SOLANO PROJECT BELOW MONTICELLO DAM
2017 WATERSHED SANITARY SURVEY

Final Report
June 2018

Prepared for Solano County Water Agency

Palencia
Consulting
Engineers

Solano Project Below Monticello Dam
2017 Watershed Sanitary Survey

FINAL REPORT
June 2018

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List of Abbreviations

BMP – Best Management Practice

CDPH – California Department of Public Health
CUPA – Certified Unified Program Agency

D/DBP – Disinfectants/Disinfection By-Products
DBP – Disinfection By-Product
DDW – Division of Drinking Water

E. coli – Escherichia coli

HAA5 – Haloacetic Acids

IESWTR – Interim Enhanced Surface Water Treatment Rule
ILRP – Irrigated Lands Regulatory Program

LT1ESWTR – Long Term 1 Enhanced Surface Water Treatment Rule
LT2ESWTR – Long Term 2 Enhanced Surface Water Treatment Rule

MCL – maximum contaminant level
µg/L - Micrograms per Liter
mgd – Million Gallons per Day
mg/L – Milligrams per Liter
MIEX – Magnetic Ino Exchange
MPN/100 mL – Most Probable Number per 100 milliliters
MS4 – Municipal Separate Storm Sewer System

NBA – North Bay Aqueduct
NBR – North Bay Regional
NTU – Nephelometric Turbidity Unit
NHC – Northwest Hydraulic Consultants

OES – California Office of Emergency Services

PACl – Polyaluminum Chlorhydate
PCAs – Potential Contaminating Activities
PSC – Putah South Canal

RCD – Resource Conservation District
Regional Board – Central Valley Regional Water Quality Control Board
RIMS – Response Information Management System
RV – Recreational Vehicle

SCADA - Systems Control and Data Acquisition

SCWA – Solano County Water Agency
SDWA – Safe Drinking Water Act
SEMS – Standardized Emergency Management System
SID – Solano Irrigation District
SMARTS – Storm Water Multiple Application and Report Tracking System
SOC – Synthetic Organic Compound
SSO – Sanitary Sewer Overflow
SVWQC – Sacramento Valley Water Quality Coalition
SWRCB – State Water Resources Control Board
SWTR – Surface Water Treatment Rule

TOC – Total Organic Carbon
TTHM – Total Trihalomethanes

URO – Urban Runoff
USEPA – US Environmental Protection Agency

VOC – volatile organic compound

WTP – Water Treatment Plant

INTRODUCTION

Watershed Sanitary Surveys were prepared on the Solano Project in 1993, 2001, 2006 and 2012. The 1993, 2001 and 2006 documents provide a comprehensive description of the watershed and water quality conditions along Putah Creek below Monticello Dam and along the Putah South Canal (PSC). The State Water Resources Control Board Department of Drinking Water (DDW) agreed that the 2012 Update could be a simplified report updating changes in the watershed and changes in water quality. This 2016 Update is patterned after the 2012 Update and will also be a simplified report. This report presents the findings of the Current Update to the Solano Project below the Monticello Dam Watershed Sanitary Survey. This study covers the period January 2012 through December 2016.

For assistance with abbreviations and acronyms, the reader is referred to the List of Abbreviations at the front of the report. A bibliography and list of contacts are provided in **Appendix A**.

OBJECTIVES OF THE UPDATE

A watershed sanitary survey focuses on the first barrier to contamination of the drinking water supply, namely source water protection. Evaluating source water quality and watershed contaminant sources provides key information to aid in understanding how to maintain and possibly improve the first barrier.

This Update is intended to accomplish the following objectives:

1) Fulfillment of the California Surface Water Treatment Rule (SWTR) and the Interim Enhanced Surface Water Treatment Rule (IESWTR) requirements that surface water agencies conduct a sanitary survey of the source watershed once every five years. Any significant changes within the last five years that affect source water quality are to be identified in each update. In addition, it is required to comment on the appropriate level of treatment for pathogens, specifically for *Giardia*, viruses, and *Cryptosporidium*.

