
Influent Temperature	**16**	°C
Minimum Temperature	5	°C
TOC		mg/L
UV254	=0.0296*TOC+0.0033	1/cm
Bromide		mg/L
Alkalinity	78	mg/L as $CaCO_3$
Calcium Hardness	35	mg/L as $CaCO_3$
Total Hardness	68	mg/L as $CaCO_3$
Ammonia	0.02	mg/L as N
Turbidity	31	NTU



NOTES:
Treatment targets equal 80% of current MCL values.
(white) = 90th percentile water quality
(red) = 2 or more treatment targets exceeded*
(yellow) = 1 treatment target exceeded *
(green) = no treatment targets exceeded

Bromide 0.2

Parameter	TOC 2	TOC 2.5	TOC 3	TOC 3.5	TOC 4	Units
Alum Dose	30	30	31	35	48	mg/L
Sulfuric Acid Dose	5.8	5.8	5.8	5.8	5.8	mg/L
Primary Chlorine Dose	0.9	1	1.1	1.1	1.1	mg/L
Secondary Chlorine Dose	1.7	1.8	2.1	2.3	2.4	mg/L
Sodium Hydroxide Dose	20	20	21	23	28	mg/L
TOC Removal	25	25	25	27	35	%
3-day TTHM	65	78	92	103	106	ug/L
3-day HAA5	25	30	36	40	42	ug/L
3-day HAA9	55	64	74	80	83	ug/L
3-day Bromate	0	0	0	0	0	ug/L

Bromide 0.16

Parameter	TOC 2	TOC 2.5	TOC 3	TOC 3.5	TOC 4	Units
Alum Dose	30	30	31	35	48	mg/L
Sulfuric Acid Dose	5.8	5.8	5.8	5.8	5.8	mg/L
Primary Chlorine Dose	0.9	1	1.1	1.1	1.1	mg/L
Secondary Chlorine Dose	1.7	1.8	2.1	2.3	2.4	mg/L
Sodium Hydroxide Dose	20	20	21	23	28	mg/L
TOC Removal	25	25	25	27	35	%
3-day TTHM	62	75	89	99	102	ug/L
3-day HAA5	26	31	37	41	43	ug/L
3-day HAA9	54	63	73	79	81	ug/L
3-day Bromate	0	0	0	0	0	ug/L

Bromide 0.12

Parameter	TOC 2	TOC 2.5	TOC 3	TOC 3.5	TOC 4	Units
Alum Dose	30	30	31	35	48	mg/L
Sulfuric Acid Dose	5.8	5.8	5.8	5.8	5.8	mg/L
Primary Chlorine Dose	0.9	1	1.1	1.1	1.1	mg/L
Secondary Chlorine Dose	1.7	1.8	2.1	2.3	2.4	mg/L
Sodium Hydroxide Dose	20	20	21	23	28	mg/L
TOC Removal	25	25	25	27	35	%
3-day TTHM	60	72	85	95	98	ug/L
3-day HAA5	26	32	38	43	44	ug/L
3-day HAA9	53	61	70	76	78	ug/L
3-day Bromate	0	0	0	0	0	ug/L

Bromide 0.06

Parameter	TOC 2	TOC 2.5	TOC 3	TOC 3.5	TOC 4	Units
Alum Dose	30	30	31	35	48	mg/L
Sulfuric Acid Dose	5.8	5.8	5.8	5.8	5.8	mg/L
Primary Chlorine Dose	0.9	1	1.1	1.1	1.1	mg/L
Secondary Chlorine Dose	1.7	1.8	2.1	2.3	2.4	mg/L
Sodium Hydroxide Dose	20	20	21	23	28	mg/L
TOC Removal	25	25	25	27	35	%
3-day TTHM	54	65	77	86	88	ug/L
3-day HAA5	29	35	42	47	48	ug/L
3-day HAA9	47	55	63	68	70	ug/L
3-day Bromate	0	0	0	0	0	ug/L

Bromide 0.02

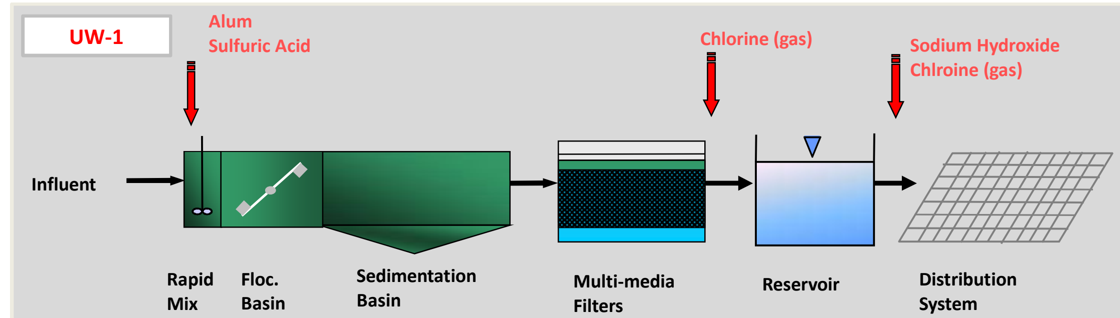
Parameter	TOC 2	TOC 2.5	TOC 3	TOC 3.5	TOC 4	Units
Alum Dose	30	30	31	35	47	mg/L
Sulfuric Acid Dose	5.8	5.8	5.8	5.8	5.8	mg/L
Primary Chlorine Dose	0.9	1	1.1	1.1	1.1	mg/L
Secondary Chlorine Dose	1.7	1.8	2.1	2.3	2.4	mg/L
Sodium Hydroxide Dose	20	20	21	23	28	mg/L
TOC Removal	25	25	25	27	35	%
3-day TTHM	46	56	66	74	76	ug/L
3-day HAA5	33	40	48	53	55	ug/L
3-day HAA9	41	47	55	59	61	ug/L
3-day Bromate	0	0	0	0	0	ug/L

TOC	2	2.5	3	3.5	4
UV254	0.063	0.077	0.092	0.107	0.122

TOC and UV254

UW-1 Plausible Regulatory Scenario

Input Parameter	Value	Units
	Water Quality	
pH	7.7	pH
Influent Temperature	**24**	°C
Minimum Temperature	5	°C
TOC		mg/L
UV254	=0.0296*TOC+0.0033	1/cm
Bromide		mg/L
Alkalinity	78	mg/L as $CaCO_3$
Calcium Hardness	35	mg/L as $CaCO_3$
Total Hardness	68	mg/L as $CaCO_3$
Ammonia	0.02	mg/L as N
Turbidity	31	NTU



NOTES:
HAA9 Plausible scenario is on LRAA basis (use avg temp = 16 C results from 'current' runs to determine exceed)
Treatment targets equal 80% of current MCL values.

- = 90th percentile water quality
- = 2 or more treatment targets exceeded*
- = 1 treatment target exceeded *
- = no treatment targets exceeded

Bromide

0.2

Parameter	TOC 2	Units	TOC 2.5	Units	TOC 3	Units	TOC 3.5	Units	TOC 4	Units
Alum Dose	29	mg/L	29	mg/L	30	mg/L	35	mg/L	40	mg/L
Sulfuric Acid Dose	5.8	mg/L	5.8	mg/L	5.8	mg/L	5.8	mg/L	5.8	mg/L
Primary Chlorine Dose	0.9	mg/L	1	mg/L	1.1	mg/L	1.1	mg/L	1.1	mg/L
Secondary Chlorine Dose	1.6	mg/L	1.8	mg/L	2.1	mg/L	2.3	mg/L	2.5	mg/L
Sodium Hydroxide Dose	19	mg/L	20	mg/L	20	mg/L	23	mg/L	25	mg/L
TOC Removal	25	%	25	%	25	%	28	%	31	%
3-day TTHM	78	ug/L	96	ug/L	112	ug/L	125	ug/L	134	ug/L
3-day HAA5	29	ug/L	35	ug/L	43	ug/L	47	ug/L	52	ug/L
3-day HAA9	55	ug/L	64	ug/L	74	ug/L	80	ug/L	83	ug/L
3-day Bromate	0	ug/L	0	ug/L	0	ug/L	0	ug/L	0	ug/L

0.16

Parameter	TOC 2	Units	TOC 2.5	Units	TOC 3	Units	TOC 3.5	Units	TOC 4	Units
Alum Dose	29	mg/L	29	mg/L	30	mg/L	35	mg/L	40	mg/L
Sulfuric Acid Dose	5.8	mg/L	5.8	mg/L	5.8	mg/L	5.8	mg/L	5.8	mg/L
Primary Chlorine Dose	0.9	mg/L	1	mg/L	1.1	mg/L	1.1	mg/L	1.1	mg/L
Secondary Chlorine Dose	1.6	mg/L	1.8	mg/L	2.1	mg/L	2.3	mg/L	2.5	mg/L
Sodium Hydroxide Dose	19	mg/L	20	mg/L	20	mg/L	23	mg/L	25	mg/L
TOC Removal	25	%	25	%	25	%	28	%	31	%
3-day TTHM	75	ug/L	93	ug/L	108	ug/L	120	ug/L	130	ug/L
3-day HAA5	30	ug/L	36	ug/L	44	ug/L	49	ug/L	53	ug/L
3-day HAA9	54	ug/L	63	ug/L	73	ug/L	79	ug/L	81	ug/L
3-day Bromate	0	ug/L	0	ug/L	0	ug/L	0	ug/L	0	ug/L

0.12

Parameter	TOC 2	Units	TOC 2.5	Units	TOC 3	Units	TOC 3.5	Units	TOC 4	Units
Alum Dose	29	mg/L	29	mg/L	30	mg/L	35	mg/L	40	mg/L
Sulfuric Acid Dose	5.8	mg/L	5.8	mg/L	5.8	mg/L	5.8	mg/L	5.8	mg/L
Primary Chlorine Dose	0.9	mg/L	1	mg/L	1.1	mg/L	1.1	mg/L	1.1	mg/L
Secondary Chlorine Dose	1.6	mg/L	1.8	mg/L	2.1	mg/L	2.3	mg/L	2.5	mg/L
Sodium Hydroxide Dose	19	mg/L	20	mg/L	20	mg/L	23	mg/L	25	mg/L
TOC Removal	25	%	25	%	25	%	28	%	31	%
3-day TTHM	72	ug/L	89	ug/L	103	ug/L	115	ug/L	124	ug/L
3-day HAA5	31	ug/L	38	ug/L	46	ug/L	50	ug/L	55	ug/L
3-day HAA9	53	ug/L	61	ug/L	70	ug/L	76	ug/L	78	ug/L
3-day Bromate	0	ug/L	0	ug/L	0	ug/L	0	ug/L	0	ug/L

0.06

Parameter	TOC 2	Units	TOC 2.5	Units	TOC 3	Units	TOC 3.5	Units	TOC 4	Units
Alum Dose	29	mg/L	29	mg/L	30	mg/L	35	mg/L	40	mg/L
Sulfuric Acid Dose	5.8	mg/L	5.8	mg/L	5.8	mg/L	5.8	mg/L	5.8	mg/L
Primary Chlorine Dose	0.9	mg/L	1	mg/L	1.1	mg/L	1.1	mg/L	1.1	mg/L
Secondary Chlorine Dose	1.6	mg/L	1.8	mg/L	2.1	mg/L	2.3	mg/L	2.5	mg/L
Sodium Hydroxide Dose	19	mg/L	20	mg/L	20	mg/L	23	mg/L	25	mg/L
TOC Removal	25	%	25	%	25	%	28	%	31	%
3-day TTHM	65	ug/L	80	ug/L	93	ug/L	104	ug/L	112	ug/L
3-day HAA5	34	ug/L	41	ug/L	50	ug/L	55	ug/L	60	ug/L
3-day HAA9	47	ug/L	55	ug/L	63	ug/L	68	ug/L	70	ug/L
3-day Bromate	0	ug/L	0	ug/L	0	ug/L	0	ug/L	0	ug/L

0.02

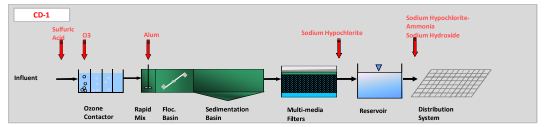
Parameter	TOC 2	Units	TOC 2.5	Units	TOC 3	Units	TOC 3.5	Units	TOC 4	Units
Alum Dose	29	mg/L	29	mg/L	30	mg/L	35	mg/L	40	mg/L
Sulfuric Acid Dose	5.8	mg/L	5.8	mg/L	5.8	mg/L	5.8	mg/L	5.8	mg/L
Primary Chlorine Dose	0.9	mg/L	1	mg/L	1.1	mg/L	1.1	mg/L	1.1	mg/L
Secondary Chlorine Dose	1.6	mg/L	1.8	mg/L	2.1	mg/L	2.3	mg/L	2.5	mg/L
Sodium Hydroxide Dose	19	mg/L	20	mg/L	20	mg/L	23	mg/L	25	mg/L
TOC Removal	25	%	25	%	25	%	28	%	31	%
3-day TTHM	55	ug/L	69	ug/L	80	ug/L	89	ug/L	96	ug/L
3-day HAA5	38	ug/L	47	ug/L	57	ug/L	63	ug/L	69	ug/L
3-day HAA9	41	ug/L	47	ug/L	55	ug/L	59	ug/L	61	ug/L
3-day Bromate	0	ug/L	0	ug/L	0	ug/L	0	ug/L	0	ug/L

TOC	2	2.5	3	3.5	4
UV254	0.063	0.077	0.092	0.107	0.122

TOC and UV254

CD-1 Current Regulatory Scenario

Input Parameter	Value	Units
90th Percentile Water Quality		
pH	7.9	pH
Influent Temperature	**18**	°C
Minimum Temperature	5	°C
TOC		mg/L
UV254	= 0.0383x - 0.0211	1/cm
Bromide		mg/L
Alkalinity	82	mg/L as $CaCO_3$
Calcium Hardness	55	mg/L as $CaCO_3$
Total Hardness	113	mg/L as $CaCO_3$
Ammonia	0.11	mg/L as N
Turbidity	23	NTU



NOTES:
Treatment targets equal 80% of current MCL values.
(white) = 90th percentile water quality
(red) = 2 or more treatment targets exceeded*
(yellow) = 1 treatment target exceeded *
(green) = no treatment targets exceeded

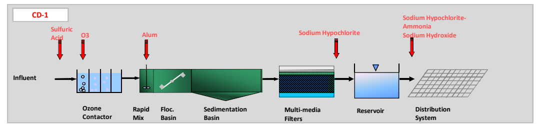
Bromide: 0.80, 0.75, 0.70, 0.65, 0.60, 0.55, 0.50, 0.45, 0.40, 0.35, 0.30, 0.25, 0.20

TOC	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
UV254	0.056	0.075	0.094	0.113	0.132	0.151	0.170	0.190	0.209	0.228	0.247	0.266	0.285

TOC and UV254

CD-1 Plausible Future Regulations

Input Parameter	Value	Units
90th Percentile Water Quality		
pH	[illegible]	pH
Influent Temperature	28	°C
Minimum Temperature	5	°C
TOC		mg/L
UV254	= 0.0363x - 0.0211	1/cm
Bromide		mg/L
Alkalinity	82	mg/L as $CaCO_3$
Calcium Hardness	55	mg/L as $CaCO_3$
Total Hardness	113	mg/L as $CaCO_3$
Ammonia	0.11	mg/L as N
Turbidity	[illegible]	NTU



NOTES:
HAA9 Plausible scenario is on UHA4 basis [illegible]
Treatment targets equal 80% of current MCL values.
= 90th percentile water quality
= 2 or more treatment targets exceeded*
= 1 treatment target exceeded *
= no treatment targets exceeded

Each table below gives one bromide level; the columns are TOC (mg/L) / UV254 values.

Bromide 0.80

Parameter	Units	2.0 / 0.056	2.5 / 0.075	3.0 / 0.094	3.5 / 0.113	4.0 / 0.132	4.5 / 0.151	5.0 / 0.170	5.5 / 0.190	6.0 / 0.209	6.5 / 0.228	7.0 / 0.247	7.5 / 0.266	8.0 / 0.285
Sulfuric Acid Dose	mg/L	28	28	28	28	28	28	28	28	28	28	28	28	28
Ozone Dose	mg/L	1	1.3	1.5	1.8	2	1.8	2.5	2.8	3	3.3	3.5	3.8	4
Alum Dose	mg/L	21	25	30	35	40	35	50	37	37	37	38	38	40
Chlorine Dose	mg/L	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2	2	2	2.1	2.1
Secondary Chlorine Dose	mg/L	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	27	29	30	32	34	32	38	33	33	33	33	33	34
TOC Removal	%	25	28	32	35	38	41	43	35	35	35	35	35	36
3-day TTHM	ug/L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3-day HAA5	ug/L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3-day HAA9	ug/L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3-day Bromate	ug/L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Bromide 0.75

Parameter	Units	2.0 / 0.056	2.5 / 0.075	3.0 / 0.094	3.5 / 0.113	4.0 / 0.132	4.5 / 0.151	5.0 / 0.170	5.5 / 0.190	6.0 / 0.209	6.5 / 0.228	7.0 / 0.247	7.5 / 0.266	8.0 / 0.285
Sulfuric Acid Dose	mg/L	28	28	28	28	28	28	28	28	28	28	28	28	28
Ozone Dose	mg/L	1	1.3	1.5	1.8	2	1.8	2.5	2.8	3	3.3	3.5	3.8	4
Alum Dose	mg/L	21	25	30	35	40	35	50	37	37	37	38	38	40
Chlorine Dose	mg/L	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2	2	2	2.1	2.1
Secondary Chlorine Dose	mg/L	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	27	29	30	32	34	32	38	33	33	33	33	33	34
TOC Removal	%	25	28	32	35	38	41	43	35	35	35	35	35	36
3-day TTHM	ug/L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3-day HAA5	ug/L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3-day HAA9	ug/L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3-day Bromate	ug/L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Bromide 0.70

Parameter	Units	2.0 / 0.056	2.5 / 0.075	3.0 / 0.094	3.5 / 0.113	4.0 / 0.132	4.5 / 0.151	5.0 / 0.170	5.5 / 0.190	6.0 / 0.209	6.5 / 0.228	7.0 / 0.247	7.5 / 0.266	8.0 / 0.285
Sulfuric Acid Dose	mg/L	28	28	28	28	28	28	28	28	28	28	28	28	28
Ozone Dose	mg/L	1	1.3	1.5	1.8	2	1.8	2.5	2.8	3	3.3	3.5	3.8	4
Alum Dose	mg/L	21	25	30	35	40	35	50	37	37	37	38	38	40
Chlorine Dose	mg/L	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2	2	2	2.1	2.1
Secondary Chlorine Dose	mg/L	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	27	29	30	32	34	32	38	33	33	33	33	33	34
TOC Removal	%	25	28	32	35	38	41	43	35	35	35	35	35	36
3-day TTHM	ug/L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3-day HAA5	ug/L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3-day HAA9	ug/L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3-day Bromate	ug/L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Bromide 0.65

