



## **Chapter 3**

### **Delivery Alternative Contaminant Barriers**

This chapter describes the different categories of contaminant barriers, defined by regulatory requirements and City finished water quality goals, for drinking water produced at BRWTF with each of the source waters considered in this study. The two water sources for BRWTF considered here were (1) seasonal use of the BFC and Boulder Reservoir and (2) direct conveyance to BRWTF through a dedicated pipeline. These two sources provide distinctly different raw water quality to BRWTF as discussed in Chapter 2, which impacts the combination of drinking water treatment processes that best addresses contaminant barriers in a cost-effective multi-barrier water delivery approach.

The BRWTF currently meets or exceeds all National Primary and Secondary drinking water regulations during routine operation, and based on source water quality data reviewed in Chapter 2, will likely continue to do so for the foreseeable future. However, finished water quality in areas served by BRWTF is vulnerable to short-term degradation due to seasonal variation in Boulder Reservoir water quality and acute contamination episodes in either BFC or Boulder Reservoir. Of particular concern are microbial contamination in BFC or Boulder Reservoir, DBP formation during treatment and distribution, contamination by organic micro-pollutants in BFC and Boulder Reservoir, seasonal manganese uptake, taste or odor episodes in Boulder Reservoir, and non-uniform total dissolved solids (TDS) and sulfate concentration across the distribution system when BRWTF uses Boulder Reservoir as its source.

Because these factors pose a potential threat to drinking water quality, the City has established drinking water quality goals that are in some instances more stringent than state or federal regulatory requirements to ensure public health. Appendix 1 lists the City's water quality goals. For the purposes of this study, the minimum contaminant barrier requirements were those specified by enforceable USEPA and CDPHE Primary Drinking Water Standards. Contaminant barriers associated with Secondary Drinking Water Standards and City drinking water quality goals were also evaluated in this report. However, the contaminant



barriers considered were not required to completely satisfy these non-enforceable secondary standards in all cases, largely for compelling economic reasons.

## **A. Barriers for Microbial Pathogen Control**

Over the past two decades the Environmental Protection Agency (EPA) has issued a series of increasingly stringent Drinking Water Regulations designed to protect the public from microbial pathogens such as viruses, *Giardia*, and *Cryptosporidium* that may be present in surface water supplies. Because turbidity is often used as an indicator of microbial water quality, it is also regulated in drinking water produced from surface water sources. Relevant regulations include the Surface Water Treatment Rule (SWTR), Interim Enhanced Surface Water Treatment Rule (IESWTR), LT1ESWTR, and most recently the Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). Each rule specifies treatment techniques required to achieve specified levels of physical removal or inactivation of specific microbial pathogens in drinking water.

### **1. Overview**

Turbidity in water is caused by suspended particles that scatter or absorb incident light, thereby reducing the water's clarity. Soil and mineral weathering products and microorganisms including bacteria, algae, and protozoa are the principal sources of turbidity in natural waters, either occurring naturally or as the result of agricultural, municipal or industrial activity. The IESWTR established a combined filter effluent (CFE) limit for turbidity of less than or equal to 0.3 nephelometric turbidity units (NTU) in at least 95 percent of monthly samples and a limit of 1 NTU for all samples, with additional limits on individual filter effluent (IFE) turbidity. The City has set internal water quality goals for turbidity of less than or equal to 0.1 NTU in at least 95 percent of all IFE samples and less than 0.15 NTU for all CFE samples.

Turbidity removal is perhaps the oldest form of drinking water treatment, traditionally relying on clarification and granular media filtration. Standard practice now includes chemical pre-treatment that modifies particle surface chemistry to improve removal. Enhanced clarification processes such as



ballasted flocculation and dissolved air flotation (DAF), as well as membrane filtration are also now being used to for turbidity removal.