2) Review and evaluation of selected constituents of interest to identify potential water quality or treatment issues for PSC water users.

3) Review and evaluation of selected potential contaminating activities to identify impacts on source water quality. Determine whether it may be useful to conduct additional monitoring to further assess contaminant levels in the source water or contaminants from a particular watershed source.

4) Identification of appropriate watershed management actions to protect and possibly improve source water quality. Development of recommendations for watershed management actions that are economically feasible and within the authority of the Solano County Water Agency and PSC water users to implement is critical.

CONSTITUENTS AND POTENTIAL CONTAMINATING ACTIVITIES COVERED IN THE CURRENT UPDATE

Several water quality constituents were selected for evaluation as part of the Current Update. **Table 1-1** presents a summary of the water quality constituents selected and the reason for selection.

Table 1-1
Water Quality Constituents Selected for Evaluation as Part of the Current Update

Constituent	Reason for Inclusion in Current Update
Turbidity	Turbidity is a measurement of suspended solids in water. Treated water turbidity levels are regulated in the SWTR and the IESWTR.
Total Coliform	Evaluation recommended under the SWTR to determine appropriate level of treatment for *Giardia* and viruses.
Fecal Coliform and *E. coli*	Source water fecal coliform is a more specific surrogate for fecal contamination.
Giardia	*Giardia lamblia* is infectious to humans. Source water levels of *Giardia* are used to determine treatment requirements under the SWTR.
Cryptosporidium	*Cryptosporidium parvum* is infectious to humans. Actual source water levels of *Cryptosporidium* will be used to determine treatment requirements as part of the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).
Total Organic Carbon	Total organic carbon (TOC) is a surrogate measure of disinfection by-products (DBP) precursor material in water. TOC levels in either source or treated water are used to determine treatment requirements in the Stage 1 Disinfectant/Disinfection By-Product Rule (D/DBP).
Volatile and Synthetic Organic Compounds	Most VOCs and SOCs are formulated for, or are by-products from, industrial, agricultural, and urban use. Pesticides are a main subgroup of the SOCs used for agriculture and urban application. Many of these constituents have been regulated by the Phase I, II, and V regulations.
Copper	Copper has a secondary MCL and is also regulated under the Lead and Copper Rule at the tap.

Eight potential contaminating activities were selected for review as part of the Current Update: spills, recreation, agriculture, canal cleaning, lateral sources, grazing, urban runoff, and fires. Each of these activities can contribute at least one of the constituents identified in **Table 1-1** to the source water. These activities were selected based on their presence in the watershed, and were identified by SCWA as key contaminating activities.

REPORT ORGANIZATION

Section 1 – Introduction

This section describes the objectives of the Current Update, lists the main constituents and potentially contaminating activities covered, and includes a description of the basic report organization.

Section 2 - The Watershed and Supply Systems

This section is largely descriptive and provides: (1) a brief overview of the physical, hydrologic, and land use characteristics of the watershed, (2) a description of the existing water supply system, and (3) contains a watershed map delineating the watershed and land use in the watershed. For more detailed descriptive information on watershed characteristics, the reader is referred to the 1993 Watershed Sanitary Survey.

Section 3 – Source Water Quality Review

This section provides a review of the constituents of interest, including an explanation for their selection and a summary of the data obtained for the period of study for each constituent.

Section 4 – Watershed Contaminant Sources Review

This section describes pertinent characteristics of each of the eight potential contaminating activities that were reviewed as part of this Update. If applicable, each potential contaminating activity will include a discussion on background and occurrence, seasonal patterns, water quality issues and data review, regulation and management, and source water protection activities.

Section 5 – Key Findings and Recommendations

This section consists of a discussion of key findings, update on recommendations from the 2012 watershed sanitary survey and a list of current recommendations.

BACKGROUND

The Solano Project supplies agricultural water and municipal drinking water to Solano County. The major facilities of the project are Lake Berryessa, formed by Monticello Dam on Putah Creek, Lake Solano, formed by the Putah Diversion Dam, the Putah South Canal (PSC), and the Terminal Reservoir. The facilities are owned by the U.S. Bureau of Reclamation and maintained and operated by Solano County Water Agency (SCWA) through an operating agreement with Solano Irrigation District (SID). SCWA is a wholesale agency that provides untreated water to communities in Solano County, and is therefore responsible for preparing the watershed sanitary surveys on the Solano Project.