Parameter	Units	2.0 / 0.056	2.5 / 0.075	3.0 / 0.094	3.5 / 0.113	4.0 / 0.132	4.5 / 0.151	5.0 / 0.170	5.5 / 0.190	6.0 / 0.209	6.5 / 0.228	7.0 / 0.247	7.5 / 0.266	8.0 / 0.285
Sulfuric Acid Dose	mg/L	28	28	28	28	28	28	28	28	28	28	28	28	28
Ozone Dose	mg/L	1	1.3	1.5	1.8	2	1.8	2.5	2.8	3	3.3	3.5	3.8	4
Alum Dose	mg/L	21	25	30	35	40	35	50	37	37	37	38	38	40
Chlorine Dose	mg/L	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2	2	2	2.1	2.1
Secondary Chlorine Dose	mg/L	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	27	29	30	32	34	32	38	33	33	33	33	33	34
TOC Removal	%	25	28	32	35	38	41	43	35	35	35	35	35	36
3-day TTHM	ug/L	37	43	48	53	56	60	64	78	85	90	94	101	104
3-day HAA5	ug/L	9	11	12	13	14	15	17	20	22	23	24	27	28
3-day HAA9	ug/L	15	18	21	22	24	25	27	32	34	37	38	41	43
3-day Bromate	ug/L	8	10	10	12	12	13	14	15	16	17	17	18	19

Bromide 0.60

Parameter	Units	2.0 / 0.056	2.5 / 0.075	3.0 / 0.094	3.5 / 0.113	4.0 / 0.132	4.5 / 0.151	5.0 / 0.170	5.5 / 0.190	6.0 / 0.209	6.5 / 0.228	7.0 / 0.247	7.5 / 0.266	8.0 / 0.285
Sulfuric Acid Dose	mg/L	28	28	28	28	28	28	28	28	28	28	28	28	28
Ozone Dose	mg/L	1	1.3	1.5	1.8	2	1.8	2.5	2.8	3	3.3	3.5	3.8	4
Alum Dose	mg/L	21	25	30	35	40	35	50	37	37	37	38	38	40
Chlorine Dose	mg/L	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2	2	2	2.1	2.1
Secondary Chlorine Dose	mg/L	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	27	29	30	32	34	32	38	33	33	33	33	33	34
TOC Removal	%	25	28	32	35	38	41	43	35	35	35	35	35	36
3-day TTHM	ug/L	36	42	48	52	56	59	63	77	84	89	93	100	104
3-day HAA5	ug/L	9	11	13	14	14	15	17	20	22	24	25	27	28
3-day HAA9	ug/L	15	18	21	23	24	25	28	32	34	37	39	42	43
3-day Bromate	ug/L	8	9	10	11	11	13	13	14	15	16	16	17	17

Bromide 0.55

Parameter	Units	2.0 / 0.056	2.5 / 0.075	3.0 / 0.094	3.5 / 0.113	4.0 / 0.132	4.5 / 0.151	5.0 / 0.170	5.5 / 0.190	6.0 / 0.209	6.5 / 0.228	7.0 / 0.247	7.5 / 0.266	8.0 / 0.285
Sulfuric Acid Dose	mg/L	28	28	28	28	28	28	28	28	28	28	28	28	28
Ozone Dose	mg/L	1	1.3	1.5	1.8	2	1.8	2.5	2.8	3	3.3	3.5	3.8	4
Alum Dose	mg/L	21	25	30	35	40	35	50	37	37	37	38	38	40
Chlorine Dose	mg/L	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2	2	2	2.1	2.1
Secondary Chlorine Dose	mg/L	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	27	29	30	32	34	32	38	33	33	33	33	33	34
TOC Removal	%	25	28	32	35	38	41	43	35	35	35	35	35	36
3-day TTHM	ug/L	36	42	47	51	55	58	62	76	83	88	92	99	102
3-day HAA5	ug/L	9	11	13	14	15	15	17	20	23	24	25	27	28
3-day HAA9	ug/L	15	19	22	23	25	26	28	33	35	38	39	42	44
3-day Bromate	ug/L	7	8	9	10	10	12	12	13	13	14	15	16	16

Bromide 0.50

Parameter	Units	2.0 / 0.056	2.5 / 0.075	3.0 / 0.094	3.5 / 0.113	4.0 / 0.132	4.5 / 0.151	5.0 / 0.170	5.5 / 0.190	6.0 / 0.209	6.5 / 0.228	7.0 / 0.247	7.5 / 0.266	8.0 / 0.285
Sulfuric Acid Dose	mg/L	28	28	28	28	28	28	28	28	28	28	28	28	28
Ozone Dose	mg/L	1	1.3	1.5	1.8	2	1.8	2.5	2.8	3	3.3	3.5	3.8	4
Alum Dose	mg/L	21	25	30	35	40	35	50	37	37	37	38	38	40
Chlorine Dose	mg/L	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2	2	2	2.1	2.1
Secondary Chlorine Dose	mg/L	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	27	29	30	32	34	32	38	33	33	33	33	33	34
TOC Removal	%	25	28	32	35	38	41	43	35	35	35	35	35	36
3-day TTHM	ug/L	35	41	47	51	54	57	61	75	81	87	91	97	101
3-day HAA5	ug/L	10	11	13	14	15	16	17	21	23	24	25	28	28
3-day HAA9	ug/L	16	19	22	24	25	26	29	33	35	38	40	43	45
3-day Bromate	ug/L	7	8	8	9	10	11	11	12	12	13	13	14	15

Bromide 0.45

Parameter	Units	2.0 / 0.056	2.5 / 0.075	3.0 / 0.094	3.5 / 0.113	4.0 / 0.132	4.5 / 0.151	5.0 / 0.170	5.5 / 0.190	6.0 / 0.209	6.5 / 0.228	7.0 / 0.247	7.5 / 0.266	8.0 / 0.285
Sulfuric Acid Dose	mg/L	28	28	28	28	28	28	28	28	28	28	28	28	28
Ozone Dose	mg/L	1	1.3	1.5	1.8	2	1.8	2.5	2.8	3	3.3	3.5	3.8	4
Alum Dose	mg/L	21	25	30	35	40	35	50	37	37	37	38	38	40
Chlorine Dose	mg/L	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2	2	2	2.1	2.1
Secondary Chlorine Dose	mg/L	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	27	29	30	32	34	32	38	33	33	33	33	33	34
TOC Removal	%	25	28	32	35	38	41	43	35	35	35	35	35	36
3-day TTHM	ug/L	35	41	46	50	54	56	60	74	80	85	90	96	99
3-day HAA5	ug/L	10	11	13	14	15	16	17	21	23	24	26	28	29
3-day HAA9	ug/L	16	19	22	24	25	27	29	34	36	39	41	44	45
3-day Bromate	ug/L	6	7	7	8	9	10	9	11	11	12	11	13	13

Bromide 0.40

Parameter	Units	2.0 / 0.056	2.5 / 0.075	3.0 / 0.094	3.5 / 0.113	4.0 / 0.132	4.5 / 0.151	5.0 / 0.170	5.5 / 0.190	6.0 / 0.209	6.5 / 0.228	7.0 / 0.247	7.5 / 0.266	8.0 / 0.285
Sulfuric Acid Dose	mg/L	28	28	28	28	28	28	28	28	28	28	28	28	28
Ozone Dose	mg/L	1	1.3	1.5	1.8	2	1.8	2.5	2.8	3	3.3	3.5	3.8	4
Alum Dose	mg/L	21	25	30	35	40	35	50	37	37	37	38	38	40
Chlorine Dose	mg/L	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2	2	2	2.1	2.1
Secondary Chlorine Dose	mg/L	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	27	29	30	32	34	32	38	33	33	33	33	33	34
TOC Removal	%	25	28	32	35	38	41	43	35	35	35	35	35	36
3-day TTHM	ug/L	34	40	45	49	53	56	59	72	79	84	88	94	98
3-day HAA5	ug/L	10	11	13	14	15	16	18	21	24	25	26	28	29
3-day HAA9	ug/L	16	20	23	24	26	27	30	35	36	40	41	45	46
3-day Bromate	ug/L	5	6	7	7	8	9	9	10	10	11	11	12	12

Bromide 0.35

Parameter	Units	2.0 / 0.056	2.5 / 0.075	3.0 / 0.094	3.5 / 0.113	4.0 / 0.132	4.5 / 0.151	5.0 / 0.170	5.5 / 0.190	6.0 / 0.209	6.5 / 0.228	7.0 / 0.247	7.5 / 0.266	8.0 / 0.285
Sulfuric Acid Dose	mg/L	28	28	28	28	28	28	28	28	28	28	28	28	28
Ozone Dose	mg/L	1	1.3	1.5	1.8	2	1.8	2.5	2.8	3	3.3	3.5	3.8	4
Alum Dose	mg/L	21	25	30	35	40	35	50	37	37	37	38	38	40
Chlorine Dose	mg/L	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2	2	2	2.1	2.1
Secondary Chlorine Dose	mg/L	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	27	29	30	32	34	32	38	33	33	33	33	33	34
TOC Removal	%	25	28	32	35	38	41	43	35	35	35	35	35	36
3-day TTHM	ug/L	33	39	44	48	52	54	58	71	77	82	86	92	96
3-day HAA5	ug/L	10	11	13	14	15	16	18	22	24	25	26	29	30
3-day HAA9	ug/L	17	20	23	25	27	28	31	35	37	40	42	45	47
3-day Bromate	ug/L	5	6	6	7	7	8	8	8	9	9	10	10	11

Bromide 0.30

Parameter	Units	2.0 / 0.056	2.5 / 0.075	3.0 / 0.094	3.5 / 0.113	4.0 / 0.132	4.5 / 0.151	5.0 / 0.170	5.5 / 0.190	6.0 / 0.209	6.5 / 0.228	7.0 / 0.247	7.5 / 0.266	8.0 / 0.285
Sulfuric Acid Dose	mg/L	28	28	28	28	28	28	28	28	28	28	28	28	28
Ozone Dose	mg/L	1	1.3	1.5	1.8	2	1.8	2.5	2.8	3	3.3	3.5	3.8	4
Alum Dose	mg/L	21	25	30	35	40	35	50	37	37	37	38	38	40
Chlorine Dose	mg/L	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2	2	2	2.1	2.1
Secondary Chlorine Dose	mg/L	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	27	29	30	32	34	32	38	33	33	33	33	33	34
TOC Removal	%	25	28	32	35	38	41	43	35	35	35	35	35	36
3-day TTHM	ug/L	33	38	43	47	50	53	57	69	76	80	84	90	94
3-day HAA5	ug/L	10	12	14	15	16	17	18	22	24	26	27	29	30
3-day HAA9	ug/L	17	21	24	26	27	28	31	36	38	41	43	46	48
3-day Bromate	ug/L	4	5	5	6	6	7	7	7	8	8	8	9	9

Bromide 0.25

Parameter	Units	2.0 / 0.056	2.5 / 0.075	3.0 / 0.094	3.5 / 0.113	4.0 / 0.132	4.5 / 0.151	5.0 / 0.170	5.5 / 0.190	6.0 / 0.209	6.5 / 0.228	7.0 / 0.247	7.5 / 0.266	8.0 / 0.285
Sulfuric Acid Dose	mg/L	28	28	28	28	28	28	28	28	28	28	28	28	28
Ozone Dose	mg/L	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	3.5	3.8	4
Alum Dose	mg/L	21	25	30	35	40	45	50	37	37	37	38	38	40
Chlorine Dose	mg/L	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2	2	2	2.1	2.1
Secondary Chlorine Dose	mg/L	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	27	29	30	32	34	36	38	33	33	33	33	33	34
TOC Removal	%	25	28	32	35	38	41	43	35	35	35	35	35	36
3-day TTHM	ug/L	32	37	42	46	49	52	55	67	74	78	82	88	91
3-day HAA5	ug/L	10	12	14	15	16	17	19	22	25	26	27	30	31
3-day HAA9	ug/L	18	21	24	26	28	29	32	36	38	41	43	46	48
3-day Bromate	ug/L	3	4	4	5	5	5	6	6	6	7	7	7	8

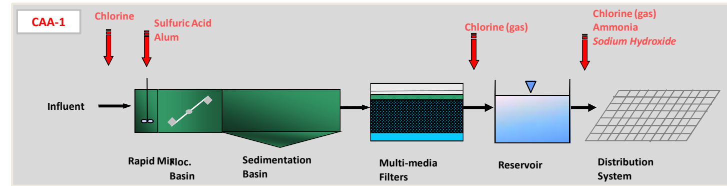
Bromide 0.20

Parameter	Units	2.0 / 0.056	2.5 / 0.075	3.0 / 0.094	3.5 / 0.113	4.0 / 0.132	4.5 / 0.151	5.0 / 0.170	5.5 / 0.190	6.0 / 0.209	6.5 / 0.228	7.0 / 0.247	7.5 / 0.266	8.0 / 0.285
Sulfuric Acid Dose	mg/L	28	28	28	28	28	28	28	28	28	28	28	28	28
Ozone Dose	mg/L	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	3.5	3.8	4
Alum Dose	mg/L	21	25	30	35	40	45	50	37	37	37	38	38	40
Chlorine Dose	mg/L	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.9	2	2	2	2.1	2.1
Secondary Chlorine Dose	mg/L	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	27	29	30	32	34	36	38	33	33	33	33	33	34
TOC Removal	%	25	28	32	35	38	41	43	35	35	35	35	35	36
3-day TTHM	ug/L	31	36	42	44	48	50	53	65	71	76	79	85	88
3-day HAA5	ug/L	11	12	14	15	17	17	19	23	26	27	28	31	32
3-day HAA9	ug/L	18	21	25	26	28	29	32	36	38	41	43	46	48
3-day Bromate	ug/L	3	3	4	4	4	4	5	5	5	6	6	6	6

Bromide (vertical axis); TOC and UV254 (horizontal axis)

CAA-1 Current Regulatory Scenario

Input Parameter	Value	Units
Water Quality		
pH	8	pH
Influent Temperature	15	°C
Minimum Temperature	5	°C
TOC		mg/L
UV254	=0.0359*TOC-0.0261	1/cm
Bromide		mg/L
Alkalinity	84	mg/L as $CaCO_3$
Calcium Hardness	60	mg/L as $CaCO_3$
Total Hardness	118	mg/L as $CaCO_3$
Ammonia	0.06	mg/L as N
Turbidity	16	NTU



NOTES:
Treatment targets equal 80% of current MCL values.
= 90th percentile water quality
= 2 or more treatment targets exceeded*
= 1 treatment target exceeded *
= no treatment targets exceeded

Bromide = 1

Parameter	TOC 2	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 9.5	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	5	0	11	10	mg/L
Alum Dose	24	52	56	60	64	60	62	mg/L
Chlorine Dose	0.7	1.1	1.1	1.1	1.2	1.2	1.3	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	28	31	33	30	28	28	34	mg/L
TOC Removal	25	36	38	38	38	40	40	%
3-day TTHM	27	63	65	68	73	72	80	ug/L
3-day HAA5	6	14	15	15	17	17	19	ug/L
3-day HAA9	13	28	29	29	31	33	36	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide = 0.95

Parameter	TOC 2	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 9.5	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	5	0	11	10	mg/L
Alum Dose	24	52	56	60	64	60	62	mg/L
Chlorine Dose	0.7	1.1	1.1	1.1	1.2	1.2	1.3	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	28	31	33	30	28	28	34	mg/L
TOC Removal	25	36	38	38	38	40	40	%
3-day TTHM	27	62	64	68	72	71	79	ug/L
3-day HAA5	6	14	15	15	17	17	19	ug/L
3-day HAA9	13	28	29	30	32	33	36	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide = 0.7

Parameter	TOC 2	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 9.5	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	5	0	11	10	mg/L
Alum Dose	24	52	56	60	64	60	62	mg/L
Chlorine Dose	0.7	1.1	1.1	1.1	1.2	1.2	1.3	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	28	31	33	30	28	28	34	mg/L
TOC Removal	25	36	38	38	38	40	40	%
3-day TTHM	26	60	61	65	69	68	76	ug/L
3-day HAA5	6	15	15	16	17	18	20	ug/L
3-day HAA9	14	29	30	31	33	35	38	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide = 0.65

Parameter	TOC 2	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 9.5	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	5	0	11	10	mg/L
Alum Dose	24	52	56	60	64	60	62	mg/L
Chlorine Dose	0.7	1.1	1.1	1.1	1.2	1.2	1.3	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	28	31	33	30	28	28	34	mg/L
TOC Removal	25	36	38	38	38	40	40	%
3-day TTHM	26	59	61	64	69	67	75	ug/L
3-day HAA5	6	15	16	16	18	18	20	ug/L
3-day HAA9	14	30	30	31	34	35	38	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide = 0.5

Parameter	TOC 2	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 9.5	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	5	0	11	10	mg/L
Alum Dose	24	52	56	60	64	60	62	mg/L
Chlorine Dose	0.7	1.1	1.1	1.1	1.2	1.2	1.3	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	28	31	33	30	28	28	34	mg/L
TOC Removal	25	36	38	38	38	40	40	%
3-day TTHM	25	57	59	62	66	65	72	ug/L
3-day HAA5	7	16	16	17	18	19	21	ug/L
3-day HAA9	14	31	32	33	35	37	40	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide = 0.45

Parameter	TOC 2	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 9.5	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	5	0	11	10	mg/L
Alum Dose	24	52	56	60	64	60	62	mg/L
Chlorine Dose	0.7	1.1	1.1	1.1	1.2	1.2	1.3	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	28	31	33	30	28	28	34	mg/L
TOC Removal	25	36	38	38	38	40	40	%
3-day TTHM	25	56	58	61	65	64	71	ug/L
3-day HAA5	7	16	16	17	18	19	21	ug/L
3-day HAA9	15	32	32	33	36	37	41	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide = 0.4

Parameter	TOC 2	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 9.5	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	5	0	11	10	mg/L
Alum Dose	24	52	56	60	64	60	62	mg/L
Chlorine Dose	0.7	1.1	1.1	1.1	1.2	1.2	1.3	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	28	31	33	30	28	28	34	mg/L
TOC Removal	25	36	38	38	38	40	40	%
3-day TTHM	24	55	57	60	64	63	70	ug/L
3-day HAA5	7	16	17	17	19	19	21	ug/L
3-day HAA9	15	32	33	34	36	38	42	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide = 0.25

Parameter	TOC 2	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 9.5	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	5	0	11	10	mg/L
Alum Dose	24	52	56	60	64	60	62	mg/L
Chlorine Dose	0.7	1.1	1.1	1.1	1.2	1.2	1.3	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	28	31	33	30	28	28	34	mg/L
TOC Removal	25	36	38	38	38	40	40	%
3-day TTHM	23	51	53	56	60	59	65	ug/L
3-day HAA5	7	17	18	18	20	21	23	ug/L
3-day HAA9	16	34	35	36	38	40	43	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide = 0.2