Based on an improved understanding of *Cryptosporidium* occurrence in surface waters and treatment process limitations, LT2ESWTR has established risk-targeted log-removal/inactivation levels for *Cryptosporidium* in addition to those specified in earlier rules. The primary purposes of this rule are to protect public health from illness due to *Cryptosporidium* and other microbial pathogens in drinking water and to address risk-risk trade-offs with the control of disinfection byproducts. Because this regulation links the required level of drinking water treatment with source water quality, a careful evaluation of source water protection and treatment options is required to ensure public health protection and regulatory compliance.

LT2ESWTR classifies source water quality into four bins based on average *Cryptosporidium* concentration and treatment type, and specifies associated levels of additional treatment required. Table 3-1 lists the required levels of additional treatment for WTPs that utilize conventional treatment consisting of chemical coagulation, flocculation, clarification, and granular media filtration.

<b>Table 3-1</b>		
<b>LT2ESWTR Cryptosporidium Treatment Requirements for Conventional WTPs</b>		
<b>Bin Designation</b>	<b>Cryptosporidium Concentration (oocysts/L)</b>	<b>Additional Removal/Inactivation Treatment Required</b>
1	Less than 0.075	None
2	0.075 or higher, but less than 1.0	1-log
3	1.0 or higher, but less than 3.0	2-log
4	3.0 or higher	2.5-log



As a public water system serving a population greater than 100,000, the City is required to conduct 24 months of initial source water monitoring beginning in October 2006, or submit grandfathered existing monitoring data to establish average *Cryptosporidium* concentrations for LT2ESWTR bin determination at BRWTF. Historical *Cryptosporidium* monitoring data for Carter Lake, BFC, and Boulder Reservoir collected between 1997 and 2006 indicate that these source waters would be classified in Bin 1 with respect to LT2ESWTR compliance, requiring no additional treatment for *Cryptosporidium*. However, if grandfathered existing data were not accepted by the regulatory primacy agency, then LT2ESWTR bin classification would be based on the results of additional source water monitoring. If these additional monitoring data were to indicate substantially higher *Cryptosporidium* levels in either BFC or Boulder Reservoir than historical levels, additional *Cryptosporidium* treatment requirements at BRWTF could be triggered.

As part of its water quality goal setting process, the City has determined that a minimum of one additional log-removal/inactivation of microbial pathogens above regulatory requirements is prudent to protect public health. Table 3-2 lists the required and target log-removal/inactivation for regulated microbial pathogens based on meeting federal regulations and City water quality goals.

<b>Table 3-2</b>			
<b>Required and Target Log-Removal/Inactivation for Regulated Microbial Pathogens</b>			
<b>Regulation/Goal</b>	<b>Pathogen</b>		
	<b>Viruses</b>	<b><i>Giardia</i></b>	<b><i>Cryptosporidium</i></b>
Regulatory Requirement	4	3	3 <sup>(1)</sup>
City Goal	5	4	5 <sup>(2)</sup>
<sup>(1)</sup> Assumes LT2ESWTR Bin 1 classification.			
<sup>(2)</sup> Provides for potential BFC and Boulder Reservoir LT2ESWTR bin 2 classification.			



**2. Existing Barriers for Microbial Pathogen Control**

BRWTF utilizes chemical pre-treatment, DAF, and granular media filtration for turbidity control. Historical operating data indicates turbidity in finished water from BRWTF has exceeded the City’s goal 0.1 NTU 14 percent of the time. Existing barriers for microbial pathogen control in place at BRWTF include conventional treatment (coagulation, flocculation, dissolved air floatation, and filtration) and chemical disinfection with free-chlorine. The presumptive log-removal/inactivation of viruses, *Giardia*, and *Cryptosporidium* credited to conventional treatment under the SWTR and IESWTR are listed in Table 3-3. The balance of virus and *Giardia* treatment required under the SWTR is currently provided by chemical disinfection with free-chlorine.