Watershed Sanitary Surveys were prepared on the Solano Project in 1993, 2001, 2006, and 2012. Prior to 2012, these documents provide a comprehensive description of the watershed and water quality conditions for Lake Berryessa, Putah Creek below Monticello Dam and along the Putah South Canal (PSC). In 2012, the California Department of Public Health (CDPH) agreed that the 2012 Update could focus on the watershed below Monticello Dam. This 2017 Update follows the same technical approach as undertaken for the 2012 Update.

SOLANO PROJECT FACILITIES

The Solano Project facilities are described in great detail in the initial watershed sanitary survey. This section provides information on the facilities to assist with understanding of this report. **Figure 2-1** shows the major facilities of the Solano Project and the watershed boundary below Monticello Dam.

Lake Berryessa and Monticello Dam

Lake Berryessa is located in eastern Napa County and has a watershed of 576 square miles and a storage capacity of 1.6 million acre-feet. Monticello Dam is 304 feet high. Water is released near the bottom of the dam and used to generate electricity. Water is released through the uncontrolled glory hole spillway when the lake reaches capacity.

Putah Creek, Lake Solano, and the Putah Diversion Dam

Putah Creek, which forms the approximate border between Solano and Yolo counties, is the only outlet from Lake Berryessa. As noted in the initial watershed sanitary survey, the watershed between Monticello Dam and the Putah Diversion Dam is approximately 30 square miles. The region below Monticello Dam is a well-established riparian habitat that has become known for its coldwater fisheries. The sub watershed for this reach of Putah Creek, shown in **Figure 2-2**, includes a small contributory area north of the creek in Yolo County and a larger contributory area south of the creek in Solano County, primarily in Pleasants Valley. The major tributaries include Thompson, Cold, and Bray Canyon Creeks and Pleasants Creek. All of these are seasonal streams that largely provide flows during the winter and spring rains.