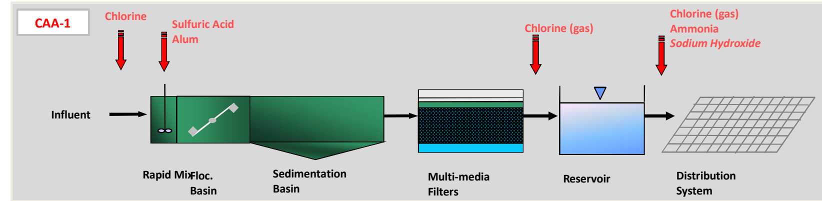
Parameter	TOC 2	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 9.5	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	5	0	11	10	mg/L
Alum Dose	24	52	56	60	64	60	62	mg/L
Chlorine Dose	0.7	1.1	1.1	1.1	1.2	1.2	1.3	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	28	31	33	30	28	28	34	mg/L
TOC Removal	25	36	38	38	38	40	40	%
3-day TTHM	22	50	51	54	58	57	63	ug/L
3-day HAA5	7	18	18	19	20	21	23	ug/L
3-day HAA9	16	34	35	36	38	40	43	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

TOC	2	6.5	7	7.5	8	8.5	9.5
UV254	0.063	0.196	0.211	0.225	0.240	0.255	0.285

Vertical axis: Bromide; horizontal axis: TOC and UV254

CAA-1 Plausible Future Regulatory Scenario

Input Parameter	Value	Units
Water Quality		
pH	8	pH
Influent Temperature	26	°C
Minimum Temperature	5	°C
TOC		mg/L
UV254	=0.0359*TOC-0.0261	1/cm
Bromide		mg/L
Alkalinity	84	mg/L as $CaCO_3$
Calcium Hardness	60	mg/L as $CaCO_3$
Total Hardness	118	mg/L as $CaCO_3$
Ammonia	0.06	mg/L as N
Turbidity	16	NTU



NOTES:
HAA9 Plausible scenario is on LRAA basis (use avg temp = 16 C results from 'current' runs to determine exceed)
Treatment targets equal 80% of current MCL values.
= 90th percentile water quality
= 2 or more treatment targets exceeded*
= 1 treatment target exceeded *
= no treatment targets exceeded

Bromide 1

Parameter	TOC 2 / UV254 0.063	TOC 4.5 / UV254 0.137	TOC 5 / UV254 0.151	TOC 5.5 / UV254 0.166	TOC 6 / UV254 0.181	TOC 6.5 / UV254 0.196	TOC 9.5 / UV254 0.285	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	15	10	5	10	mg/L
Alum Dose	23	45	50	44	48	52	62	mg/L
Chlorine Dose	0.7	0.9	1	1	1	1.1	1.2	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	27	28	30	32	30	27	35	mg/L
TOC Removal	25	35	37	35	36	36	41	%
3-day TTHM	36	62	66*	73*	78*	84*	103*	ug/L
3-day HAA5	8	13	15	16	17	18	23	ug/L
3-day HAA9	13		23			28	36	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide 0.85

Parameter	TOC 2 / UV254 0.063	TOC 4.5 / UV254 0.137	TOC 5 / UV254 0.151	TOC 5.5 / UV254 0.166	TOC 6 / UV254 0.181	TOC 6.5 / UV254 0.196	TOC 9.5 / UV254 0.285	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	15	10	5	10	mg/L
Alum Dose	23	45	50	44	48	52	62	mg/L
Chlorine Dose	0.7	0.9	1	1	1	1.1	1.2	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	27	28	30	32	30	27	35	mg/L
TOC Removal	25	35	37	35	36	36	41	%
3-day TTHM	35	61	65*	71*	76*	82*	101*	ug/L
3-day HAA5	8	14	15	16	17	19	23	ug/L
3-day HAA9	13		23					ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide 0.8

Parameter	TOC 2 / UV254 0.063	TOC 4.5 / UV254 0.137	TOC 5 / UV254 0.151	TOC 5.5 / UV254 0.166	TOC 6 / UV254 0.181	TOC 6.5 / UV254 0.196	TOC 9.5 / UV254 0.285	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	15	10	5	10	mg/L
Alum Dose	23	45	50	44	48	52	62	mg/L
Chlorine Dose	0.7	0.9	1	1	1	1.1	1.2	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	27	28	30	32	30	27	35	mg/L
TOC Removal	25	35	37	35	36	36	41	%
3-day TTHM	35	60	64	71	76	81	100	ug/L
3-day HAA5	8	14	15	16	17	19	24	ug/L
3-day HAA9	13		24			29	37	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide 0.45

Parameter	TOC 2 / UV254 0.063	TOC 4.5 / UV254 0.137	TOC 5 / UV254 0.151	TOC 5.5 / UV254 0.166	TOC 6 / UV254 0.181	TOC 6.5 / UV254 0.196	TOC 9.5 / UV254 0.285	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	15	10	5	10	mg/L
Alum Dose	23	45	50	44	48	52	62	mg/L
Chlorine Dose	0.7	0.9	1	1	1	1.1	1.2	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	27	28	30	32	30	27	35	mg/L
TOC Removal	25	35	37	35	36	36	41	%
3-day TTHM	32	56	59	65	70	75	92	ug/L
3-day HAA5	8	15	16	17	18	20	25	ug/L
3-day HAA9	15		26			32	41	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide 0.4

Parameter	TOC 2 / UV254 0.063	TOC 4.5 / UV254 0.137	TOC 5 / UV254 0.151	TOC 5.5 / UV254 0.166	TOC 6 / UV254 0.181	TOC 6.5 / UV254 0.196	TOC 9.5 / UV254 0.285	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	15	10	5	10	mg/L
Alum Dose	23	45	50	44	48	52	62	mg/L
Chlorine Dose	0.7	0.9	1	1	1	1.1	1.2	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	27	28	30	32	30	27	35	mg/L
TOC Removal	25	35	37	35	36	36	41	%
3-day TTHM	32	55	58	64	68	73	90	ug/L
3-day HAA5	9	15	16	18	19	20	26	ug/L
3-day HAA9	15		27			32	42	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide 0.3

Parameter	TOC 2 / UV254 0.063	TOC 4.5 / UV254 0.137	TOC 5 / UV254 0.151	TOC 5.5 / UV254 0.166	TOC 6 / UV254 0.181	TOC 6.5 / UV254 0.196	TOC 9.5 / UV254 0.285	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	15	10	5	10	mg/L
Alum Dose	23	45	50	44	48	52	62	mg/L
Chlorine Dose	0.7	0.9	1	1	1	1.1	1.2	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	27	28	30	32	30	27	35	mg/L
TOC Removal	25	35	37	35	36	36	41	%
3-day TTHM	30	52	56	61	66	70	87	ug/L
3-day HAA5	9	15	17	18	19	21	27	ug/L
3-day HAA9	16		28			33	43	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

Bromide 0.25

Parameter	TOC 2 / UV254 0.063	TOC 4.5 / UV254 0.137	TOC 5 / UV254 0.151	TOC 5.5 / UV254 0.166	TOC 6 / UV254 0.181	TOC 6.5 / UV254 0.196	TOC 9.5 / UV254 0.285	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	15	10	5	10	mg/L
Alum Dose	23	45	50	44	48	52	62	mg/L
Chlorine Dose	0.7	0.9	1	1	1	1.1	1.2	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	27	28	30	32	30	27	35	mg/L
TOC Removal	25	35	37	35	36	36	41	%
3-day TTHM	29	51	54	60	64	69	84	ug/L
3-day HAA5	9	16	17	19	20	22	27	ug/L
3-day HAA9	16		28			34	43	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

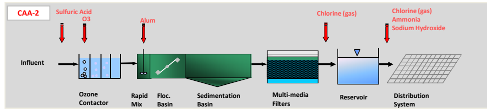
Bromide 0.2

Parameter	TOC 2 / UV254 0.063	TOC 4.5 / UV254 0.137	TOC 5 / UV254 0.151	TOC 5.5 / UV254 0.166	TOC 6 / UV254 0.181	TOC 6.5 / UV254 0.196	TOC 9.5 / UV254 0.285	Units
Chlorine Dose	0.5	0.5	0.5	0.5	0.5	0.5	0.5	mg/L
Sulfuric Acid Dose	20	10	10	15	10	5	10	mg/L
Alum Dose	23	45	50	44	48	52	62	mg/L
Chlorine Dose	0.7	0.9	1	1	1	1.1	1.2	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	27	28	30	32	30	27	35	mg/L
TOC Removal	25	35	37	35	36	36	41	%
3-day TTHM	29	49	52	58	62	66	81	ug/L
3-day HAA5	9	16	18	19	20	22	28	ug/L
3-day HAA9	16		29			34	43	ug/L
3-day Bromate	0	0	0	0	0	0	0	ug/L

TOC and UV254

CAA-2 Current Regulatory Scenario

Input Parameter	Value	Units
Water Quality		
pH	8	pH
Influent Temperature	15	°C
Minimum Temperature	5	°C
TOC		mg/L
UV254	=0.0359*TOC-0.0261	1/cm
Bromide		mg/L
Alkalinity	84	mg/L as $CaCO_3$
Calcium Hardness	60	mg/L as $CaCO_3$
Total Hardness	118	mg/L as $CaCO_3$
Ammonia	0.06	mg/L as N
Turbidity	16	NTU



NOTES:
Treatment targets equal 80% of current MCL values.
= 90th percentile water quality
= 2 or more treatment targets exceeded*
= 1 treatment target exceeded *
= no treatment targets exceeded

Bromide = 1; TOC = 2, 2.5, 3, 3.5, 4:

Parameter	TOC 2	TOC 2.5	TOC 3	TOC 3.5	TOC 4	Units
Sulfuric Acid Dose	30	30	30	30	30	mg/L
Ozone Dose	1	1.3	1.5	1.8	2	mg/L
Alum Dose	20	25	29	35	40	mg/L
Chlorine Dose	1.2	1.2	1.2	1.3	1.3	mg/L
Secondary Chlorine Dose	2.6	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	34	36	38	41	43	mg/L
TOC Removal	35	38	40	43	46	%
3-day TTHM	27	31	34	38	40	ug/L
3-day HAA5	6	7	8	9	10	ug/L
3-day HAA9	14	15	17	19	20	ug/L
3-day Bromate	8	10	11	13	13	ug/L

Remaining grid cells (Bromide 1, 0.85, 0.8, 0.75, 0.7, 0.65, 0.6, 0.55, 0.5, 0.45, 0.4, 0.35, 0.3, 0.2 × TOC 2–9.5): [illegible]

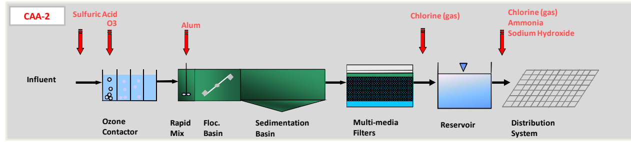
	TOC	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5
	UV254	0.063	0.077	0.092	0.107	0.122	0.137	0.151	0.166	0.181	0.196	0.211	0.225	0.240	0.255	0.270	0.285

Bromide

TOC and UV254

CAA-2 Plausible Future Regulatory Scenario

Input Parameter	Value	Units
Water Quality		
pH	8	pH
Influent Temperature	26	°C
Minimum Temperature	5	°C
TOC		mg/L
UV254	=0.0359*TOC-0.0261	1/cm
Bromide		mg/L
Alkalinity	84	mg/L as $CaCO_3$
Calcium Hardness	60	mg/L as $CaCO_3$
Total Hardness	118	mg/L as $CaCO_3$
Ammonia	0.06	mg/L as N
Turbidity	16	NTU



NOTES:
HAA9 Plausible scenario is on LRAA basis (use avg temp = 16 C results from 'current' runs to determine exceed)
Treatment targets equal 80% of current MCL values.
= 90th percentile water quality
= 2 or more treatment targets exceeded*
= 1 treatment target exceeded *
= no treatment targets exceeded

Bromide (mg/L) by TOC (mg/L) and UV254 (1/cm)

TOC: 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 8, 9.5
UV254: 0.063, 0.077, 0.092, 0.107, 0.122, 0.137, 0.151, 0.166, 0.181, 0.196, 0.240, 0.285

Bromide 1

Parameter	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	8	9.5	Units
Sulfuric Acid Dose	30	30	30	30	30	30	30	30	30	30	30	30	mg/L
Ozone Dose	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	4	4.8	mg/L
Alum Dose	20	25	29	35	40	45	50	27.5	30	32.5	40	47.5	mg/L
Chlorine Dose	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.5	1.5	1.6	1.6	1.7	mg/L
Secondary Chlorine Dose	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	35	36	38	41	43	45	47	38	39	40	43	46	mg/L
TOC Removal	36	39	41	44	47	49	50	38	40	41	44	47	%
3-day TTHM	36	40	45	49	52	55	57	76	80	84	93	100	ug/L
3-day HAA5	8	9	10	11	12	13	13	17	18	20	22	24	ug/L
3-day HAA9	14	15	17	19	20	21	21	27	28	30	33	37	ug/L
3-day Bromate	11	14	15	17	18	21	22	24	25	26	30	34	ug/L

Bromide 0.75

Parameter	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	8	9.5	Units
Sulfuric Acid Dose	30	30	30	30	30	30	30	30	30	30	30	30	mg/L
Ozone Dose	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	4	4.8	mg/L
Alum Dose	20	25	30	35	40	45	50	27.5	30	32.5	40	47.5	mg/L
Chlorine Dose	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.5	1.5	1.6	1.6	1.7	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	34	36	38	41	43	45	47	38	39	40	43	46	mg/L
TOC Removal	36	39	42	44	47	49	50	38	40	41	44	47	%
3-day TTHM	34	38	42	47	50	53	55	73	76	81	89	96	ug/L
3-day HAA5	8	9	10	12	12	13	14	18	19	21	23	25	ug/L
3-day HAA9	14	16	17	19	20	21	22	28	29	32	34	38	ug/L
3-day Bromate	9	11	11	13	14	16	16	18	19	20	23	26	ug/L

Bromide 0.7

Parameter	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	8	9.5	Units
Sulfuric Acid Dose	30	30	30	30	30	30	30	30	30	30	30	30	mg/L
Ozone Dose	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	4	4.8	mg/L
Alum Dose	20	25	30	35	40	45	50	27.5	30	32.5	40	47.5	mg/L
Chlorine Dose	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.5	1.5	1.6	1.6	1.7	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	34	36	38	41	43	45	47	38	39	40	43	46	mg/L
TOC Removal	36	39	42	44	47	49	50	38	40	41	44	47	%
3-day TTHM	34	38	42	47	50	52	54	72	76	80	88	95	ug/L
3-day HAA5	9	9	10	12	13	13	14	18	19	21	23	25	ug/L
3-day HAA9	14	16	17	20	21	21	22	29	30	32	35	39	ug/L
3-day Bromate	8	10	11	12	13	15	15	17	17	19	21	24	ug/L

Bromide 0.6

Parameter	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	8	9.5	Units
Sulfuric Acid Dose	30	30	30	30	30	30	30	30	30	30	30	30	mg/L
Ozone Dose	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	4	4.8	mg/L
Alum Dose	20	25	30	35	40	45	50	27.5	30	32.5	40	47.5	mg/L
Chlorine Dose	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.5	1.5	1.6	1.6	1.7	mg/L
Secondary Chlorine Dose	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	35	36	38	41	43	45	47	38	39	40	43	46	mg/L
TOC Removal	36	39	42	44	47	49	50	38	40	41	44	47	%
3-day TTHM	33	37	41	46	49	51	53	71	74	78	86	93	ug/L
3-day HAA5	9	10	11	12	13	13	14	19	19	21	23	26	ug/L
3-day HAA9	15	16	18	20	21	22	23	29	30	33	36	40	ug/L
3-day Bromate	7	9	9	11	11	13	13	14	15	16	18	21	ug/L

Bromide 0.55

Parameter	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	8	9.5	Units
Sulfuric Acid Dose	30	30	30	30	30	30	30	30	30	30	30	30	mg/L
Ozone Dose	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	4	4.8	mg/L
Alum Dose	20	25	30	35	40	45	50	27.5	30	32.5	40	47.5	mg/L
Chlorine Dose	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.5	1.5	1.6	1.6	1.7	mg/L
Secondary Chlorine Dose	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	35	36	38	41	43	45	47	38	39	40	43	46	mg/L
TOC Removal	36	39	42	44	47	49	50	38	40	41	44	47	%
3-day TTHM	33	37	41	45	48	50	52	70	73	76	85	92	ug/L
3-day HAA5	9	10	11	12	13	14	14	19	20	20	23	26	ug/L
3-day HAA9	15	17	18	20	21	22	23	30	31	33	36	40	ug/L
3-day Bromate	6	8	8	10	10	12	12	13	14	15	17	19	ug/L

Bromide 0.5

Parameter	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	8	9.5	Units
Sulfuric Acid Dose	30	30	30	30	30	30	30	30	30	30	30	30	mg/L
Ozone Dose	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	4	4.8	mg/L
Alum Dose	20	25	30	35	40	45	50	27.5	30	32.5	40	47.5	mg/L
Chlorine Dose	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.5	1.5	1.6	1.6	1.7	mg/L
Secondary Chlorine Dose	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	35	36	38	41	43	45	47	38	39	40	43	46	mg/L
TOC Removal	36	39	42	44	47	49	50	38	40	41	44	47	%
3-day TTHM	32	36	40	44	47	50	52	69	72	76	84	91	ug/L
3-day HAA5	9	10	11	12	13	14	14	19	20	22	24	27	ug/L
3-day HAA9	15	17	18	21	22	23	24	30	31	34	37	41	ug/L
3-day Bromate	6	7	8	9	9	11	11	12	13	14	15	18	ug/L

Bromide 0.45

Parameter	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	8	9.5	Units
Sulfuric Acid Dose	30	30	30	30	30	30	30	30	30	30	30	30	mg/L
Ozone Dose	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	4	4.8	mg/L
Alum Dose	20	25	30	35	40	45	50	27.5	30	32.5	40	47.5	mg/L
Chlorine Dose	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.5	1.5	1.6	1.6	1.7	mg/L
Secondary Chlorine Dose	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	35	36	38	41	43	45	47	38	39	40	43	46	mg/L
TOC Removal	36	39	42	44	47	49	50	38	40	41	44	47	%
3-day TTHM	32	36	39	44	47	49	51	68	71	75	82	89	ug/L
3-day HAA5	9	10	11	12	13	14	14	19	20	22	24	27	ug/L
3-day HAA9	16	17	19	21	22	23	24	31	32	34	37	42	ug/L
3-day Bromate	5	6	7	8	9	10	10	11	11	12	14	16	ug/L

Bromide 0.4

Parameter	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	8	9.5	Units
Sulfuric Acid Dose	30	30	30	30	30	30	30	30	30	30	30	30	mg/L
Ozone Dose	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	4	4.8	mg/L
Alum Dose	20	25	30	35	40	45	50	27.5	30	32.5	40	47.5	mg/L
Chlorine Dose	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.5	1.5	1.6	1.6	1.7	mg/L
Secondary Chlorine Dose	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	35	36	38	41	43	45	47	38	39	40	43	46	mg/L
TOC Removal	36	39	42	44	47	49	50	38	40	41	44	47	%
3-day TTHM	31	35	39	43	46	48	50	67	70	74	81	88	ug/L
3-day HAA5	9	10	11	13	13	14	15	20	20	22	24	27	ug/L
3-day HAA9	16	18	19	21	23	24	25	31	33	35	38	42	ug/L
3-day Bromate	5	6	6	7	8	9	9	10	10	11	12	14	ug/L