<b>Table 3-3</b>				
<b>Regulatory Requirements and Additional Pathogen Removal/Inactivation to Meet City Goals at BRWTF</b>				
<b>Pathogen</b>	<b>Conventional Treatment</b>	<b>Disinfection</b>	<b>Regulatory Requirement</b>	<b>Additional Needed to Meet City Goal</b>
Viruses	2	2	4	1
<i>Giardia</i>	2.5	0.5	3	1
<i>Cryptosporidium</i>	3	--	3*	2*
* Assumes LT2ESWTR Bin 1 classification.				

**3. Potential Additional Barriers for Microbial Pathogen Control**

The LT2ESWTR Microbial Toolbox is a list of potential treatment options for additional *Cryptosporidium* removal/inactivation, as given in Table 3-4. Table 3-4 also gives a preliminary evaluation of the potential applicability of these techniques at BRWTF. Because of the pristine microbial quality of Carter Lake is low (Chapter 2, Section C.1.a), full containment of source water in a dedicated pipeline to BRWTF would also provide an additional barrier.



<b>Table 3-4</b>			
<b>LT2ESWTR Microbial Toolbox</b>			
<b>Treatment Technique</b>	<b>Removal/ Inactivation Credit</b>	<b>Applicability</b>	<b>Comments</b>
<b>Source Water Protection and Management</b>			
Watershed Control Program	0.5	Likely	Treatment cost avoidance and direct credit
<b>Prefiltration</b>			
Presedimentation and Coagulation	0.5	Possible	Reduces acute loading to BRWTF
Two-Stage Lime Softening	0.5	Unlikely	Not required by source water hardness
Bank Filtration	0.5 – 1.0	Possible	Boulder Reservoir delivery alternative
<b>Treatment Performance</b>			
Combined Filter Performance	0.5	Likely	Presumptive operational credit
Individual Filter Performance	0.5	Likely	Presumptive operational credit
Demonstration of Performance	Variable	Unlikely	Requires state approved protocol
<b>Additional Filtration</b>			
Bag and Cartridge Filters	2.0 singly, 2.5 in series	Possible	Additional pumping, small footprint
Membrane Filtration	Demonstrated removal efficiency	Possible	Retrofit in existing filter boxes
Second Stage Filtration	0.5	Unlikely	Additional pumping likely
Slow Sand Filtration	2.5 – 3.0	Unlikely	Additional pumping likely
<b>Inactivation</b>			
Chlorine Dioxide	Based on measured CT	Likely	Manganese and taste & odor control
Ozone	Based on measured CT	Likely	Manganese and taste & odor control
UV	Based on validated UV dose	Likely	Advanced oxidation of EDCs with H <sub>2</sub> O <sub>2</sub>



## **B. Barriers for Disinfection Byproduct Control**

DBPs are compounds formed during drinking water treatment through reaction of chemical disinfectants with either organic or inorganic constituents present in the source water.

### **1. Overview**

The most widespread and well documented class of DBPs is halogenated organic compounds formed by reaction of free-chlorine and natural organic matter. Typically, only 30 to 60 percent of halogenated organic DBPs are chemically identifiable, with trihalomethanes (THMs) and haloacetic acids (HAAs) occurring in the highest concentrations. The Stage 2 Disinfectants and Disinfection Byproduct Rule (Stage 2 DBPR) standards for total THMs and five HAAs (HAA<sub>5</sub>) are 80 and 60 micrograms per liter ( $\mu\text{g/L}$ ), respectively, measured as locational running annual averages (LRAAs) at each monitoring site. The City has set internal water quality goals of 40  $\mu\text{g/L}$  and 30  $\mu\text{g/L}$  for THMs and HAAs as LRAAs, respectively.

Disinfection of drinking water with ozone leads to formation of low-molecular weight organic byproducts through oxidation of NOM, and bromate ( $\text{BrO}_3^-$ ) by oxidation of bromide ( $\text{Br}^-$ ). The organic by-products are primarily aldehydes, ketoacids, and carboxylic acids that are not currently believed to pose a health hazard and are therefore not regulated in drinking water. Bromate is believed to be a human carcinogen and is currently regulated by the Stage 1 Disinfectants and Disinfection Byproduct Rule (Stage 1 DBPR) at 10  $\mu\text{g/L}$ , with a future maximum contaminant level (MCL) of 5  $\mu\text{g/L}$  under consideration. The City currently has no internal water quality goal for bromate.