Figure 2-1. Solano Project Facilities

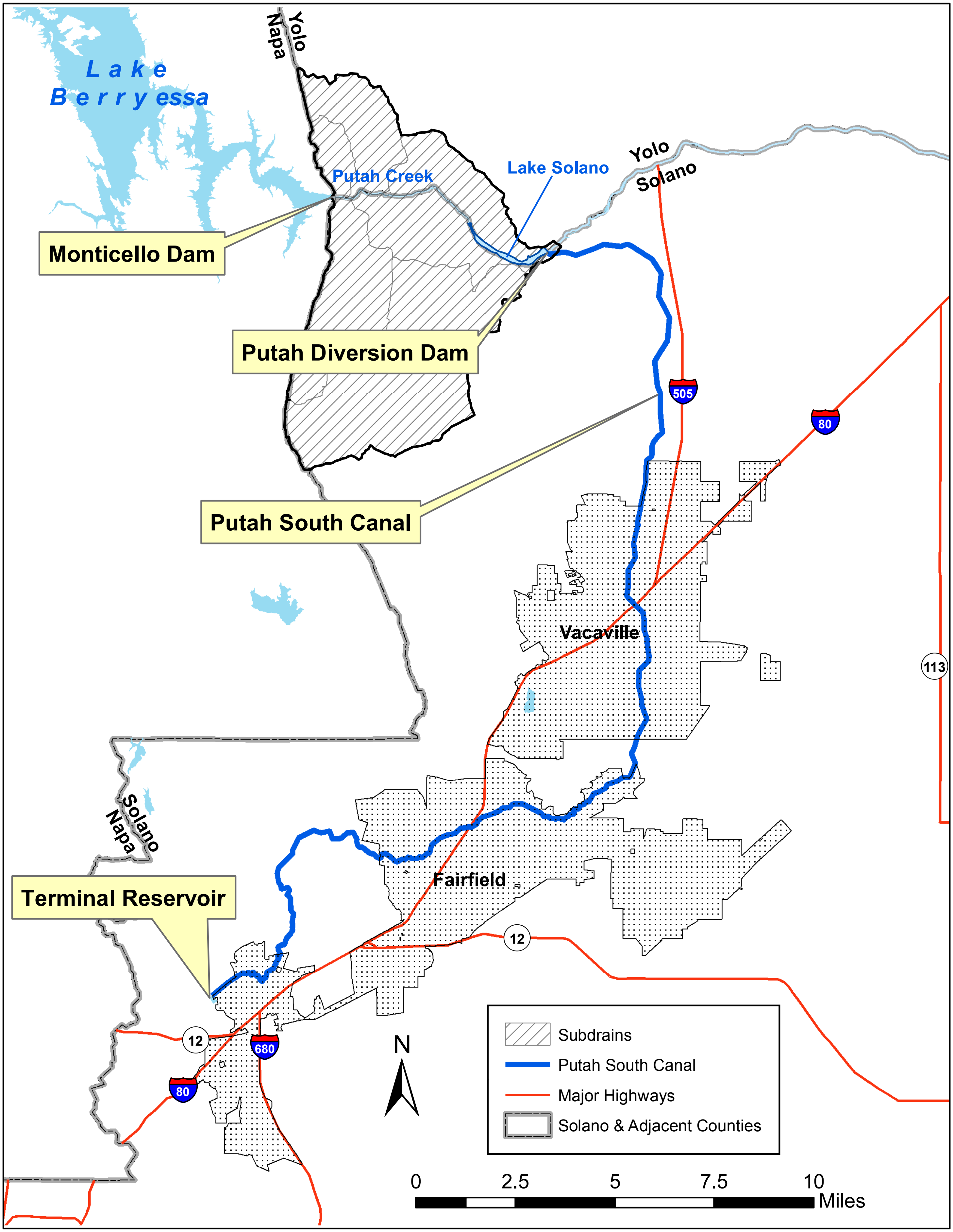
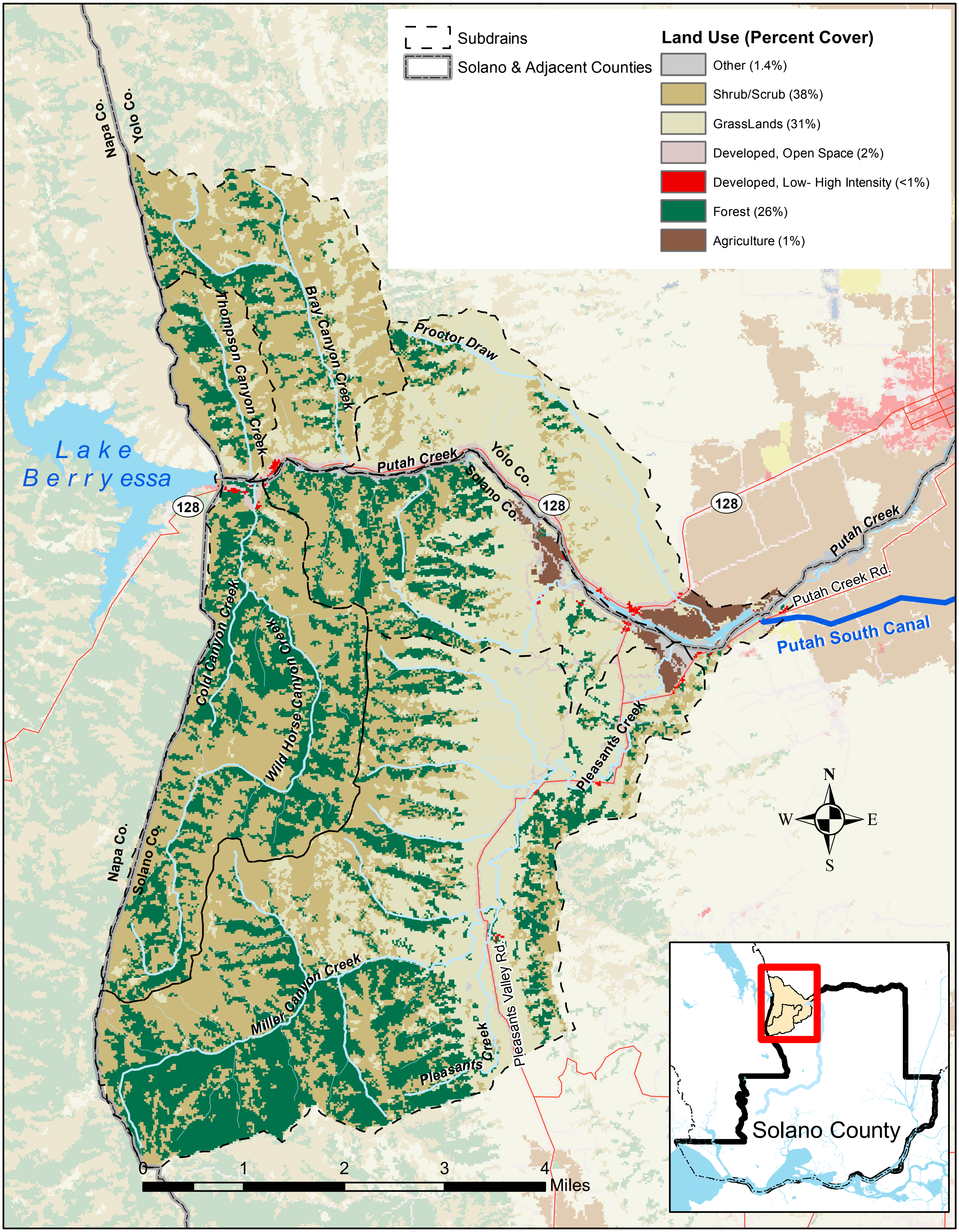