Bromide 0.35

Parameter	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	8	9.5	Units
Sulfuric Acid Dose	30	30	30	30	30	30	30	30	30	30	30	30	mg/L
Ozone Dose	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	4	4.8	mg/L
Alum Dose	20	25	30	35	40	45	50	27.5	30	32.5	40	47.5	mg/L
Chlorine Dose	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.5	1.5	1.6	1.6	1.7	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	34	36	38	41	43	45	47	38	39	40	43	46	mg/L
TOC Removal	36	39	42	44	47	49	50	38	40	41	44	47	%
3-day TTHM	31	34	38	42	45	47	49	65	68	72	79	86	ug/L
3-day HAA5	9	10	11	13	14	14	15	20	21	23	25	28	ug/L
3-day HAA9	16	18	19	22	23	24	25	32	33	36	39	43	ug/L
3-day Bromate	4	5	6	6	7	8	8	9	9	10	11	13	ug/L

Bromide 0.3

Parameter	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	8	9.5	Units
Sulfuric Acid Dose	30	30	30	30	30	30	30	30	30	30	30	30	mg/L
Ozone Dose	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	4	4.8	mg/L
Alum Dose	20	25	30	35	40	45	50	27.5	30	32.5	40	47.5	mg/L
Chlorine Dose	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.5	1.5	1.6	1.6	1.7	mg/L
Secondary Chlorine Dose	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	35	36	38	41	43	45	47	38	39	40	43	46	mg/L
TOC Removal	36	39	42	44	47	49	50	38	40	41	44	47	%
3-day TTHM	30	34	37	41	44	46	48	64	67	71	78	84	ug/L
3-day HAA5	9	11	11	13	14	15	15	20	21	23	25	28	ug/L
3-day HAA9	17	18	20	22	24	25	26	33	34	36	39	43	ug/L
3-day Bromate	4	4	5	5	6	6	7	7	8	8	9	11	ug/L

Bromide 0.25

Parameter	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	8	9.5	Units
Sulfuric Acid Dose	30	30	30	30	30	30	30	30	30	30	30	30	mg/L
Ozone Dose	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	4	4.8	mg/L
Alum Dose	20	25	30	35	40	45	50	27.5	30	32.5	40	47.5	mg/L
Chlorine Dose	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.5	1.5	1.6	1.6	1.7	mg/L
Secondary Chlorine Dose	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	35	36	38	41	43	45	47	38	39	40	43	46	mg/L
TOC Removal	36	39	42	44	47	49	50	38	40	41	44	47	%
3-day TTHM	29	33	36	40	43	45	47	62	65	69	76	82	ug/L
3-day HAA5	10	11	12	13	14	15	16	21	22	24	26	29	ug/L
3-day HAA9	17	[illegible]	[illegible]	[illegible]	24	25	26	33	34	[illegible]	[illegible]	[illegible]	ug/L
3-day Bromate	3	4	4	5	5	5	6	6	6	7	8	9	ug/L

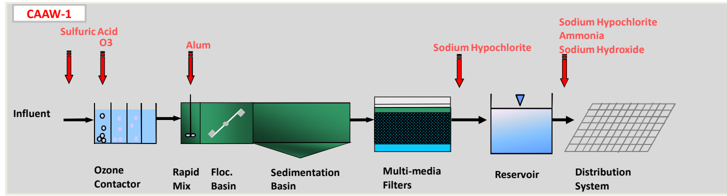
Bromide 0.2

Parameter	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	8	9.5	Units
Sulfuric Acid Dose	30	30	30	30	30	30	30	30	30	30	30	30	mg/L
Ozone Dose	1	1.3	1.5	1.8	2	2.3	2.5	2.8	3	3.3	4	4.8	mg/L
Alum Dose	20	25	30	35	40	45	50	27.5	30	32.5	40	47.5	mg/L
Chlorine Dose	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.5	1.5	1.6	1.6	1.7	mg/L
Secondary Chlorine Dose	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	35	36	38	41	43	45	47	38	39	40	43	46	mg/L
TOC Removal	36	39	42	44	47	49	50	38	40	41	44	47	%
3-day TTHM	28	32	35	39	41	43	45	60	63	66	73	79	ug/L
3-day HAA5	10	11	12	14	15	15	16	21	22	24	26	30	ug/L
3-day HAA9	17	19	21	23	24	25	26	33	34	37	40	44	ug/L
3-day Bromate	2	3	3	4	4	4	5	5	5	6	6	7	ug/L

TOC and UV254

CAAW-1 Current Regulatory Scenario

Input Parameter	Value	Units
Water Quality		
pH	8.8	pH
Influent Temperature	16	°C
Minimum Temperature	5	°C
TOC		mg/L
UV254	=0.035*TOC-0.0573	1/cm
Bromide		mg/L
Alkalinity	106	mg/L as $CaCO_3$
Calcium Hardness	94	mg/L as $CaCO_3$
Total Hardness	158	mg/L as $CaCO_3$
Ammonia	0.041	mg/L as N
Turbidity	3	NTU



NOTES:
Treatment targets equal 80% of current MCL values.
- (white) = 90th percentile water quality
- (red) = 2 or more treatment targets exceeded*
- (yellow) = 1 treatment target exceeded *
- (green) = no treatment targets exceeded

Bromide (rows) vs. TOC and UV254 (columns)

TOC	2.5	5	5.5	6	6.5	7	7.5	8	8.5	10
UV254	0.030	0.118	0.135	0.153	0.170	0.188	0.205	0.223	0.240	0.293

Bromide 0.6

Parameter	Units	TOC 2.5	TOC 5	TOC 5.5	TOC 6	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 10
Sulfuric Acid Dose	mg/L	40	40	40	40	40	40	40	40	40	40
Ozone Dose	mg/L	1.3	2.5	2.8	3	3.3	3.5	3.8	4	4.3	5
Alum Dose	mg/L	25	50	27.5	30	32.5	35	37.5	40	42.5	50
Chlorine Dose	mg/L	1	1.2	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6
Secondary Chlorine Dose	mg/L	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammmonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	34	44	35	36	37	38	39	40	41	44
TOC Removal	%	34	46	36	37	38	40	41	42	43	46
3-day TTHM	ug/L	21	40	52	57	59	62	66	68	71	78
3-day HAA5	ug/L	6	11	14	16	16	17	18	19	20	22
3-day HAA9	ug/L	13	23	28	30	32	33	35	37	38	42
3-day Bromate	ug/L	11	11	12	12	13	13	14	14	15	16

Bromide 0.5

Parameter	Units	TOC 2.5	TOC 5	TOC 5.5	TOC 6	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 10
Sulfuric Acid Dose	mg/L	40	40	40	40	40	40	40	40	40	40
Ozone Dose	mg/L	1.3	2.5	2.8	3	3.3	3.5	3.8	4	4.3	5
Alum Dose	mg/L	25	50	27.5	30	32.5	35	37.5	40	42.5	50
Chlorine Dose	mg/L	1	1.2	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6
Secondary Chlorine Dose	mg/L	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammmonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	34	44	35	36	37	38	39	40	41	44
TOC Removal	%	34	46	36	37	38	40	41	42	43	46
3-day TTHM	ug/L	21	39	51	55	58	61	64	67	69	76
3-day HAA5	ug/L	6	11	14	16	17	17	19	19	20	23
3-day HAA9	ug/L	13	24	29	31	33	34	37	38	39	43
3-day Bromate	ug/L	9	9	10	10	11	11	12	12	12	13

Bromide 0.45

Parameter	Units	TOC 2.5	TOC 5	TOC 5.5	TOC 6	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 10
Sulfuric Acid Dose	mg/L	40	40	40	40	40	40	40	40	40	40
Ozone Dose	mg/L	1.3	2.5	2.8	3	3.3	3.5	3.8	4	4.3	5
Alum Dose	mg/L	25	50	27.5	30	32.5	35	37.5	40	42.5	50
Chlorine Dose	mg/L	1	1.2	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6
Secondary Chlorine Dose	mg/L	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammmonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	34	44	35	36	37	38	39	40	41	44
TOC Removal	%	34	46	36	37	38	40	41	42	43	46
3-day TTHM	ug/L	21	39	50	54	57	60	63	66	68	75
3-day HAA5	ug/L	6	12	14	16	17	17	19	20	20	23
3-day HAA9	ug/L	14	24	29	32	33	35	37	38	39	44
3-day Bromate	ug/L	8	8	9	9	10	10	10	11	11	12

Bromide 0.4

Parameter	Units	TOC 2.5	TOC 5	TOC 5.5	TOC 6	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 10
Sulfuric Acid Dose	mg/L	40	40	40	40	40	40	40	40	40	40
Ozone Dose	mg/L	1.3	2.5	2.8	3	3.3	3.5	3.8	4	4.3	5
Alum Dose	mg/L	25	50	27.5	30	32.5	35	37.5	40	42.5	50
Chlorine Dose	mg/L	1	1.2	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6
Secondary Chlorine Dose	mg/L	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammmonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	34	44	35	36	37	38	39	40	41	44
TOC Removal	%	34	46	36	37	38	40	41	42	43	46
3-day TTHM	ug/L	20	38	49	53	56	59	62	65	67	73
3-day HAA5	ug/L	6	12	15	16	17	18	19	20	21	23
3-day HAA9	ug/L	14	25	30	33	34	35	38	39	40	45
3-day Bromate	ug/L	8	8	8	8	9	9	9	9	10	11

Bromide 0.35

Parameter	Units	TOC 2.5	TOC 5	TOC 5.5	TOC 6	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 10
Sulfuric Acid Dose	mg/L	40	40	40	40	40	40	40	40	40	40
Ozone Dose	mg/L	1.3	2.5	2.8	3	3.3	3.5	3.8	4	4.3	5
Alum Dose	mg/L	25	50	27.5	30	32.5	35	37.5	40	42.5	50
Chlorine Dose	mg/L	1	1.2	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6
Secondary Chlorine Dose	mg/L	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammmonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	34	44	35	36	37	38	39	40	41	44
TOC Removal	%	34	46	36	37	38	40	41	42	43	46
3-day TTHM	ug/L	20	37	48	52	55	58	61	63	65	72
3-day HAA5	ug/L	6	12	15	17	17	18	20	20	21	24
3-day HAA9	ug/L	14	25	30	33	35	36	39	40	41	45
3-day Bromate	ug/L	7	7	7	7	8	8	8	8	9	9

Bromide 0.3

Parameter	Units	TOC 2.5	TOC 5	TOC 5.5	TOC 6	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 10
Sulfuric Acid Dose	mg/L	40	40	40	40	40	40	40	40	40	40
Ozone Dose	mg/L	1.3	2.5	2.8	3	3.3	3.5	3.8	4	4.3	5
Alum Dose	mg/L	25	50	27.5	30	32.5	35	37.5	40	42.5	50
Chlorine Dose	mg/L	1	1.2	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6
Secondary Chlorine Dose	mg/L	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammmonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	34	44	35	36	37	38	39	40	41	44
TOC Removal	%	34	46	36	37	38	40	41	42	43	46
3-day TTHM	ug/L	19	37	47	51	54	56	60	62	64	70
3-day HAA5	ug/L	6	12	15	17	18	18	20	21	21	24
3-day HAA9	ug/L	15	26	31	34	35	37	39	40	41	46
3-day Bromate	ug/L	6	6	6	6	7	7	7	7	8	8

Bromide 0.15

Parameter	Units	TOC 2.5	TOC 5	TOC 5.5	TOC 6	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 10
Sulfuric Acid Dose	mg/L	40	40	40	40	40	40	40	40	40	40
Ozone Dose	mg/L	1.3	2.5	2.8	3	3.3	3.5	3.8	4	4.3	5
Alum Dose	mg/L	25	50	27.5	30	32.5	35	37.5	40	42.5	50
Chlorine Dose	mg/L	1	1.2	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6
Secondary Chlorine Dose	mg/L	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammmonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	34	44	35	36	37	38	39	40	41	44
TOC Removal	%	34	46	36	37	38	40	41	42	43	46
3-day TTHM	ug/L	18	33	43	46	49	51	54	56	58	64
3-day HAA5	ug/L	7	13	17	18	19	20	22	22	23	26
3-day HAA9	ug/L	15	26	31	34	35	36	39	40	41	45
3-day Bromate	ug/L	3	3	3	3	3	3	4	4	4	4

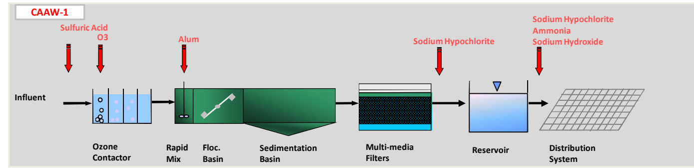
Bromide 0.05

Parameter	Units	TOC 2.5	TOC 5	TOC 5.5	TOC 6	TOC 6.5	TOC 7	TOC 7.5	TOC 8	TOC 8.5	TOC 10
Sulfuric Acid Dose	mg/L	40	40	40	40	40	40	40	40	40	40
Ozone Dose	mg/L	1.3	2.5	2.8	3	3.3	3.5	3.8	4	4.3	5
Alum Dose	mg/L	25	50	27.5	30	32.5	35	37.5	40	42.5	50
Chlorine Dose	mg/L	1	1.2	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6
Secondary Chlorine Dose	mg/L	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Ammmonia Dose	mg/L	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sodium Hydroxide Dose	mg/L	34	44	35	36	37	38	39	40	41	44
TOC Removal	%	34	46	36	37	38	40	41	42	43	46
3-day TTHM	ug/L	15	28	37	40	42	44	46	48	49	54
3-day HAA5	ug/L	8	15	19	21	22	23	25	26	26	30
3-day HAA9	ug/L	13	23	27	29	30	31	34	34	35	39
3-day Bromate	ug/L	1	1	1	1	1	1	1	1	1	1

TOC and UV254

CAAW-1 Plausible Future Regulatory Scenario

Input Parameter	Value	Units
Water Quality		
pH	8.8	pH
Influent Temperature	22	°C
Minimum Temperature	5	°C
TOC		mg/L
UV254	=0.035*TOC-0.0573	1/cm
Bromide		mg/L
Alkalinity	106	mg/L as $CaCO_3$
Calcium Hardness	94	mg/L as $CaCO_3$
Total Hardness	158	mg/L as $CaCO_3$
Ammonia	0.041	mg/L as N
Turbidity	3	NTU



NOTES:
HAA9 Plausible scenario is on LRAA basis (use avg temp = 16 C results from 'current' runs to determine exceed)
Treatment targets equal 80% of current MCL values.

- (white, bold outline) = 90th percentile water quality
- (red) = 2 or more treatment targets exceeded*
- (yellow) = 1 treatment target exceeded *
- (green) = no treatment targets exceeded

Bromide (rows, mg/L) vs. **TOC and UV254** (columns). Each cell of the grid lists the following values; cell colour is shown in the "Cell colour" row.

TOC 2.5, UV254 0.030

Parameter (Bromide →)	0.6	0.55	0.5	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05	Units
Sulfuric Acid Dose	40	40	40	40	40	40	40	40	40	40	40	mg/L
Ozone Dose	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	mg/L
Alum Dose	25	25	25	25	25	25	25	25	25	25	25	mg/L
Chlorine Dose	1	1	1	1	1	1	1	1	1	1	1	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	34	34	34	34	34	34	34	34	34	34	34	mg/L
TOC Removal	34	34	34	34	34	34	34	34	34	34	34	%
3-day TTHM	25	25	24	24	23	23	22	21	20	19	17	ug/L
3-day HAA5	7	7	7	7	7	7	7	8	8	8	9	ug/L
3-day HAA9	13	13	13	14	14	15	15	15	15		13	ug/L
3-day Bromate	13	12	11	9	8	7	6	5	4	2	1	ug/L
Cell colour	yellow	yellow	yellow	yellow	green	green	green	green	green	green	green	

TOC 5.5, UV254 0.135

Parameter (Bromide →)	0.6	0.55	0.5	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05	Units
Sulfuric Acid Dose	40	40	40	40	40	40	40	40	40	40	40	mg/L
Ozone Dose	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	mg/L
Alum Dose	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5	mg/L
Chlorine Dose	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	35	35	35	35	35	35	35	35	35	35	35	mg/L
TOC Removal	36	36	36	36	36	36	36	36	36	36	36	%
3-day TTHM	61	60	59	57	56	55	53	52	49	47	42	ug/L
3-day HAA5	16	16	16	17	17	17	18	18	19	20	21	ug/L
3-day HAA9	28		29	30	30	31	31	31	31		27	ug/L
3-day Bromate	14	13	12	10	8	7	6	5	4	3	1	ug/L
Cell colour	yellow	yellow	yellow	yellow	green	green	green	green	green	green	green	

TOC 6, UV254 0.153

Parameter (Bromide →)	0.6	0.55	0.5	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05	Units
Sulfuric Acid Dose	40	40	40	40	40	40	40	40	40	40	40	mg/L
Ozone Dose	3	3	3	3	3	3	3	3	3	3	3	mg/L
Alum Dose	30	30	30	30	30	30	30	30	30	30	30	mg/L
Chlorine Dose	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	36	36	36	36	36	36	36	36	36	36	36	mg/L
TOC Removal	38	38	38	38	38	38	38	38	38	38	38	%
3-day TTHM	65	65	64	62	61	59	58	56	53	50	46	ug/L
3-day HAA5	18	18	18	18	19	19	20	20	21	22	24	ug/L
3-day HAA9	30		31	33	33	34	34	34	34		29	ug/L
3-day Bromate	14	13	12	10	9	7	6	5	4	3	1	ug/L
Cell colour	red	red	yellow	yellow	yellow	green	green	green	green	green	green	

TOC 6.5, UV254 0.170

Parameter (Bromide →)	0.6	0.55	0.5	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05	Units
Sulfuric Acid Dose	40	40	40	40	40	40	40	40	40	40	40	mg/L
Ozone Dose	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	mg/L
Alum Dose	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	32.5	mg/L
Chlorine Dose	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	37	37	37	37	37	37	37	37	37	37	37	mg/L
TOC Removal	39	39	39	39	39	39	39	39	39	39	39	%
3-day TTHM	69	68	67	65	64	62	61	59	56	53	48	ug/L
3-day HAA5	18	19	19	19	20	20	20	21	22	23	25	ug/L
3-day HAA9	32		33	34	35	35	35	35	35		30	ug/L
3-day Bromate	15	14	13	10	9	8	7	5	4	3	1	ug/L
Cell colour	red	red	red	red	yellow	green	green	green	green	green	green	

TOC 7, UV254 0.188

Parameter (Bromide →)	0.6	0.55	0.5	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05	Units
Sulfuric Acid Dose	40	40	40	40	40	40	40	40	40	40	40	mg/L
Ozone Dose	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	mg/L
Alum Dose	35	35	35	35	35	35	35	35	35	35	35	mg/L
Chlorine Dose	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	38	38	38	38	38	38	38	38	38	38	38	mg/L
TOC Removal	40	40	40	40	40	40	40	40	40	40	40	%
3-day TTHM	72	71	70	68	67	65	63	61	59	56	50	ug/L
3-day HAA5	19	19	20	20	20	21	21	22	23	24	26	ug/L
3-day HAA9	33		34	35	36	37			36		31	ug/L
3-day Bromate	15	14	13	10	9	8	7	5	4	3	1	ug/L
Cell colour	red	red	red	red	red	yellow	green	green	green	green	green	