Chlorine dioxide ( $\text{ClO}_2$ ) is much less reactive with NOM compared with free-chlorine or ozone, and produces very few halogenated organic DBPs. However, the reduced inorganic byproducts chlorite ( $\text{ClO}_2^-$ ) and chlorate ( $\text{ClO}_3^-$ ) may be produced during onsite  $\text{ClO}_2$  generation or by  $\text{ClO}_2$  oxidation of NOM and reduced iron or manganese. Stage 1 DBPR set an MCL of 1 mg/L for chlorite. Chlorate is currently not regulated in drinking water due to a lack of conclusive evidence regarding adverse health effects. The City currently has no internal water quality goals for chlorite or chlorate.



Combined-chlorine ( $\text{NH}_2\text{Cl}$  – monochloramine) is also much less reactive with NOM than free-chlorine, producing on average less than 20 and 50 percent of the THM and HAA concentrations, respectively, at comparable disinfectant concentrations. Reaction between combined-chlorine and certain cationic resins and polymers has recently been implicated in the formation of nitrosodimethylamine (NDMA), which is classified as a probable human carcinogen by USEPA. NDMA is not currently regulated in drinking water, but has an estimated  $10^{-6}$  cancer risk at 0.7 nanograms per liter (ng/L), which is below the level often measured in chloraminated drinking water. The City currently has no internal water quality goal for NDMA.

## **2. Existing Barriers for DBP Control**

DBP precursor removal at BRWTF relies solely on TOC removal by enhanced coagulation; alternative oxidants are not currently used, nor is activated carbon adsorption applied. Although BRWTF has consistently met the treatment technique requirement for TOC removal (Figure 2-14), the City's THM and HAA water quality goals have not been met consistently (Figures 2-15 and 2-16). Between 1998 and 2006, the City's goals have been exceeded in 56 to 70 percent of THM samples, and 65 to 90 percent of HAA samples, collected from locations served exclusively by the BRWTF.

## **3. Potential Additional Barriers for DBP Control**

Treatment technologies that seek to minimize DBP formation follow one of three strategies related to the reactions between chemical disinfectants and organic or inorganic source water constituents: (1) remove the undesirable byproduct once formed, (2) alter the reaction conditions so as to reduce byproduct formation, or (3) reduce or remove one of the byproduct precursors. Because DBPs are generally non-volatile, solid phase adsorption processes have long been viewed as candidates for DBP removal from finished drinking water. Granular activated carbon (GAC) adsorption and ion exchange (IX) have been extensively explored as treatment techniques for organic and inorganic DBP removal, respectively. However, these processes have not been widely deployed for DBP removal from finished drinking water because of limitations



including insufficient adsorption capacity, lack of specificity for targeted DBPs, undesirable interactions with residual disinfectants, and operational and economic considerations.

Controlling DBP formation by altering reaction conditions such as temperature or contact time is of only limited value or practicality. Utilities have very little if any control over source and finished water temperatures, and lowering water temperature during treatment is economically unviable. Although the point(s) of disinfectant application may sometimes be moved further downstream in the treatment process train, disinfection contact time requirements and distribution system residence time limit the extent to which contact time can be reduced. For these reasons, minimizing DBP formation during drinking water treatment has largely focused on reducing or removing DBP precursors, and has governed development of the interrelated set of microbial and DBP regulations over the past decade.