Figure 2-2. Land Uses in Putah Creek and Lake Solano Subwatershed



This is a largely uninhabited area that consists of native vegetation. The United States Bureau of Land Management (BLM) owns a substantial amount of land in the Vaca Mountains along Blue Ridge in Pleasants Valley. Land is also owned by the California Department of Fish and Game and the University of California Natural Reserve System in Cold Canyon. The soils in the watershed are highly erodible.

Putah Diversion Dam is located on Putah Creek approximately six miles below Monticello Dam. The principal function of the dam is to divert water into the PSC. The dam creates Lake Solano, which is about 1.5 miles long with a capacity of 750 acre-feet. The lake provides recreation in an area already popular for picnicking, non-motorized boating, swimming, and fishing.

Putah South Canal

The PSC originates at the Putah Diversion Dam and runs easterly for about 4 miles. It then turns south, then southwest, to follow the edge of the foothills for about 30 miles and terminates in Cordelia. The canal is concrete lined, except for several siphons which are pre-cast reinforced concrete pipe. The largest siphon is the Green Valley Siphon, a one-mile segment that is pre-cast reinforced concrete pipe and designated as the Putah South Pipeline. The canal from the Diversion Dam through Allendale is surrounded by high earthen berms. The canal has a diversion capacity of 956 cubic feet per second (cfs) with a terminal capacity of 116 cfs. The Putah South Canal is almost completely fenced and patrolled by SID three times per week.

Terminal Dam and Reservoir

The Terminal Dam is a 119 acre-foot reservoir located at the end of the PSC and serves as a Terminal Reservoir for the canal and a forebay from which water is delivered to the cities of Vallejo and Benicia. This reservoir regulates the terminal flows in the canal and provides a small carryover supply in case of an interruption in flow.

WATERSHED DESCRIPTION

Land Use

The majority of the land use in the study watershed is forest, grasslands and shrub. **Table 2-1** provides further information for the major land use categories, and **Figure 2-2** shows land use in the watershed. There are no incorporated cities in the watershed.