TOC 7.5, UV254 0.205

Parameter (Bromide →)	0.6	0.55	0.5	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05	Units
Sulfuric Acid Dose	40	40	40	40	40	40	40	40	40	40	40	mg/L
Ozone Dose	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	mg/L
Alum Dose	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	mg/L
Chlorine Dose	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	39	39	39	39	39	39	39	39	39	39	39	mg/L
TOC Removal	41	41	41	41	41	41	41	41	41	41	41	%
3-day TTHM	76	75	74	72	70	69	67	65	62	59	53	ug/L
3-day HAA5	21	21	21	22	22	23	23	24	25	26	28	ug/L
3-day HAA9	35		37	38	39	39	39	39	39		34	ug/L
3-day Bromate	16	15	14	11	10	8	7	6	4	3	2	ug/L
Cell colour	red	red	red	red	red	yellow	yellow	yellow	green	green	green	

TOC 8, UV254 0.223

Parameter (Bromide →)	0.6	0.55	0.5	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05	Units
Sulfuric Acid Dose	40	40	40	40	40	40	40	40	40	40	40	mg/L
Ozone Dose	4	4	4	4	4	4	4	4	4	4	4	mg/L
Alum Dose	40	40	40	40	40	40	40	40	40	40	40	mg/L
Chlorine Dose	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	40	40	40	40	40	40	40	40	40	40	40	mg/L
TOC Removal	42	42	42	42	42	42	42	42	42	42	42	%
3-day TTHM	79	78	77	75	73	71	70	67	65	61	55	ug/L
3-day HAA5	21	22	22	23	23	23	24	25	25	27	29	ug/L
3-day HAA9	37		38	39	40	40	40	40	40		34	ug/L
3-day Bromate	17	15	14	11	10	9	7	6	4	3	2	ug/L
Cell colour	red	red	red	red	red	red	yellow	yellow	yellow	green	green	

TOC 8.5, UV254 0.240

Parameter (Bromide →)	0.6	0.55	0.5	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05	Units
Sulfuric Acid Dose	40	40	40	40	40	40	40	40	40	40	40	mg/L
Ozone Dose	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	mg/L
Alum Dose	42.5	42.5	42.5	42.5	42.5	42.5	42.5	42.5	42.5	42.5	42.5	mg/L
Chlorine Dose	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	41	41	41	41	41	41	41	41	41	41	41	mg/L
TOC Removal	43	43	43	43	43	43	43	43	43	43	43	%
3-day TTHM	82	81	79	77	75	74	72	69	67	63	57	ug/L
3-day HAA5	22	22	23	23	24	24	25	25	26	27	30	ug/L
3-day HAA9	38		39	40	41	41	41	41	41		35	ug/L
3-day Bromate	17	16	15	12	10	9	8	6	5	3	2	ug/L
Cell colour	red	red	red	red	red	red	yellow	yellow	yellow	green	green	

TOC 9, UV254 0.258

Parameter (Bromide →)	0.6	0.55	0.5	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05	Units
Sulfuric Acid Dose	40	40	40	40	40	40	40	40	40	40	40	mg/L
Ozone Dose	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	mg/L
Alum Dose	45	45	45	45	45	45	45	45	45	45	45	mg/L
Chlorine Dose	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	42	42	42	42	42	42	42	42	42	42	42	mg/L
TOC Removal	44	44	44	44	44	44	44	44	44	44	44	%
3-day TTHM	84	83	82	79	78	76	74	72	69	65	59	ug/L
3-day HAA5	23	23	23	24	24	25	25	26	27	28	31	ug/L
3-day HAA9												ug/L
3-day Bromate	18	16	15	12	11	9	8	6	5	3	2	ug/L
Cell colour	red	red	red	red	red	red	yellow	yellow	yellow	yellow	green	

TOC 10, UV254 0.293

Parameter (Bromide →)	0.6	0.55	0.5	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05	Units
Sulfuric Acid Dose	40	40	40	40	40	40	40	40	40	40	40	mg/L
Ozone Dose	5	5	5	5	5	5	5	5	5	5	5	mg/L
Alum Dose	50	50	50	50	50	50	50	50	50	50	50	mg/L
Chlorine Dose	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	mg/L
Secondary Chlorine Dose	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	mg/L
Ammmonia Dose	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	mg/L
Sodium Hydroxide Dose	43	43	43	43	43	43	43	43	43	43	43	mg/L
TOC Removal	46	46	46	46	46	46	46	46	46	46	46	%
3-day TTHM	89	88	87	84	82	81	78	76	73	69	62	ug/L
3-day HAA5	25	25	25	26	27	27	28	29	30	31	34	ug/L
3-day HAA9	42		43	45	45	46			45		39	ug/L
3-day Bromate	19	17	16	13	11	10	8	7	5	3	2	ug/L
Cell colour	red	red	red	red	red	red	yellow	yellow	yellow	yellow	green	

Bromide

TOC and UV254

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Appendix G

Cost Estimates for Future VWTP Upgrades

Unit Cost Summary

Capital Costs ($2010)/mgd

Item	Design Flow (mgd)					Cost Source
	20	40	100	200	400	
Treatment Units						
Raw Water Pumping	$ 15,313	$ 13,784	$ 12,867	$ 12,561	$ 12,408	4
Rapid Mix	$ 6,054	$ 4,565	$ 3,651	$ 3,569	$ 3,549	1
Flocculation	$ 59,127	$ 38,676	$ 25,040	$ 19,361	$ 15,302	1
Sedimentation	$ 163,298	$ 121,663	$ 104,296	$ 95,615	$ 89,103	1
Filtration (Total)	$ 153,180	$ 122,868	$ 95,332	$ 79,126	$ 67,486	1
GAC Contactors	$ 766,630	$ 632,184	$ 506,554	$ 430,883	$ 362,101	2
UV Disinfection	$ 432,051	$ 415,697	$ 394,443	$ 379,090	$ 364,334	1
Chlorine Contact Basin	$ 22,693	$ 16,981	$ 12,562	$ 9,850	$ 8,227	1
Reservoir	$ 102,142	$ 96,726	$ 93,477	$ 92,393	$ 91,852	4
Finished Water Pumping	$ 26,109	$ 22,565	$ 20,439	$ 19,731	$ 19,376	4
Chemical Systems						
Alum	$ 8,942	$ 6,317	$ 4,764	$ 3,992	$ 3,078	1
Chlorine (hypochlorination)	$ 8,366	$ 6,034	$ 3,923	$ 2,956	$ 2,195	1
Chlorine (gas chlorination)	$ 15,656	$ 12,105	$ 7,684	$ 6,475	$ 5,411	1
Ammonia (0.55 mg/L NH_3-N)	$ 8,140	$ 7,411	$ 5,539	$ 3,243	$ 1,930	2
Ozone (1-log rmvl, no pH adjst)	$ 335,381	$ 290,265	$ 237,557	$ 195,459	$ 174,723	2
Ozone (8.25/4.22 mg/L, with pH adjst)	$ 361,210	$ 315,000	$ 261,491	$ 219,125	$ 198,256	2
Ozone (4.5/2.43 mg/L, with pH adjst)	$ 302,190	$ 266,809	$ 225,610	$ 192,812	$ 165,227	2
Sulfuric Acid	$ 2,234	$ 1,503	$ 973	$ 757	$ 617	1
Caustic	$ 7,637	$ 6,553	$ 4,565	$ 3,473	$ 2,642	1
Solids Handling Process	$ 90,355	$ 54,448	$ 43,204	$ 31,024	$ 24,852	1
Admin/Laboratory/Maintenance Buildings	$ 41,201	$ 34,973	$ 21,463	$ 13,797	$ 8,870	1

Annual O&M Costs ($2010)/ kgal

Item	Design Flow (mgd)					Cost Source
	20	40	100	200	400	
Treatment Units						
Raw Water Pumping	$ 0.041	$ 0.040	$ 0.039	$ 0.038	$ 0.038	4
Rapid Mix	$ 0.012	$ 0.010	$ 0.008	$ 0.008	$ 0.008	1
Flocculation	$ 0.008	$ 0.006	$ 0.003	$ 0.003	$ 0.002	1
Sedimentation	$ 0.035	$ 0.024	$ 0.018	$ 0.014	$ 0.011	1
Filtration (Total)	$ 0.032	$ 0.022	$ 0.015	$ 0.011	$ 0.013	1
GAC Contactors	$ 0.431	$ 0.382	$ 0.338	$ 0.309	$ 0.293	2
UV Disinfection	$ 0.196	$ 0.194	$ 0.191	$ 0.189	$ 0.187	1
Chlorine Contact Basin	$ -	$ -	$ -	$ -	$ -	1
Reservoir	$ -	$ -	$ -	$ -	$ -	1
Finished Water Pumping	$ 0.050	$ 0.040	$ 0.039	$ 0.038	$ 0.038	4
Chemical Systems						
Alum	$ 0.030	$ 0.029	$ 0.029	$ 0.029	$ 0.029	1
Chlorine (hypochlorination)	$ 0.046	$ 0.044	$ 0.044	$ 0.044	$ 0.043	1
Chlorine (gas chlorination)	$ 0.020	$ 0.017	$ 0.016	$ 0.014	$ 0.014	1
Ammonia (0.55 mg/L NH_3-N)	$ 0.006	$ 0.004	$ 0.003	$ 0.002	$ 0.002	2
Ozone (1-log rmvl, no pH adjst)	$ 0.082	$ 0.072	$ 0.066	$ 0.064	$ 0.061	2
Ozone (8.25/4.22 mg/L, with pH adjst)	$ 0.227	$ 0.218	$ 0.211	$ 0.209	$ 0.206	2
Ozone (4.5/2.43 mg/L, with pH adjst)	$ 0.205	$ 0.196	$ 0.189	$ 0.188	$ 0.185	2
Sulfuric Acid	$ 0.014	$ 0.013	$ 0.013	$ 0.012	$ 0.012	1
Caustic	$ 0.028	$ 0.027	$ 0.027	$ 0.026	$ 0.026	1
Solids Handling Process	$ 0.054	$ 0.036	$ 0.029	$ 0.022	$ 0.017	1
Admin/Laboratory/Maintenance Buildings	$ 0.077	$ 0.046	$ 0.027	$ 0.015	$ 0.009	1

LAST UPDATED: 4/25/2011

Standard Design Criteria Sources

1	AWWA 2005. Water Treatment Plant Design, 4th Edition. McGraw-Hill Handbooks.
2	Jackson County Water Supply Project Design Confirmation Report. 2004. Malcolm Pirnie 4644006.
3	AWWA 2001. Self-Assessment for Treatment Plant Optimization Guidance Manual.
4	Kawamura 2000. Integrated Design and Operation of Water Treatment Facilities, 2nd Edition. John Wiley & Sons.

Cost Estimate Sources

1	W/WW Cost Model
2	December 2005 LT2ESWTR T&C Document
3	October 2006 Final Ground Water Rule T&C Document
4	McGivney and Kawamura 2008. Cost Estimating Manual for Water Treatment Facilities. John Wiley & Sons.

ENR Cost Indices

CCI

2000 Annual Average	6221		
2003 Annual Average	6694		
Jul-08	8293		
Dec-10	8952		
Building Cost			
January 2000	3503		
July 2008	4723		
Material Cost			
January 2000	2197		
July 2008	2815		
Skilled Labor		$/ hr	
January 2000	5641		
July 2008	7806	26	Inland Empire Utilities Agency, average of maintenance worker hourly rates.
		38	Increased to represent total cost (includes health and welfare, vacation and holiday, pension, and other payments)
Housing Cost	$/ sq ft		
January 2000	150		
July 2008			
Power	$/kWh		
California	0.15	Malcolm Pirnie Client in California (San Diego Water Authority)	
Chemical Costs			
Chlorine Gas			
1-ton Cylinder	0.31	$/lb	Greenway Water Treatment Plant
Sodium Hypochlorite	1.2	$/gal	
Liquid Alum	315	$/ton	
Sulfuric Acid	270	$/ton	SG = 1.84
Caustic Soda	580	$/ton	50% Solution Basic Chemical Solutions Quote (9/2/08)
			SG= 1.53

California Urban Water Agencies

Drinking Water Treatment Evaluation

Capital and O&M Costs for UW-1

MALCOLM PIRNIE

4/25/2011

UW-1 Design Capacity (mgd)	**100**
UW-1 Average Flow (mgd)	**50**

Baseline VWTP (Current Regulations)

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 12,867	100	4	$ 1,286,671
Rapid Mix	mgd	$ 3,651	100	1	$ 365,059
Flocculation	mgd	$ 25,040	100	1	$ 2,504,018
Sedimentation	mgd	$ 104,296	100	1	$ 10,429,597
Filtration	mgd	$ 95,332	100	1	$ 9,533,195
Reservoir	mgd	$ 93,477	100	1	$ 9,347,655
Finished Water Pumping	mgd	$ 20,439	100	1	$ 2,043,927
Treatment Unit Subtotal					$ 35,510,122
Chemical Systems					
Alum	mgd	$ 4,764	100	1	$ 476,385
Chlorine (gas chlorination)	mgd	$ 7,684	100	1	$ 768,434
Sulfuric Acid	mgd	$ 973	100	1	$ 97,258
Caustic	mgd	$ 4,565	100	1	$ 456,487
Chemical Systems Subtotal					$ 1,798,564
Solids Handling Process	mgd	$ 43,204	100	1	$ 4,320,414
Admin/Laboratory/Maintenance Buildings	mgd	$ 21,463	100	1	$ 2,146,267

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 43,775,366
Site Work	5%	$ 2,188,769
Electrical	12%	$ 5,253,044
Instrumentation and Controls	12%	$ 5,253,044
Subtotal		$ 56,470,223
Contractor OH & Profit	15%	$ 8,470,534
Contractor bonds, insurance, mob, demob	6%	$ 3,388,214
Sales Tax	3.64%	$ 2,055,517
Subtotal		$ 70,384,488
Engineering Fee	25%	$ 17,596,123
Legal/Administrative Fee	5%	$ 879,807
Subtotal		$ 88,860,418
Contingency	50%	$ 44,430,210
TOTAL CAPITAL COST		$ 133,290,628

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.039	18,250,000	1	$ 705,661
Rapid Mix	1000 gallon	$ 0.008	18,250,000	1	$ 148,441
Flocculation	1000 gallon	$ 0.003	18,250,000	1	$ 60,957
Sedimentation	1000 gallon	$ 0.018	18,250,000	1	$ 323,396
Filtration	1000 gallon	$ 0.015	18,250,000	1	$ 271,597
Reservoir	1000 gallon	$ -	18,250,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.039	18,250,000	1	$ 705,661
Treatment Unit Subtotal					$ 2,215,714
Chemical Systems					
Alum	1000 gallon	$ 0.029	18,250,000	1	$ 524,891
Chlorine (gas chlorination)	1000 gallon	$ 0.016	18,250,000	1	$ 291,692
Sulfuric Acid	1000 gallon	$ 0.013	18,250,000	1	$ 229,067
Caustic	1000gallon	$ 0.027	18,250,000	1	$ 484,402
Chemical Systems Subtotal					$ 1,530,052
Solids Handling Process	1000 gallon	$ 0.029	18,250,000	1	$ 532,733
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.027	18,250,000	1	$ 488,611
TOTAL O&M COST					$ 4,767,110

California Urban Water Agencies

Drinking Water Treatment Evaluation

Capital and O&M Costs for UW-1

MALCOLM PIRNIE | 4/25/2011

UW-1 Design Capacity (mgd)	**100**
UW-1 Average Flow (mgd)	**50**

UPGRADED VWTP (Plausible Regulatory Scenario)- Option 1

Convert to chloramines as secondary disfectant.

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 12,867	100	1	$ 1,286,671
Rapid Mix	mgd	$ 3,651	100	1	$ 365,059
Flocculation	mgd	$ 25,040	100	1	$ 2,504,018
Sedimentation	mgd	$ 104,296	100	1	$ 10,429,597
Filtration	mgd	$ 95,332	100	1	$ 9,533,195
Reservoir	mgd	$ 93,477	100	1	$ 9,347,655
Finished Water Pumping	mgd	$ 20,439	100	1	$ 2,043,927
Treatment Unit Subtotal					$ 35,510,122
Chemical Systems					
Alum	mgd	$ 4,764	100	1	$ 476,385
Chlorine (gas chlorination)	mgd	$ 7,684	100	1	$ 768,434
Ammonia (0.55 mg/L NH_3-N)	mgd	$ 5,539	100	2	$ 553,868
Sulfuric Acid	mgd	$ 973	100	1	$ 97,258
Caustic	mgd	$ 4,565	100	1	$ 456,487
Chemical Systems Subtotal					$ 2,352,432
Solids Handling Process	mgd	$ 43,204	100	1	$ 4,320,414
Admin/Laboratory/Maintenance Buildings	mgd	$ 21,463	100	1	$ 2,146,267

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 44,329,235
Site Work	5%	$ 2,216,462
Electrical	12%	$ 5,319,509
Instrumentation and Controls	12%	$ 5,319,509
Subtotal		$ 57,184,715
Contractor OH & Profit	15%	$ 8,577,708
Contractor bonds, insurance, mob, demob	6%	$ 3,431,083
Sales Tax	3.64%	$ 2,081,524
Subtotal		$ 71,275,030
Engineering Fee	25%	$ 17,818,758
Legal/Administrative Fee	5%	$ 890,938
Subtotal		$ 89,984,726
Contingency	50%	$ 44,992,363
TOTAL CAPITAL COST		$ 134,977,089

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.039	18,250,000	1	$ 705,661
Rapid Mix	1000 gallon	$ 0.008	18,250,000	1	$ 148,441
Flocculation	1000 gallon	$ 0.003	18,250,000	1	$ 60,957
Sedimentation	1000 gallon	$ 0.018	18,250,000	1	$ 323,396
Filtration	1000 gallon	$ 0.015	18,250,000	1	$ 271,597
Reservoir	1000 gallon	$ -	18,250,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.039	18,250,000	1	$ 705,661
Treatment Unit Subtotal					$ 2,215,714
Chemical Systems					
Alum	1000 gallon	$ 0.029	18,250,000	1	$ 524,891
Chlorine (gas chlorination)	1000 gallon	$ 0.016	18,250,000	1	$ 291,692
Ammonia (0.55 mg/L NH_3-N)	1000 gallon	$ 0.003	18,250,000	1	$ 51,727
Sulfuric Acid	1000 gallon	$ 0.013	18,250,000	1	$ 229,067
Caustic	1000gallon	$ 0.027	18,250,000	1	$ 484,402
Chemical Systems Subtotal					$ 1,581,779
Solids Handling Process	1000 gallon	$ 0.029	18,250,000	1	$ 532,733
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.027	18,250,000	1	$ 488,611
TOTAL O&M COST					$ 4,818,837

Drinking Water Treatment Evaluation
Capital and O&M Costs for UW-1

4/25/2011

UW-1 Design Capacity (mgd)	100
UW-1 Average Flow (mgd)	50

UPGRADED VWTP (Plausible Regulatory Scenario)- Option 2

In the case that chloramines are not accepted in this source water area, install GAC contactors.