Strategies for DBP precursor removal include use of alternative disinfectants, precipitative NOM removal by enhanced coagulation, and NOM adsorption on activated carbon. Ozone, chlorine dioxide, chloramines and UV light have been used to either partially or completely replace free-chlorine, thereby lowering THM and HAA formation. However, alternative chemical disinfectants do produce other DBPs as previously discussed. Stage 1 DBPR mandates a treatment technique for NOM removal in facilities that utilize conventional treatment of surface water based on source water total organic carbon (TOC) and alkalinity concentrations, as indicated in Table 3-5.



**Table 3-5**

**Percent TOC Removal Required by Enhanced Coagulation for Surface Water Systems Utilizing Conventional Treatment**

Source Water TOC (mg/L)	Source Water Alkalinity (mg/L as CaCO <sub>3</sub> )		
	0–60	>60 – 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

Alternative Compliance Criteria:

- (1) Source water TOC < 2.0 mg/L
- (2) Finished water TOC < 2.0 mg/L
- (3) Source water TOC < 4.0 mg/L, alkalinity > 60 mg/L as CaCO<sub>3</sub>, TTHM < 40 µg/L, and HAA < 30µg/L
- (4) TTHM < 40 µg/L and HAA < 30µg/L, and only chlorine used for disinfection and residual maintenance
- (5) Source water SUVA prior to any treatment ≤ 2.0 L/mg·m
- (6) Treated water SUVA ≤ 2.0 L/mg·m

### **C. Barriers for Organic Micro-Pollutant Control**

Organic micro-pollutants enter source waters from industrial and municipal effluents, agricultural runoff, and unregulated waste discharge.

#### **1. Overview**

Organic micro-pollutants encompass a wide range of chemical compounds with diverse physical and chemical properties. Historically important classes of synthetic organic compounds (SOCs) include solvents, plasticizers, propellants, petroleum additives, chemical intermediates, herbicides, and pesticides. Emerging SOC classes of concern that are not currently regulated include endocrinologically active compounds (EDCs), pharmaceutically active compounds (PhACs), and personal care products (PCPs). Although SOCs typically occur at low concentrations in source waters, and at trace levels in drinking water supplies, many of these compounds are highly toxic or carcinogenic and therefore pose a health risk if present in drinking water. There



are currently national primary drinking water standards for 62 SOCs and pending standards for another 38 listed in the Contaminant Candidate List 2. The City currently has no internal water quality goal for specific organic micro-pollutants.

## **2. Existing Barriers for Organic Micropollutant Control**

There are currently no known industrial or municipal effluent discharges to Carter Lake, BFC, or Boulder Reservoir; although, all three water sources for BRWTF are potentially subject to organic micro-pollutant contamination to varying degrees through surface runoff and unregulated waste releases. Carter Lake is the least susceptible of BRWTF sources because of its remote location, small catchment area and lack of natural tributaries, and restricted adjacent land usage. Boulder Reservoir is somewhat more vulnerable to organic micro-pollutant contamination due to natural tributaries and ditches that flow in and extensive recreational use. BFC is highly vulnerable to organic micro-pollutant contamination because of its extended length with virtually uncontrolled access, numerous outfalls and street crossings, and adjacent residential, commercial, agricultural, and recreational land uses. There are no dedicated SOC treatment processes at BRWTF, and only very limited organic pollutant removal is provided by DAF and co-precipitation during natural organic matter (NOM) coagulation.

## **3. Potential Additional Barriers for Organic Micropollutant Control**

Organic micro-pollutant control in drinking water supplies utilizes watershed management to limit effluent discharges, as well as treatment processes including air stripping, chemical oxidation, coagulation, activated carbon adsorption, reverse osmosis, and advanced oxidation for removal during treatment. Chemical characteristics such as volatility, polarity, charge, molecular weight, and solubility, determine which processes are appropriate for SOC removal during drinking water treatment. Because the potential for introduction of organic micropollutants into Carter Lake is low (Chapter 2, Section C.1), full containment of source water in a dedicated pipeline to BRWTF would also provide an additional barrier.