Table 2-1.
Land Use in the Putah Creek and Lake Solano Subwatersheds

Land Use	Percent of Watershed
Shrub	38%
Grasslands	31%
Forest	26%
Developed, Open Space	2%
Other	1.4%
Agriculture	1%
Developed, low-high intensity	<1%

Precipitation

Figure 2-3 shows monthly precipitation totals from the SCWA's rain gage at Lake Solano from January 2012 to December 2016. The average annual rainfall over this five year period (by water year) was 16.2 inches at Lake Solano. **Table 2-2** shows annual rainfall totals by water year. According to SCWA, 25 inches of precipitation is a normal year, so the reporting period from 2012 to 2016 was during a dry period.

Figure 2-3.
Daily Rainfall Totals at Lake Solano, 2012-2016

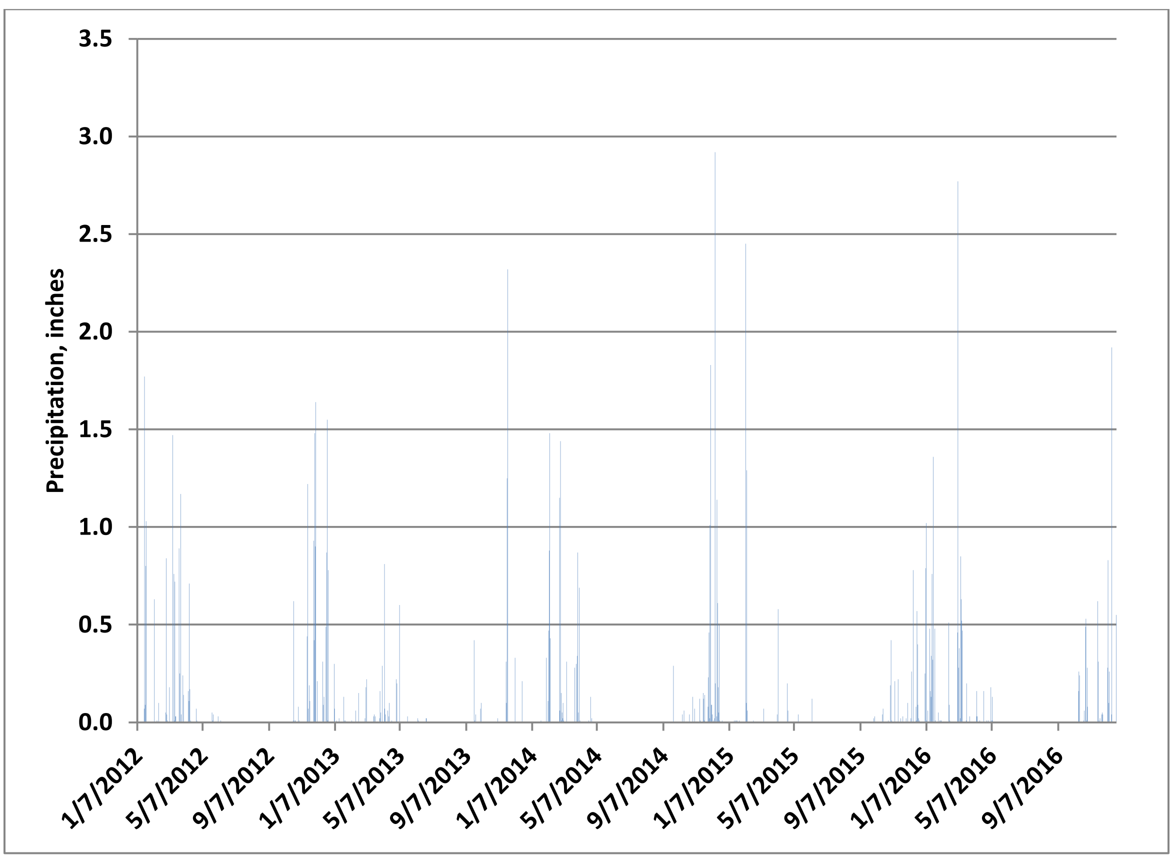


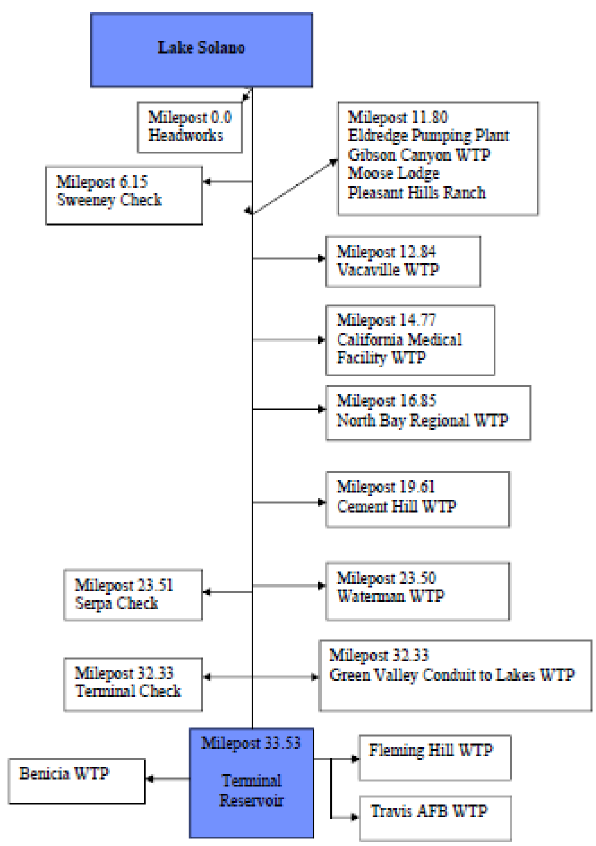
Table 2-2.
Annual Rainfall Totals at Lake Solano
2012-2016

Water Year	Headworks, inches
2012	16.1
2013	17.1
2014	14.7
2015	15.5
2016	17.6

WATER TREATMENT PLANTS

A number of agencies rely on PSC water for all or a portion of their drinking water supply. The water treatment plants (WTPs) which receive 100 percent PSC water are Gibson Canyon WTP, Vacaville WTP, California Medical Facility WTP, Cement Hill WTP, and Waterman WTP. **Figure 2-4** is a schematic showing the relative location of the water treatment plants (WTPs) and other facilities on the Putah South Canal. The facilities are identified by milepost along the Putah South Canal. The headworks of the canal is milepost 0.0.

Figure 2-4. Schematic of Solano Project Facilities and Water Treatment Plants



2.1 Gibson Canyon Water Treatment Plant