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 12,867	100	1	$ 1,286,671
Rapid Mix	mgd	$ 3,651	100	1	$ 365,059
Flocculation	mgd	$ 25,040	100	1	$ 2,504,018
Sedimentation	mgd	$ 104,296	100	1	$ 10,429,597
Filtration	mgd	$ 95,332	100	1	$ 9,533,195
GAC Contactors	mgd	$ 506,554	100	2	$ 50,655,425
Reservoir	mgd	$ 93,477	100	1	$ 9,347,655
Finished Water Pumping	mgd	$ 20,439	100	1	$ 2,043,927
Treatment Unit Subtotal					$ 86,165,546
Chemical Systems					
Alum	mgd	$ 4,764	100	1	$ 476,385
Chlorine (gas chlorination)	mgd	$ 7,684	100	1	$ 768,434
Sulfuric Acid	mgd	$ 973	100	1	$ 97,258
Caustic	mgd	$ 4,565	100	1	$ 456,487
Chemical Systems Subtotal					$ 1,798,564
Solids Handling Process	mgd	$ 43,204	100	1	$ 4,320,414
Admin/Laboratory/Maintenance Buildings	mgd	$ 21,463	100	1	$ 2,146,267

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 94,430,791
Site Work	5%	$ 4,721,540
Electrical	12%	$ 11,331,695
Instrumentation and Controls	12%	$ 11,331,695
Subtotal		$ 121,815,721
Contractor OH & Profit	15%	$ 18,272,359
Contractor bonds, insurance, mob, demob	6%	$ 7,308,944
Sales Tax	3.64%	$ 4,434,093
Subtotal		$ 151,831,117
Engineering Fee	25%	$ 37,957,780
Legal/Administrative Fee	5%	$ 1,897,889
Subtotal		$ 191,686,786
Contingency	50%	$ 95,843,394
TOTAL CAPITAL COST		$ 287,530,180

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.039	18,250,000	1	$ 705,661
Rapid Mix	1000 gallon	$ 0.008	18,250,000	1	$ 148,441
Flocculation	1000 gallon	$ 0.003	18,250,000	1	$ 60,957
Sedimentation	1000 gallon	$ 0.018	18,250,000	1	$ 323,396
Filtration	1000 gallon	$ 0.015	18,250,000	1	$ 271,597
GAC Contactors	1000 gallon	$ 0.338	18,250,000	1	$ 6,167,433
Reservoir	1000 gallon	$ -	18,250,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.039	18,250,000	1	$ 705,661
Treatment Unit Subtotal					$ 8,383,147
Chemical Systems					
Alum	1000 gallon	$ 0.029	18,250,000	1	$ 524,891
Chlorine (gas chlorination)	1000 gallon	$ 0.016	18,250,000	1	$ 291,692
Sulfuric Acid	1000 gallon	$ 0.013	18,250,000	1	$ 229,067
Caustic	1000gallon	$ 0.027	18,250,000	1	$ 484,402
Chemical Systems Subtotal					$ 1,530,052
Solids Handling Process	1000 gallon	$ 0.029	18,250,000	1	$ 532,733
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.027	18,250,000	1	$ 488,611
TOTAL O&M COST					$ 10,934,543

California Urban Water Agencies

Drinking Water Treatment Evaluation
Capital and O&M Costs for UW-1

MALCOLM PIRNIE

4/25/2011

UW-1 Design Capacity (mgd)	100
UW-1 Average Flow (mgd)	50

UPGRADED VWTP (Outer Boundary Regulatory Scenario)

Add GAC Contactors and UV Disinfection. Continue to use free chlorine as secondary disinfectant.

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 12,867	100	1	$ 1,286,671
Rapid Mix	mgd	$ 3,651	100	1	$ 365,059
Flocculation	mgd	$ 25,040	100	1	$ 2,504,018
Sedimentation	mgd	$ 104,296	100	1	$ 10,429,597
Filtration	mgd	$ 95,332	100	1	$ 9,533,195
GAC Contactors	mgd	$ 506,554	100	2	$ 50,655,425
UV Disinfection	mgd	$ 394,443	100	3	$ 39,444,292
Reservoir	mgd	$ 93,477	100	1	$ 9,347,655
Finished Water Pumping	mgd	$ 20,439	100	1	$ 2,043,927
Treatment Unit Subtotal					$ 125,609,838
Chemical Systems					
Alum	mgd	$ 4,764	100	1	$ 476,385
Chlorine (gas chlorination)	mgd	$ 7,684	100	1	$ 768,434
Ammonia (0.55 mg/L NH_3-N)	mgd	$ 5,539	100	2	$ 553,868
Sulfuric Acid	mgd	$ 973	100	1	$ 97,258
Caustic	mgd	$ 4,565	100	1	$ 456,487
Chemical Systems Subtotal					$ 2,352,432
Solids Handling Process	mgd	$ 43,204	100	1	$ 4,320,414
Admin/Laboratory/Maintenance Buildings	mgd	$ 21,463	100	1	$ 2,146,267

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 134,428,952
Site Work	5%	$ 6,721,448
Electrical	12%	$ 16,131,475
Instrumentation and Controls	12%	$ 16,131,475
Subtotal		$ 173,413,350
Contractor OH & Profit	15%	$ 26,012,003
Contractor bonds, insurance, mob, demob	6%	$ 10,404,801
Sales Tax	3.64%	$ 6,312,246
Subtotal		$ 216,142,400
Engineering Fee	25%	$ 54,035,600
Legal/Administrative Fee	5%	$ 2,701,780
Subtotal		$ 272,879,780
Contingency	50%	$ 136,439,890
TOTAL CAPITAL COST		$ 409,319,670

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.039	18,250,000	1	$ 705,661
Rapid Mix	1000 gallon	$ 0.008	18,250,000	1	$ 148,441
Flocculation	1000 gallon	$ 0.003	18,250,000	1	$ 60,957
Sedimentation	1000 gallon	$ 0.018	18,250,000	1	$ 323,396
Filtration	1000 gallon	$ 0.015	18,250,000	1	$ 271,597
GAC Contactors	1001 gallon	$ 0.338	18,250,000	2	$ 6,167,433
UV Disinfection	1002 gallon	$ 0.191	18,250,000	3	$ 3,488,339
Reservoir	1000 gallon	$ -	18,250,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.039	18,250,000	1	$ 705,661
Treatment Unit Subtotal					$ 11,871,486
Chemical Systems					
Alum	1000 gallon	$ 0.029	18,250,000	1	$ 524,891
Chlorine (gas chlorination)	1000 gallon	$ 0.016	18,250,000	1	$ 291,692
Ammonia (0.55 mg/L NH_3-N)	1000 gallon	$ 0.003	0	1	$ -
Sulfuric Acid	1000 gallon	$ 0.013	18,250,000	1	$ 229,067
Caustic	1000gallon	$ 0.027	18,250,000	1	$ 484,402
Chemical Systems Subtotal					$ 1,530,052
Solids Handling Process	1000 gallon	$ 0.029	18,250,000	1	$ 532,733
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.027	18,250,000	1	$ 488,611
TOTAL O&M COST					$ 14,422,882

California Urban Water Agencies

Drinking Water Treatment Evaluation
Capital and O&M Costs for CD-1

MALCOLM PIRNIE

4/25/2011

CD-1 Design Capacity (mgd)	**40**
CD-1 Average Flow (mgd)	**20**

Baseline VWTP (Current Regulations)

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 13,784	40	4	$ 551,356
Rapid Mix	mgd	$ 4,565	40	1	$ 182,593
Flocculation	mgd	$ 38,676	40	1	$ 1,547,042
Sedimentation	mgd	$ 121,663	40	1	$ 4,866,529
Filtration	mgd	$ 122,868	40	1	$ 4,914,713
Reservoir	mgd	$ 96,726	40	1	$ 3,869,050
Finished Water Pumping	mgd	$ 22,565	40	1	$ 902,615
Treatment Unit Subtotal					$ 16,833,897
Chemical Systems					
Alum	mgd	$ 6,317	40	1	$ 252,693
Ozone (8.25/4.22 mg/L, with pH adjst)	mgd	$ 315,000	40	2	$ 12,600,011
Chlorine (hypochlorination)	mgd	$ 6,034	40	1	$ 241,340
Ammonia (0.55 mg/L NH_3-N)	mgd	$ 7,411	40	2	$ 296,433
Chemical Systems Subtotal					$ 13,390,477
Solids Handling Process	mgd	$ 54,448	40	1	$ 2,177,928
Admin/Laboratory/Maintenance Buildings	mgd	$ 34,973	40	2	$ 1,398,907

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 33,801,209
Site Work	5%	$ 1,690,061
Electrical	12%	$ 4,056,146
Instrumentation and Controls	12%	$ 4,056,146
Subtotal		$ 43,603,562
Contractor OH & Profit	15%	$ 6,540,535
Contractor bonds, insurance, mob, demob	6%	$ 2,616,214
Sales Tax	3.64%	$ 1,587,170
Subtotal		$ 54,347,481
Engineering Fee	25%	$ 13,586,871
Legal/Administrative Fee	5%	$ 679,344
Subtotal		$ 68,613,696
Contingency	50%	$ 34,306,849
TOTAL CAPITAL COST		$ 102,920,545

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.040	7,300,000	1	$ 290,551
Rapid Mix	1000 gallon	$ 0.010	7,300,000	1	$ 70,383
Flocculation	1000 gallon	$ 0.006	7,300,000	1	$ 41,671
Sedimentation	1000 gallon	$ 0.024	7,300,000	1	$ 175,102
Filtration	1000 gallon	$ 0.022	7,300,000	1	$ 161,756
Reservoir	1000 gallon	$ -	7,300,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.040	7,300,000	1	$ 290,551
Treatment Unit Subtotal					$ 1,030,014
Chemical Systems					
Alum	1000 gallon	$ 0.029	7,300,000	1	$ 212,015
Ozone (8.25/4.22 mg/L, with pH adjst)	1000 gallon	$ 0.218	7,300,000	2	$ 1,591,527
Chlorine (hypochlorination)	1000 gallon	$ 0.044	7,300,000	1	$ 323,924
Ammonia (0.55 mg/L NH_3-N)	1000 gallon	$ 0.004	7,300,000	2	$ 30,957
Chemical Systems Subtotal					$ 2,158,423
Solids Handling Process	1000 gallon	$ 0.036	7,300,000	1	$ 259,200
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.046	7,300,000	1	$ 334,006
TOTAL O&M COST					$ 3,781,643

Drinking Water Treatment Evaluation
Capital and O&M Costs for CD-1

MALCOLM PIRNIE 4/25/2011

CD-1 Design Capacity (mgd)	40
CD-1 Average Flow (mgd)	20

UPGRADED VWTP (Plausible Regulatory Scenario)

Reduce ozone dose and add UV disinfection. Short (10 min) free chlorine contact will be achieved in contact tank prior to conversion to chloramines.

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 13,784	40	0	$ 551,356
Rapid Mix	mgd	$ 4,565	40	0	$ 182,593
Flocculation	mgd	$ 38,676	40	1	$ 1,547,042
Sedimentation	mgd	$ 121,663	40	1	$ 4,866,529
Filtration	mgd	$ 122,868	40	1	$ 4,914,713
UV Disinfection	mgd	$ 415,697	40	1	$ 16,627,884
Chlorine Contact Basin	mgd	$ 16,981	40	1	$ 679,230
Reservoir	mgd	$ 96,726	40	1	$ 3,869,050
Finished Water Pumping	mgd	$ 22,565	40	0	$ 902,615
Treatment Unit Subtotal					$ 34,141,012
Chemical Systems					
Alum	mgd	$ 6,317	40	1	$ 252,693
Ozone (8.25/4.22 mg/L, with pH adjst)	mgd	$ 315,000	40	2	$ 12,600,011
Chlorine (hypochlorination) original feed at res inlet	mgd	$ 6,034	40	1	$ 241,340
Ammonia (0.55 mg/L NH_3-N) original feed at res outlet	mgd	$ 7,411	40	2	$ 296,433
Chlorine (hypochlorination) feed at contact basin	mgd	$ 6,034	40	1	$ 241,340
Ammonia (0.55 mg/L NH_3-N) feed at res inlet	mgd	$ 7,411	40	2	$ 296,433
Chemical Systems Subtotal					$ 13,928,250
Solids Handling Process	mgd	$ 54,448	40	1	$ 2,177,928
Admin/Laboratory/Maintenance Buildings	mgd	$ 34,973	40	2	$ 1,398,907

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 51,646,097
Site Work	5%	$ 2,582,305
Electrical	12%	$ 6,197,532
Instrumentation and Controls	12%	$ 6,197,532
Subtotal		$ 66,623,466
Contractor OH & Profit	15%	$ 9,993,520
Contractor bonds, insurance, mob, demob	6%	$ 3,997,408
Sales Tax	3.64%	$ 2,425,095
Subtotal		$ 83,039,489
Engineering Fee	25%	$ 20,759,873
Legal/Administrative Fee	5%	$ 1,037,994
Subtotal		$ 104,837,356
Contingency	50%	$ 52,418,678
TOTAL CAPITAL COST		$ 157,256,034

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.040	7,300,000	1	$ 290,551
Rapid Mix	1000 gallon	$ 0.010	7,300,000	1	$ 70,383
Flocculation	1000 gallon	$ 0.006	7,300,000	1	$ 41,671
Sedimentation	1000 gallon	$ 0.024	7,300,000	1	$ 175,102
Filtration	1000 gallon	$ 0.022	7,300,000	1	$ 161,756
UV Disinfection	1000 gallon	$ 0.194	7,300,000	1	$ 1,417,699
Chlorine Contact Basin	1000 gallon	$ -	7,300,000	1	$ -
Reservoir	1000 gallon	$ -	7,300,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.040	7,300,000	1	$ 290,551
Treatment Unit Subtotal					$ 2,447,713
Chemical Systems					
Alum	1000 gallon	$ 0.029	7,300,000	1	$ 212,015
Ozone (4.5/2.43 mg/L, with pH adjst) reduced dose	1000 gallon	$ 0.196	7,300,000	2	$ 1,428,195
Chlorine (hypochlorination) original feed at res inlet	1000 gallon	$ 0.044	0	1	$ -
Ammonia (0.55 mg/L NH_3-N) original feed at res outlet	1000 gallon	$ 0.004	0	2	$ -
Chlorine (hypochlorination) feed at contact basin	1000 gallon	$ 0.044	7,300,000	1	$ 323,924
Ammonia (0.55 mg/L NH_3-N) feed at res inlet	1000 gallon	$ 0.004	7,300,000	2	$ 30,957
Chemical Systems Subtotal					$ 1,995,091
Solids Handling Process	1000 gallon	$ 0.036	7,300,000	1	$ 259,200
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.046	7,300,000	1	$ 334,006
TOTAL O&M COST					$ 5,036,010

California Urban Water Agencies

Drinking Water Treatment Evaluation
Capital and O&M Costs for CD-1

MALCOLM PIRNIE | 4/25/2011

CD-1 Design Capacity (mgd)	**40**
CD-1 Average Flow (mgd)	**20**

UPGRADED VWTP (Outer Boundary Regulatory Scenario)

Add GAC Contactors and UV Disinfection. Eliminate chloramination and return to free chlorine as secondary disinfectant.

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 13,784	40	0	$ 551,356
Rapid Mix	mgd	$ 4,565	40	0	$ 182,593
Flocculation	mgd	$ 38,676	40	1	$ 1,547,042
Sedimentation	mgd	$ 121,663	40	1	$ 4,866,529
Filtration	mgd	$ 122,868	40	1	$ 4,914,713
GAC Contactors	mgd	$ 632,184	40	2	$ 25,287,349
UV Disinfection	mgd	$ 415,697	40	1	$ 16,627,884
Reservoir	mgd	$ 96,726	40	1	$ 3,869,050
Finished Water Pumping	mgd	$ 22,565	40	0	$ 902,615
Treatment Unit Subtotal					$ 58,749,131
Chemical Systems					
Alum	mgd	$ 6,317	40	1	$ 252,693
Ozone (8.25/4.22 mg/L, with pH adjst)	mgd	$ 315,000	40	2	$ 12,600,011
Chlorine (hypochlorination)	mgd	$ 6,034	40	1	$ 241,340
Ammonia (0.55 mg/L NH_3-N)	mgd	$ 7,411	40	2	$ 296,433
Chemical Systems Subtotal					$ 13,390,477
Solids Handling Process	mgd	$ 54,448	40	1	$ 2,177,928
Admin/Laboratory/Maintenance Buildings	mgd	$ 34,973	40	2	$ 1,398,907

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 75,716,443
Site Work	5%	$ 3,785,823
Electrical	12%	$ 9,085,974
Instrumentation and Controls	12%	$ 9,085,974
Subtotal		$ 97,674,214
Contractor OH & Profit	15%	$ 14,651,133
Contractor bonds, insurance, mob, demob	6%	$ 5,860,453
Sales Tax	3.64%	$ 3,555,342
Subtotal		$ 121,741,142
Engineering Fee	25%	$ 30,435,286
Legal/Administrative Fee	5%	$ 1,521,765
Subtotal		$ 153,698,193
Contingency	50%	$ 76,849,097
TOTAL CAPITAL COST		$ 230,547,290

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.040	7,300,000	1	$ 290,551
Rapid Mix	1000 gallon	$ 0.010	7,300,000	1	$ 70,383
Flocculation	1000 gallon	$ 0.006	7,300,000	1	$ 41,671
Sedimentation	1000 gallon	$ 0.024	7,300,000	1	$ 175,102
Filtration	1000 gallon	$ 0.022	7,300,000	1	$ 161,756
GAC Contactors	1000 gallon	$ 0.382	7,300,000	1	$ 2,791,273
UV Disinfection	1000 gallon	$ 0.194	7,300,000	1	$ 1,417,699
Reservoir	1000 gallon	$ -	7,300,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.040	7,300,000	1	$ 290,551
Treatment Unit Subtotal					$ 5,238,986
Chemical Systems					
Alum	1000 gallon	$ 0.029	7,300,000	1	$ 212,015
Ozone (8.25/4.22 mg/L, with pH adjst)	1000 gallon	$ 0.218	7,300,000	2	$ 1,591,527
Chlorine (hypochlorination) original feed at res inlet	1000 gallon	$ 0.044	7,300,000	1	$ 323,924
Ammonia (0.55 mg/L NH_3-N)	1000 gallon	$ 0.004	0	2	$ -
Chemical Systems Subtotal					$ 2,127,466
Solids Handling Process	1000 gallon	$ 0.036	7,300,000	1	$ 259,200
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.046	7,300,000	1	$ 334,006
TOTAL O&M COST					$ 7,959,658

Drinking Water Treatment Evaluation

Capital and O&M Costs for CAA-1

California Urban Water Agencies | MALCOLM PIRNIE | 4/25/2011

CAA-1 Design Capacity (mgd)	**40**
CAA-1 Average Flow (mgd)	**20**

Baseline VWTP (Current Regulations)