## **D. Barriers for Manganese Control**

Manganese may be present in ground and surface waters that are in contact with manganese containing minerals, occurring as either soluble  $Mn^{2+}$  (reduced form) or precipitated  $MnO_2$  (oxidized form), depending on pH and oxygen concentration.

### **1. Overview**

Aesthetic issues associated with manganese in drinking water include staining of laundry and fixtures and unpleasant taste. Manganese concentrations of less than 0.5 milligrams per liter (mg/L) may promote bacterial growth in reservoirs and drinking water distribution systems. Consumer complaints regarding aesthetic issues associated with manganese in drinking water have been documented at concentrations as low as 0.02 mg/L. There are presently no known adverse health effects of manganese in drinking water, but the USEPA has set a secondary maximum contaminant level (SMCL) for manganese at 0.05 mg/L based on aesthetic concerns. The City has set an internal goal of 0.03 mg/L for manganese in finished drinking water.

### **2. Existing Barriers for Manganese Control**

Manganese concentrations in Carter Lake have historically been very low year-round. Manganese concentrations increase only slightly as a result of conveying water to BRWTF through BFC. However, seasonal manganese mobilization is routinely observed in Boulder Reservoir during late summer and early fall due to hypolimnetic anoxia produced by thermal stratification. Although the manganese concentration in the hypolimnion of Boulder Reservoir exceeds the City's goal in 33 percent of samples, with levels of 0.5 mg/L to 1.0 mg/L not uncommon, manganese loading in BRWTF influent has historically been minimized by using the low manganese BFC source almost exclusively during periods when stratification results in mobilization. Because oxidation of  $Mn^{2+}$  with oxygen and free-chlorine is relatively slow at pH less than 9.5, the efficiency of manganese removal for the conventional treatment process configuration currently in place at BRWTF may not be sufficient if Boulder Reservoir was used as the water source year-round.



### **3. Potential Additional Barriers for Manganese Control**

Manganese control during drinking water treatment most often involves oxidation of soluble  $Mn^{2+}$  to particulate  $MnO_2$ , with subsequent removal by clarification or filtration. Manganese removal through autocatalytic adsorption and oxidation on  $MnO_2$  coated filter media surfaces is also practiced, and less frequently by ion exchange, nanofiltration/reverse osmosis or precipitative softening. Because the potential for soluble manganese release from bed sediments in Carter Lake is low (Chapter 2, Sections C.1.b and C.1.c), full containment of source water in a dedicated pipeline to BRWTF would also provide an additional barrier.

## **E. Barriers for Taste and Odor Control**

Objectionable tastes and odors in drinking water may occur due to the presence of microbial metabolites and degradation products, anthropogenic volatile and synthetic organic compounds, and naturally occurring inorganic compounds.

### **1. Overview**

Numerous microbial species belonging to cyanobacteria, green algae, diatom, and flagellate groups that may be present in surface waters produce odors variously described as sweet, grassy, musty, earthy, swampy, fishy, and septic. Geosmin and 2-methylisoborneol (MIB) are the most well known microbial odor-causing metabolites found in drinking water supplies, producing earthy and musty odors, respectively. Medicinal and phenolic off-tastes and odors are often associated with drinking water supplies developed from source waters that receive organic solvents, pesticides, and petroleum products from industrial effluent, agricultural runoff, and liquid waste disposal. Often, these chemicals produce tastes and odors that are not directly attributable to a parent organic compound, but rather to chlorinated disinfection byproducts that occur in discharged waste effluents or finished drinking water. Thermal stratification in lakes and reservoirs often leads to anaerobic conditions at depth, releasing inorganic taste and odor compounds through mobilization of soluble iron and manganese ( $Fe^{2+}$  and  $Mn^{2+}$ ) from insoluble oxide minerals in bottom sediments, as well as sulfide production. There are currently no national drinking water



regulations for taste; however, USEPA has set a SMCL for odor at a threshold odor number of three. The City has set an internal water quality goal of no detectable tastes or odors in finished drinking water.

## **2. Existing Barriers for Taste and Odor Control**

BRWTF currently depends largely on source water control strategies for taste and odor control, as chemical oxidation with free-chlorine is only marginally effective at controlling algal metabolites and oxidizing soluble manganese. Algicides are periodically applied in BFC, but not to Carter Lake or Boulder Reservoir. There is no aeration for volatile organic removal or activated carbon or ion exchange processes for soluble contaminant removal, nor is there is a routine monitoring program for seasonal formation of algal taste and odor compounds in Carter Lake, BFC, or Boulder Reservoir.

## **3. Potential Additional Barriers for Taste and Odor Control**

Taste and odor control in drinking water supplies may rely on source water management or removal during treatment, or frequently a combination of both strategies. Source water management strategies include lake and reservoir aeration, chemical inhibition of algal growth, watershed management to limit nutrient input, and effluent discharge restrictions. Chemical characteristics of taste and odor compounds such as volatility, polarity, charge, molecular weight, and solubility, determine which processes are appropriate for their removal during drinking water treatment. Treatment processes commonly used for taste and odor control include aeration, chemical oxidation, activated carbon adsorption, ion exchange, and precipitation. Because the potential for objectionable taste or odor episodes in Carter Lake is low (Chapter 2, Section C.1.c), full containment of source water in a dedicated pipeline to BRWTF would also provide an additional barrier.

## **F. Barriers for Inorganic Contaminant Control**

Natural waters contain a variety of inorganic constituents that occur primarily as the result of mineral weathering and leaching reactions in soil, sediment, and rock formations; although, industrial, municipal, agricultural, and surface runoff effluents may in some instances contribute inorganic constituents.



## **1. Overview**

Inorganic constituents typically occur in ionic form in aqueous solution, and may be present as suspended and colloidal solids or dissolved species. Major cations (positively charged) in natural waters include sodium, potassium, calcium, magnesium, iron, and manganese; whereas, major anions (negatively charged) include bicarbonate, chloride, sulfate, sulfide, nitrate, nitrite, fluoride, and silicate. Other trace inorganic constituents that may be present in source waters are alkali and alkaline metals, other metallic elements, and nonmetals. There are currently National Primary Drinking Water Standards for 16 inorganic elements and compounds, and National Secondary Drinking Water Standards for 10 inorganics. There is also a National Secondary Drinking Water Standard for pH of 6.5 to 8.5 standard units (s.u.), as an indicator of finished water quality and corrosivity. The City has set internal water quality goals for sodium (5 to 20 mg/L), sulfate (less than 20 mg/L), TDS (less than 100 mg/L), fluoride ( $0.9 \pm 0.1$  mg/L), and pH ( $7.8 \pm 0.2$  s.u.) that are more restrictive than required by state and federal regulations.

## **2. Existing Barriers for Inorganic Contaminant Control**

BRWTF utilizes conventional treatment for suspended and colloidal inorganic contaminant removal. No dedicated processes for dissolved inorganic contaminant removal are currently in place at BRWTF. The City's water quality goals for sulfate and TDS have historically been routinely exceeded (Figure 2-17). In addition, finished water pH at the BRWTF has routinely been outside the City's desired range, exceeding the upper limit and falling below the lower limit 10 percent and 42 percent of the time, respectively.

## **3. Potential Additional Barriers for Inorganic Contaminant Control**

Suspended and colloidal inorganic constituents may be effectively removed from source waters by standard treatment methods including coagulation, clarification, and filtration. However, with the exception of several regulated metals, dissolved inorganic constituents are typically only poorly removed by these methods, if at all. The concentrations of multivalent ions may be reduced by precipitative softening or ion exchange, but reverse osmosis is the only practical treatment method to lower TDS or remove monovalent ions.



Because the potential for naturally-occurring or human-induced inorganic contamination in Carter Lake is very low (Chapter 2, Section C.1.c), full containment of source water in a dedicated pipeline to BRWTF would also provide an additional barrier.