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 13,784	40	1	$ 551,356
Rapid Mix	mgd	$ 4,565	40	1	$ 182,593
Flocculation	mgd	$ 38,676	40	1	$ 1,547,042
Sedimentation	mgd	$ 121,663	40	1	$ 4,866,529
Filtration	mgd	$ 122,868	40	1	$ 4,914,713
Reservoir	mgd	$ 96,726	40	1	$ 3,869,050
Finished Water Pumping	mgd	$ 22,565	40	1	$ 902,615
Treatment Unit Subtotal					$ 16,833,897
Chemical Systems					
Alum	mgd	$ 6,317	40	1	$ 252,693
Chlorine (gas chlorination)	mgd	$ 12,105	40	1	$ 484,187
Ammonia (0.55 mg/L NH_3-N)	mgd	$ 7,411	40	2	$ 296,433
Chemical Systems Subtotal					$ 1,033,313
Solids Handling Process	mgd	$ 54,448	40	2	$ 2,177,928
Admin/Laboratory/Maintenance Buildings	mgd	$ 34,973	40	2	$ 1,398,907

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 21,444,045
Site Work	5%	$ 1,072,203
Electrical	12%	$ 2,573,286
Instrumentation and Controls	12%	$ 2,573,286
Subtotal		$ 27,662,820
Contractor OH & Profit	15%	$ 4,149,424
Contractor bonds, insurance, mob, demob	6%	$ 1,659,770
Sales Tax	3.64%	$ 1,006,927
Subtotal		$ 34,478,941
Engineering Fee	25%	$ 8,619,736
Legal/Administrative Fee	5%	$ 430,987
Subtotal		$ 43,529,664
Contingency	50%	$ 21,764,833
TOTAL CAPITAL COST		$ 65,294,497

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.040	7,300,000	1	$ 290,551
Rapid Mix	1000 gallon	$ 0.010	7,300,000	1	$ 70,383
Flocculation	1000 gallon	$ 0.006	7,300,000	1	$ 41,671
Sedimentation	1000 gallon	$ 0.024	7,300,000	1	$ 175,102
Filtration	1000 gallon	$ 0.022	7,300,000	1	$ 161,756
Reservoir	1000 gallon	$ -	7,300,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.040	7,300,000	1	$ 290,551
Treatment Unit Subtotal					$ 1,030,014
Chemical Systems					
Alum	1000 gallon	$ 0.029	7,300,000	1	$ 212,015
Chlorine (gas chlorination)	1000 gallon	$ 0.017	7,300,000	1	$ 127,606
Ammonia (0.55 mg/L NH_3-N)	1000 gallon	$ 0.004	7,300,000	2	$ 30,957
Chemical Systems Subtotal					$ 370,578
Solids Handling Process	1000 gallon	$ 0.036	7,300,000	2	$ 259,200
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.046	7,300,000	2	$ 334,006
TOTAL O&M COST					$ 1,400,592

California Urban Water Agencies

Drinking Water Treatment Evaluation
Capital and O&M Costs for CAA-1

MALCOLM PIRNIE | 4/25/2011

CAA-1 Design Capacity (mgd)	**40**
CAA-1 Average Flow (mgd)	**20**

UPGRADED VWTP (Plausible Regulatory Scenario)- No Upgrades Needed

UPGRADED VWTP (Outer Boundary Regulatory Scenario)

Add GAC Contactors and UV Disinfection. Eliminate chloramination and return to free chlorine as secondary disinfectant.

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 13,784	40	1	$ 551,356
Rapid Mix	mgd	$ 4,565	40	1	$ 182,593
Flocculation	mgd	$ 38,676	40	1	$ 1,547,042
Sedimentation	mgd	$ 121,663	40	1	$ 4,866,529
Filtration	mgd	$ 122,868	40	1	$ 4,914,713
GAC Contactors	mgd	$ 632,184	40	2	$ 25,287,349
UV Disinfection	mgd	$ 415,697	40	3	$ 16,627,884
Reservoir	mgd	$ 96,726	40	1	$ 3,869,050
Finished Water Pumping	mgd	$ 22,565	40	1	$ 902,615
Treatment Unit Subtotal					$ 58,749,131
Chemical Systems					
Alum	mgd	$ 6,317	40	1	$ 252,693
Chlorine (gas chlorination)	mgd	$ 12,105	40	1	$ 484,187
Ammonia (0.55 mg/L NH_3-N)	mgd	$ 7,411	40	2	$ 296,433
Chemical Systems Subtotal					$ 1,033,313
Solids Handling Process	mgd	$ 54,448	40	2	$ 2,177,928
Admin/Laboratory/Maintenance Buildings	mgd	$ 34,973	40	2	$ 1,398,907

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 63,359,279
Site Work	5%	$ 3,167,964
Electrical	12%	$ 7,603,114
Instrumentation and Controls	12%	$ 7,603,114
Subtotal		$ 81,733,471
Contractor OH & Profit	15%	$ 12,260,021
Contractor bonds, insurance, mob, demob	6%	$ 4,904,009
Sales Tax	3.64%	$ 2,975,099
Subtotal		$ 101,872,600
Engineering Fee	25%	$ 25,468,150
Legal/Administrative Fee	5%	$ 1,273,408
Subtotal		$ 128,614,158
Contingency	50%	$ 64,307,079
TOTAL CAPITAL COST		$ 192,921,237

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.040	7,300,000	1	$ 290,551
Rapid Mix	1000 gallon	$ 0.010	7,300,000	1	$ 70,383
Flocculation	1000 gallon	$ 0.006	7,300,000	1	$ 41,671
Sedimentation	1000 gallon	$ 0.024	7,300,000	1	$ 175,102
Filtration	1000 gallon	$ 0.022	7,300,000	1	$ 161,756
GAC Contactors	1001 gallon	$ 0.382	7,300,000	2	$ 2,791,273
UV Disinfection	1002 gallon	$ 0.194	7,300,000	3	$ 1,417,699
Reservoir	1000 gallon	$ -	7,300,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.040	7,300,000	1	$ 290,551
Treatment Unit Subtotal					$ 5,238,986
Chemical Systems					
Alum	1000 gallon	$ 0.029	7,300,000	1	$ 212,015
Chlorine (gas chlorination)	1000 gallon	$ 0.017	7,300,000	1	$ 127,606
Ammonia (0.55 mg/L NH_3-N)	1000 gallon	$ 0.004	0	2	$ -
Chemical Systems Subtotal					$ 339,621
Solids Handling Process	1000 gallon	$ 0.036	7,300,000	2	$ 259,200
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.046	7,300,000	2	$ 334,006
TOTAL O&M COST					$ 5,578,607

Drinking Water Treatment Evaluation
Capital and O&M Costs for CAA-2

MALCOLM PIRNIE 4/25/2011

CAA-2 Design Capacity (mgd)	**500**
CAA-2 Average Flow (mgd)	**325**

Baseline VWTP (Current Regulations)

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 12,408	500	1	$ 6,204,056
Rapid Mix	mgd	$ 3,549	500	1	$ 1,774,699
Flocculation	mgd	$ 15,302	500	1	$ 7,651,018
Sedimentation	mgd	$ 89,103	500	1	$ 44,551,420
Filtration	mgd	$ 67,486	500	1	$ 33,742,957
Reservoir	mgd	$ 91,852	500	1	$ 45,925,856
Finished Water Pumping	mgd	$ 19,376	500	1	$ 9,688,109
Treatment Unit Subtotal					$ 149,538,117
Chemical Systems					
Alum	mgd	$ 3,078	500	1	$ 1,538,994
Ozone (1-log rmvl, with pH adjst)	mgd	$ 198,256	500	2	$ 99,128,056
Chlorine (gas chlorination)	mgd	$ 5,411	500	1	$ 2,705,666
Ammonia (0.55 mg/L NH_3-N)	mgd	$ 1,930	500	2	$ 965,067
Chemical Systems Subtotal					$ 104,337,783
Solids Handling Process	mgd	$ 24,852	500	1	$ 12,426,110
Admin/Laboratory/Maintenance Buildings	mgd	$ 8,870	500	2	$ 4,434,891

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 270,736,901
Site Work	5%	$ 13,536,846
Electrical	12%	$ 32,488,429
Instrumentation and Controls	12%	$ 32,488,429
Subtotal		$ 349,250,605
Contractor OH & Profit	15%	$ 52,387,591
Contractor bonds, insurance, mob, demob	6%	$ 20,955,037
Sales Tax	3.64%	$ 12,712,723
Subtotal		$ 435,305,956
Engineering Fee	25%	$ 108,826,489
Legal/Administrative Fee	5%	$ 5,441,325
Subtotal		$ 549,573,770
Contingency	50%	$ 274,786,885
TOTAL CAPITAL COST		$ 824,360,655

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.038	118,625,000	1	$ 4,464,488
Rapid Mix	1000 gallon	$ 0.008	118,625,000	1	$ 895,171
Flocculation	1000 gallon	$ 0.002	118,625,000	1	$ 272,966
Sedimentation	1000 gallon	$ 0.011	118,625,000	1	$ 1,339,456
Filtration	1000 gallon	$ 0.013	118,625,000	1	$ 1,486,575
Reservoir	1000 gallon	$ -	118,625,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.038	118,625,000	1	$ 4,464,488
Treatment Unit Subtotal					$ 12,923,144
Chemical Systems					
Alum	1000 gallon	$ 0.029	118,625,000	1	$ 3,382,950
Ozone (1-log rmvl, with pH adjst)	1000 gallon	$ 0.206	118,625,000	2	$ 24,489,595
Chlorine (gas chlorination)	1000 gallon	$ 0.014	118,625,000	1	$ 1,611,627
Ammonia (0.55 mg/L NH_3-N)	1000 gallon	$ 0.002	118,625,000	2	$ 261,960
Chemical Systems Subtotal					$ 29,746,131
Solids Handling Process	1000 gallon	$ 0.017	118,625,000	1	$ 2,022,986
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.009	118,625,000	1	$ 1,098,701
TOTAL O&M COST					$ 45,790,962

California Urban Water Agencies

Drinking Water Treatment Evaluation
Capital and O&M Costs for CAA-2

MALCOLM PIRNIE

4/25/2011

CAA-2 Design Capacity (mgd)	500
CAA-2 Average Flow (mgd)	325

UPGRADED VWTP (Plausible Regulatory Scenario)

Reduce ozone dose and add UV disinfection. Short (10 min) free chlorine contact will be achieved in contact tank prior to conversion to chloramines.

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 12,408	500	1	$ 6,204,056
Rapid Mix	mgd	$ 3,549	500	1	$ 1,774,699
Flocculation	mgd	$ 15,302	500	1	$ 7,651,018
Sedimentation	mgd	$ 89,103	500	1	$ 44,551,420
Filtration	mgd	$ 67,486	500	1	$ 33,742,957
UV Disinfection	mgd	$ 364,334	500	1	$ 182,167,102
Chlorine Contact Basin	mgd	$ 8,227	500	1	$ 4,113,398
Reservoir	mgd	$ 91,852	500	1	$ 45,925,856
Finished Water Pumping	mgd	$ 19,376	500	1	$ 9,688,109
Treatment Unit Subtotal					$ 335,818,617
Chemical Systems					
Alum	mgd	$ 3,078	500	1	$ 1,538,994
Ozone (8.25/4.22 mg/L, with pH adjst)	mgd	$ 198,256	500	2	$ 99,128,056
Chlorine (hypochlorination) original feed at res inlet	mgd	$ 2,195	500	1	$ 1,097,695
Ammonia (0.55 mg/L NH_3-N) original feed at res outlet	mgd	$ 1,930	500	1	$ 965,067
Chlorine (hypochlorination) feed at contact basin	mgd	$ 2,195	500	1	$ 1,097,695
Ammonia (0.55 mg/L NH_3-N) feed at res inlet	mgd	$ 1,930	500	2	$ 965,067
Chemical Systems Subtotal					$ 104,792,575
Solids Handling Process	mgd	$ 24,852	500	1	$ 12,426,110
Admin/Laboratory/Maintenance Buildings	mgd	$ 8,870	500	2	$ 4,434,891

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 457,472,194
Site Work	5%	$ 22,873,610
Electrical	12%	$ 54,896,664
Instrumentation and Controls	12%	$ 54,896,664
Subtotal		$ 590,139,132
Contractor OH & Profit	15%	$ 88,520,870
Contractor bonds, insurance, mob, demob	6%	$ 35,408,348
Sales Tax	3.64%	$ 21,481,065
Subtotal		$ 735,549,415
Engineering Fee	25%	$ 183,887,354
Legal/Administrative Fee	5%	$ 9,194,368
Subtotal		$ 928,631,137
Contingency	50%	$ 464,315,569
TOTAL CAPITAL COST		$ 1,392,946,706

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.038	118,625,000	1	$ 4,464,488
Rapid Mix	1000 gallon	$ 0.008	118,625,000	1	$ 895,171
Flocculation	1000 gallon	$ 0.002	118,625,000	1	$ 272,966
Sedimentation	1000 gallon	$ 0.011	118,625,000	1	$ 1,339,456
Filtration	1000 gallon	$ 0.013	118,625,000	1	$ 1,486,575
UV Disinfection	1000 gallon	$ 0.187	118,625,000	1	$ 22,220,770
Chlorine Contact Basin	1000 gallon	$ -	118,625,000	1	$ -
Reservoir	1000 gallon	$ -	118,625,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.038	118,625,000	1	$ 4,464,488
Treatment Unit Subtotal					$ 35,143,914
Chemical Systems					
Alum	1000 gallon	$ 0.029	118,625,000	1	$ 3,382,950
Ozone (4.5/2.43 mg/L, with pH adjst) reduced dose	1000 gallon	$ 0.185	118,625,000	2	$ 21,912,352
Chlorine (hypochlorination) original feed at res inlet	1000 gallon	$ 0.043	0	1	$ -
Ammonia (0.55 mg/L NH_3-N) original feed at res outlet	1000 gallon	$ 0.002	0	1	$ -
Chlorine (hypochlorination) feed at contact basin	1000 gallon	$ 0.043	118,625,000	1	$ 5,155,251
Ammonia (0.55 mg/L NH_3-N)	1000 gallon	$ 0.002	118,625,000	2	$ 261,960
Chemical Systems Subtotal					$ 30,712,512
Solids Handling Process	1000 gallon	$ 0.017	118,625,000	1	$ 2,022,986
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.009	118,625,000	1	$ 1,098,701
TOTAL O&M COST					$ 68,978,113

Drinking Water Treatment Evaluation
Capital and O&M Costs for CAA-2

MALCOLM PIRNIE | 4/25/2011

CAA-2 Design Capacity (mgd)	**500**
CAA-2 Average Flow (mgd)	**325**

UPGRADED VWTP (Outer Boundary Regulatory Scenario)

Add GAC Contactors and UV Disinfection. Eliminate chloramination and return to free chlorine as secondary disinfectant.

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 12,408	500	1	$ 6,204,056
Rapid Mix	mgd	$ 3,549	500	1	$ 1,774,699
Flocculation	mgd	$ 15,302	500	1	$ 7,651,018
Sedimentation	mgd	$ 89,103	500	1	$ 44,551,420
Filtration	mgd	$ 67,486	500	1	$ 33,742,957
GAC Contactors	mgd	$ 362,101	500	1	$ 181,050,399
UV Disinfection	mgd	$ 364,334	500	1	$ 182,167,102
Reservoir	mgd	$ 91,852	500	1	$ 45,925,856
Finished Water Pumping	mgd	$ 19,376	500	1	$ 9,688,109
Treatment Unit Subtotal					$ 512,755,618
Chemical Systems					
Alum	mgd	$ 3,078	500	1	$ 1,538,994
Ozone (8.25/4.22 mg/L, with pH adjst)	mgd	$ 198,256	500	2	$ 99,128,056
Chlorine (hypochlorination)	mgd	$ 2,195	500	1	$ 1,097,695
Ammonia (0.55 mg/L NH_3-N)	mgd	$ 1,930	500	1	$ 965,067
Chemical Systems Subtotal					$ 102,729,813
Solids Handling Process	mgd	$ 24,852	500	1	$ 12,426,110
Admin/Laboratory/Maintenance Buildings	mgd	$ 8,870	500	2	$ 4,434,891

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 632,346,432
Site Work	5%	$ 31,617,322
Electrical	12%	$ 75,881,572
Instrumentation and Controls	12%	$ 75,881,572
Subtotal		$ 815,726,898
Contractor OH & Profit	15%	$ 122,359,035
Contractor bonds, insurance, mob, demob	6%	$ 48,943,614
Sales Tax	3.64%	$ 29,692,460
Subtotal		$ 1,016,722,007
Engineering Fee	25%	$ 254,180,502
Legal/Administrative Fee	5%	$ 12,709,026
Subtotal		$ 1,283,611,535
Contingency	50%	$ 641,805,768
TOTAL CAPITAL COST		$ 1,925,417,303

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.038	118,625,000	1	$ 4,464,488
Rapid Mix	1000 gallon	$ 0.008	118,625,000	1	$ 895,171
Flocculation	1000 gallon	$ 0.002	118,625,000	1	$ 272,966
Sedimentation	1000 gallon	$ 0.011	118,625,000	1	$ 1,339,456
Filtration	1000 gallon	$ 0.013	118,625,000	1	$ 1,486,575
GAC Contactors	1000 gallon	$ 0.293	118,625,000	1	$ 34,798,860
UV Disinfection	1000 gallon	$ 0.187	118,625,000	1	$ 22,220,770
Reservoir	1000 gallon	$ -	118,625,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.038	118,625,000	1	$ 4,464,488
Treatment Unit Subtotal					$ 69,942,774
Chemical Systems					
Alum	1000 gallon	$ 0.029	118,625,000	1	$ 3,382,950
Ozone (8.25/4.22 mg/L, with pH adjst)	1000 gallon	$ 0.206	118,625,000	2	$ 24,489,595
Chlorine (hypochlorination) original feed at res inlet	1000 gallon	$ 0.043	118,625,000	1	$ 5,155,251
Ammonia (0.55 mg/L NH_3-N)	1000 gallon	$ 0.002	0	2	$ -
Chemical Systems Subtotal					$ 33,027,796
Solids Handling Process	1000 gallon	$ 0.017	118,625,000	1	$ 2,022,986
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.009	118,625,000	1	$ 1,098,701
TOTAL O&M COST					$ 106,092,257

Drinking Water Treatment Evaluation
Capital and O&M Costs for CAAW-1

California Urban Water Agencies

MALCOLM PIRNIE

4/25/2011

CAAW-1 Design Capacity (mgd)	**800**
CAAW-1 Average Flow (mgd)	**600**

Baseline VWTP (Current Regulations)

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 12,408	800	2	$ 9,926,490
Rapid Mix	mgd	$ 3,549	800	1	$ 2,839,519
Flocculation	mgd	$ 15,302	800	1	$ 12,241,630
Sedimentation	mgd	$ 89,103	800	1	$ 71,282,273
Filtration	mgd	$ 67,486	800	1	$ 53,988,732
Reservoir	mgd	$ 91,852	800	1	$ 73,481,370
Finished Water Pumping	mgd	$ 19,376	800	2	$ 15,500,975
Treatment Unit Subtotal					$ 239,260,987
Chemical Systems					
Alum	mgd	$ 3,078	800	1	$ 2,462,390
Ozone (8.25/4.22 mg/L, with pH adjst)	mgd	$ 198,256	800	2	$ 158,604,890
Chlorine (gas chlorination)	mgd	$ 5,411	800	1	$ 4,329,065
Ammonia (0.55 mg/L NH_3-N)	mgd	$ 1,930	800	2	$ 1,544,107
Chemical Systems Subtotal					$ 166,940,453
Solids Handling Process	mgd	$ 24,852	800	2	$ 19,881,776
Admin/Laboratory/Maintenance Buildings	mgd	$ 8,870	800	2	$ 7,095,826

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 433,179,042
Site Work	5%	$ 21,658,953
Electrical	12%	$ 51,981,485
Instrumentation and Controls	12%	$ 51,981,485
Subtotal		$ 558,800,965
Contractor OH & Profit	15%	$ 83,820,145
Contractor bonds, insurance, mob, demob	6%	$ 33,528,058
Sales Tax	3.64%	$ 20,340,356
Subtotal		$ 696,489,524
Engineering Fee	25%	$ 174,122,381
Legal/Administrative Fee	5%	$ 8,706,120
Subtotal		$ 879,318,025
Contingency	50%	$ 439,659,013
TOTAL CAPITAL COST		$ 1,318,977,038

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.038	219,000,000	2	$ 8,242,132
Rapid Mix	100 gallon	$ 0.008	219,000,000	1	$ 1,652,623
Flocculation	1000 gallon	$ 0.002	219,000,000	1	$ 503,938
Sedimentation	1000 gallon	$ 0.011	219,000,000	1	$ 2,472,841
Filtration	1000 gallon	$ 0.013	219,000,000	1	$ 2,744,446
Reservoir	1000 gallon	$ -	219,000,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.038	219,000,000	2	$ 8,242,132
Treatment Unit Subtotal					$ 23,858,112
Chemical Systems					
Alum	1000 gallon	$ 0.029	219,000,000	1	$ 6,245,446
Ozone (8.25/4.22 mg/L, with pH adjst)	1000 gallon	$ 0.206	219,000,000	2	$ 45,211,560
Chlorine (gas chlorination)	1000 gallon	$ 0.014	219,000,000	1	$ 2,975,311
Ammonia (0.55 mg/L NH_3-N)	1000 gallon	$ 0.002	219,000,000	2	$ 483,618
Chemical Systems Subtotal					$ 54,915,935
Solids Handling Process	1000 gallon	$ 0.017	219,000,000	2	$ 3,734,744
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.009	219,000,000	2	$ 2,028,370
TOTAL O&M COST					$ 84,537,161

California Urban Water Agencies

Drinking Water Treatment Evaluation
Capital and O&M Costs for CAAW-1

MALCOLM PIRNIE

4/25/2011

CAAW-1 Design Capacity (mgd)	**800**
CAAW-1 Average Flow (mgd)	**600**

UPGRADED VWTP (Plausible Regulatory Scenario)- No Upgrades Needed

UPGRADED VWTP (Outer Boundary Regulatory Scenario)

Add GAC Contactors and UV Disinfection. Eliminate chloramination and return to free chlorine as secondary disinfectant.

CAPTIAL COSTS

Major Items	Units	Unit Cost	No. of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	mgd	$ 12,408	800	2	$ 9,926,490
Rapid Mix	mgd	$ 3,549	800	1	$ 2,839,519
Flocculation	mgd	$ 15,302	800	1	$ 12,241,630
Sedimentation	mgd	$ 89,103	800	1	$ 71,282,273
Filtration	mgd	$ 67,486	800	1	$ 53,988,732
GAC Contactors	mgd	$ 362,101	800	2	$ 289,680,639
UV Disinfection	mgd	$ 364,334	800	3	$ 291,467,364
Reservoir	mgd	$ 91,852	800	1	$ 73,481,370
Finished Water Pumping	mgd	$ 19,376	800	2	$ 15,500,975
Treatment Unit Subtotal					$ 820,408,989
Chemical Systems					
Alum	mgd	$ 3,078	800	1	$ 2,462,390
Ozone (8.25/4.22 mg/L, with pH adjst)	mgd	$ 198,256	800	2	$ 158,604,890
Chlorine (gas chlorination)	mgd	$ 5,411	800	1	$ 4,329,065
Ammonia (0.55 mg/L NH_3-N)	mgd	$ 1,930	800	2	$ 1,544,107
Chemical Systems Subtotal					$ 166,940,453
Solids Handling Process	mgd	$ 24,852	800	2	$ 19,881,776
Admin/Laboratory/Maintenance Buildings	mgd	$ 8,870	800	2	$ 7,095,826

Cost Multipliers

Multiplier	Percentage of Subtotal	Total
Subtotal for Treatment Units and Chemical Systems		$ 1,014,327,044
Site Work	5%	$ 50,716,353
Electrical	12%	$ 121,719,246
Instrumentation and Controls	12%	$ 121,719,246
Subtotal		$ 1,308,481,889
Contractor OH & Profit	15%	$ 196,272,284
Contractor bonds, insurance, mob, demob	6%	$ 78,508,914
Sales Tax	3.64%	$ 47,628,741
Subtotal		$ 1,630,891,828
Engineering Fee	25%	$ 407,722,958
Legal/Administrative Fee	5%	$ 20,386,148
Subtotal		$ 2,059,000,934
Contingency	50%	$ 1,029,500,468
TOTAL CAPITAL COST		$ 3,088,501,402

O&M COSTS

Major Items	Units	Unit Cost	No of Units	Cost Basis	Total (2010 $)
Treatment Units					
Raw Water Pumping	1000 gallon	$ 0.038	219,000,000	2	$ 8,242,132
Rapid Mix	100 gallon	$ 0.008	219,000,000	1	$ 1,652,623
Flocculation	1000 gallon	$ 0.002	219,000,000	1	$ 503,938
Sedimentation	1000 gallon	$ 0.011	219,000,000	1	$ 2,472,841
Filtration	1000 gallon	$ 0.013	219,000,000	1	$ 2,744,446
GAC Contactors	1001 gallon	$ 0.293	219,000,000	2	$ 64,244,049
UV Disinfection	1002 gallon	$ 0.187	219,000,000	3	$ 41,022,960
Reservoir	1000 gallon	$ -	219,000,000	1	$ -
Finished Water Pumping	1000 gallon	$ 0.038	219,000,000	2	$ 8,242,132
Treatment Unit Subtotal					$ 129,125,121
Chemical Systems					
Alum	1000 gallon	$ 0.029	219,000,000	1	$ 6,245,446
Ozone (8.25/4.22 mg/L, with pH adjst)	1000 gallon	$ 0.206	219,000,000	2	$ 45,211,560
Chlorine (gas chlorination)	1000 gallon	$ 0.014	219,000,000	1	$ 2,975,311
Ammonia (0.55 mg/L NH_3-N)	1000 gallon	$ 0.002	0	2	$ -
Chemical Systems Subtotal					$ 54,432,317
Solids Handling Process	1000 gallon	$ 0.017	219,000,000	2	$ 3,734,744
Admin/Laboratory/Maintenance Buildings	1000 gallon	$ 0.009	219,000,000	2	$ 2,028,370
TOTAL O&M COST					$ 189,320,552

California Urban Water Agencies

Drinking Water Treatment Evaluation

Virtual Water Treatment Plant Cost Summary

MALCOLM PIRNIE

4/25/2011

BASELINE VWTPS (Current Regulations)

MEDIAN

Virtual Water Treatment Plant (VWTP)	Design Flow	Average Flow	Capital Cost		Annual O&M Cost		Present Worth of Annual O&M	Total Present Worth	Annualized Construction Cost	Total Equivalent Annual Cost
	(mgd)	(mgd)	(Millions $)	$/gal	(Millions $/yr)	$/kgal	(Millions $)	(Millions $)	(Millions $/yr)	(Millions $/yr)
UW-1	100	50	$133	$1.33	$4.8	$0.26	$55	$188	$12	$16
CD-1	40	20	$103	$2.57	$3.8	$0.52	$43	$146	$9	$13
CAA-1	40	20	$65	$1.63	$1.4	$0.19	$16	$81	$6	$7
CAA-2	500	325	$824	$1.65	$45.8	$0.39	$525	$1,350	$72	$118
CAAW-1	800	600	$1,319	$1.65	$84.5	$0.39	$970	$2,289	$115	$200

LOW RANGE

Virtual Water Treatment Plant (VWTP)	Design Flow	Average Flow	Capital Cost		Annual O&M Cost		Present Worth of Annual O&M	Total Present Worth	Annualized Construction Cost	Total Equivalent Annual Cost
	(mgd)	(mgd)	(Millions $)	$/gal	(Millions $/yr)	$/kgal	(Millions $)	(Millions $)	(Millions $/yr)	(Millions $/yr)
UW-1	mgd	mgd	$93	$0.93	$3.3	$0.18	$38	$132	$8	$11
CD-1	mgd	mgd	$72	$1.80	$2.6	$0.36	$30	$102	$6	$9
CAA-1	mgd	mgd	$46	$1.14	$1.0	$0.13	$11	$57	$4	$5
CAA-2	mgd	mgd	$577	$1.15	$32.1	$0.27	$368	$945	$50	$82
CAAW-1	mgd	mgd	$923	$1.15	$59.2	$0.27	$679	$1,602	$80	$140

HIGH RANGE

Virtual Water Treatment Plant (VWTP)	Design Flow	Average Flow	Capital Cost		Annual O&M Cost		Present Worth of Annual O&M	Total Present Worth	Annualized Construction Cost	Total Equivalent Annual Cost
	(mgd)	(mgd)	(Millions $)	$/gal	(Millions $/yr)	$/kgal	(Millions $)	(Millions $)	(Millions $/yr)	(Millions $/yr)
UW-1	mgd	mgd	$200	$2.00	$7.2	$0.39	$82	$282	$17	$25
CD-1	0	mgd	$154	$3.86	$5.7	$0.78	$65	$219	$13	$19
CAA-1	0	mgd	$98	$2.45	$2.1	$0.29	$24	$122	$9	$11
CAA-2	0	mgd	$1,237	$2.47	$68.7	$0.58	$788	$2,024	$108	$176
CAAW-1	0	mgd	$1,978	$2.47	$126.8	$0.58	$1,454	$3,433	$172	$299

Assumptions: Years (n) = 20 Rate (i) = 6%

California Urban Water Agencies

Drinking Water Treatment Evaluation
Virtual Water Treatment Plant Cost Summary

MALCOLM PIRNIE

4/25/2011

UPGRADED VWTPS (Plausible Regulatory Scenario)

MEDIAN

Virtual Water Treatment Plant (VWTP)	Design Flow (mgd)	Average Flow (mgd)	Capital Cost (Millions $)	Capital Cost $/gal	Annual O&M Cost (Millions $/yr)	Annual O&M Cost $/kgal	Present Worth of Annual O&M (Millions $)	Total Present Worth (Millions $)	Annualized Construction Cost (Millions $/yr)	Total Equivalent Annual Cost (Millions $/yr)
UW-1	100	50	$135	$1.35	$4.8	$0.26	$55	$190	$12	$17
	100	50	$288	$2.88	$10.9	$0.60	$125	$413	$25	$36
CD-1	40	20	$157	$3.93	$5.0	$0.69	$58	$215	$14	$19
CAA-1*	40	20	$65	$1.63	$1.4	$0.19	$16	$81	$6	$7
CAA-2	500	325	$1,393	$2.79	$69.0	$0.58	$791	$2,184	$121	$190
CAAW-1*	800	600	$1,319	$1.65	$84.5	$0.39	$970	$2,289	$115	$200

LOW RANGE

Virtual Water Treatment Plant (VWTP)	Design Flow (mgd)	Average Flow (mgd)	Capital Cost (Millions $)	Capital Cost $/gal	Annual O&M Cost (Millions $/yr)	Annual O&M Cost $/kgal	Present Worth of Annual O&M (Millions $)	Total Present Worth (Millions $)	Annualized Construction Cost (Millions $/yr)	Total Equivalent Annual Cost (Millions $/yr)
UW-1	mgd	mgd	$94	$0.94	$3.4	$0.18	$39	$133	$8	$12
	100	50	$201	$2.01	$7.7	$0.42	$88	$289	$18	$25
CD-1	mgd	mgd	$110	$2.75	$3.5	$0.48	$40	$151	$10	$13
CAA-1*	mgd	mgd	$46	$1.14	$1.0	$0.13	$11	$57	$4	$5
CAA-2	mgd	mgd	$975	$1.95	$48.3	$0.41	$554	$1,529	$85	$133
CAAW-1*	mgd	mgd	$923	$1.15	$59.2	$0.27	$679	$1,602	$80	$140

HIGH RANGE

Virtual Water Treatment Plant (VWTP)	Design Flow (mgd)	Average Flow (mgd)	Capital Cost (Millions $)	Capital Cost $/gal	Annual O&M Cost (Millions $/yr)	Annual O&M Cost $/kgal	Present Worth of Annual O&M (Millions $)	Total Present Worth (Millions $)	Annualized Construction Cost (Millions $/yr)	Total Equivalent Annual Cost (Millions $/yr)
UW-1	mgd	mgd	$202	$2.02	$7.2	$0.40	$83	$285	$18	$25
	100	50	$431	$4.31	$16.4	$0.90	$188	$619	$38	$54
CD-1	mgd	mgd	$236	$5.90	$7.6	$1.03	$87	$323	$21	$28
CAA-1*	mgd	mgd	$98	$2.45	$2.1	$0.29	$24	$122	$9	$11
CAA-2	mgd	mgd	$2,089	$4.18	$103.5	$0.87	$1,187	$3,276	$182	$286
CAAW-1*	mgd	mgd	$1,978	$2.47	$126.8	$0.58	$1,454	$3,433	$172	$299

*No upgrades needed, baseline cc *Assumptions:* *Years (n) =* *20* *Rate (i) =* *6%*

California Urban Water Agencies

Drinking Water Treatment Evaluation

Virtual Water Treatment Plant Cost Summary

MALCOLM PIRNIE

4/25/2011

UPGRADED VWTPS (Outer Boundary Regulatory Scenario)

MEDIAN

Virtual Water Treatment Plant (VWTP)	Design Flow	Average Flow	Capital Cost		Annual O&M Cost		Present Worth of Annual O&M	Total Present Worth	Annualized Construction Cost	Total Equivalent Annual Cost
	(mgd)	(mgd)	(Millions $)	$/gal	(Millions $/yr)	$/kgal	(Millions $)	(Millions $)	(Millions $/yr)	(Millions $/yr)
UW-1	100	50	$409	$4.09	$14.4	$0.79	$165	$575	$36	$50
CD-1	40	20	$231	$5.76	$8.0	$1.09	$91	$322	$20	$28
CAA-1	40	20	$193	$4.82	$5.6	$0.76	$64	$257	$17	$22
CAA-2	500	325	$1,925	$3.85	$106.1	$0.89	$1,217	$3,142	$168	$274
CAAW-1	800	600	$3,089	$3.86	$189.3	$0.86	$2,171	$5,260	$269	$459

LOW RANGE

Virtual Water Treatment Plant (VWTP)	Design Flow	Average Flow	Capital Cost		Annual O&M Cost		Present Worth of Annual O&M	Total Present Worth	Annualized Construction Cost	Total Equivalent Annual Cost
	(mgd)	(mgd)	(Millions $)	$/gal	(Millions $/yr)	$/kgal	(Millions $)	(Millions $)	(Millions $/yr)	(Millions $/yr)
UW-1	mgd	mgd	$287	$2.87	$10.1	$0.55	$116	$402	$25	$35
CD-1	mgd	mgd	$161	$4.03	$5.6	$0.76	$64	$225	$14	$20
CAA-1	mgd	mgd	$135	$3.38	$3.9	$0.53	$45	$180	$12	$16
CAA-2	mgd	mgd	$1,348	$2.70	$74.3	$0.63	$852	$2,200	$118	$192
CAAW-1	mgd	mgd	$2,162	$2.70	$132.5	$0.61	$1,520	$3,682	$188	$321

HIGH RANGE

Virtual Water Treatment Plant (VWTP)	Design Flow	Average Flow	Capital Cost		Annual O&M Cost		Present Worth of Annual O&M	Total Present Worth	Annualized Construction Cost	Total Equivalent Annual Cost
	(mgd)	(mgd)	(Millions $)	$/gal	(Millions $/yr)	$/kgal	(Millions $)	(Millions $)	(Millions $/yr)	(Millions $/yr)
UW-1	mgd	mgd	$614	$6.14	$21.6	$1.19	$248	$862	$54	$75
CD-1	0	mgd	$346	$8.65	$11.9	$1.64	$137	$483	$30	$42
CAA-1	0	mgd	$289	$7.23	$8.4	$1.15	$96	$385	$25	$34
CAA-2	0	mgd	$2,888	$5.78	$159.1	$1.34	$1,825	$4,713	$252	$411
CAAW-1	0	mgd	$4,633	$5.79	$284.0	$1.30	$3,257	$7,890	$404	$688

Assumptions: Years (n) = 20 Rate (i) = 6%

Drinking Water Treatment Evaluation
Virtual Water Treatment Plant Cost Summary

REGIONAL ADDED COSTS

Virtual Water Treatment Plant (VWTP)	VWTP Design Capacity (mgd)	Representative Regional Treatment Capacity/ VWTP Capacity	Scenario	Added Capital Cost (Millions $)			Added Annual O&M Cost (Millions $/yr)		
				Low Range	Median	High Range	Low Range	Median	High Range
Upper Watersheds- 818 mgd Total Regional Treatment Capacity									
UW-1	100	8.18	Plausible	$ 10	$ 14	$ 21	$ 0.3	$ 0.4	$ 0.6
				$ 883	$ 1,262	$ 1,893	$ 35.3	$ 50.4	$ 75.7
			Outer Boundary	$ 1,581	$ 2,258	$ 3,387	$ 55.3	$ 79.0	$ 118.5
Central Delta- 284 mgd Total Regional Treatment Capacity									
CD-1	40	7.1	Plausible	$ 270	$ 386	$ 579	$ 6.2	$ 8.9	$ 13.4
			Outer Boundary	$ 634	$ 906	$ 1,359	$ 20.8	$ 29.7	$ 44.5
CAA- 2201 mgd Total Regional Treatment Capacity									
CAA-1	40	3.86	Plausible*						
			Outer Boundary	$ 345	$ 493	$ 739	$ 11.3	$ 16.1	$ 24.2
CAA-2	500	6.78	Plausible	$ 2,699	$ 3,855	$ 5,783	$ 110.0	$ 157.2	$ 235.8
			Outer Boundary	$ 5,226	$ 7,465	$ 11,198	$ 286.2	$ 408.8	$ 613.3
CAA-West - 836 mgd Total Regional Treatment Capacity									
CAAW-1	800	1.04	Plausible*						
			Outer Boundary	$ 1,288	$ 1,840	$ 2,760	$ 76.3	$ 109.0	$ 163.5
TOTAL			Plausible	$ 2,978	$ 4,255	$ 6,382	$ 116.6	$ 167	$ 249.8
				$ 3,852	$ 5,502	$ 8,254	$ 151.6	$ 217	$ 324.8
			Outer Boundary	$ 9,074	$ 12,962	$ 19,443	$ 449.8	$ 643	$ 963.9

*No upgrades needed, baseline costs remain.