The Gibson Canyon WTP receives water from the PSC at milepost 11.80. Water is pumped from the canal by SID's Eldredge Pumping Plant to the 21 acre-feet Bascherini Reservoir. SID owns and operates the 1.3 million gallons per day (mgd) membrane microfiltration plant that serves 157 service connections. The typical production rate is 0.5 to 0.55 mgd. There have been no changes to the water treatment process in the last five years and there are currently no future plans to make changes to the treatment process. Canal cleaning and storm events are the most challenging conditions for the WTP. When source water is degraded, the plant will shut down occasionally to avoid taking the highly turbid and high TOC water into the plant.

2.2 Moose Lodge

The Moose Lodge receives water from the PSC at milepost 11.80. Water is pumped from the canal by the Eldredge Pumping Plant and delivered to the Moose Lodge by an SID pipeline. The Moose Lodge owns and operates a nanofiltration membrane plant with chlorine disinfection. The Moose Lodge is classified as a transient non-community water system.

2.3 Pleasant Hills Ranch Estates

In March of 2014, SID entered into a funding agreement with the State of California to construct a centralized microfiltration water treatment plant under Proposition 50 for the Pleasant Hills Ranch Estates Public Water System. Construction of the Pleasant Hills Ranch Estates Treatment Plant was completed in July 2017. SID constructed and is operating a 1.15 mgd PALL microfiltration hollow fiber membrane water treatment plant to provide drinking water to 26 active connections, and a population of 86.

2.4 City of Vacaville

The Vacaville WTP receives water from the PSC at milepost 12.84. This WTP treats Solano Project water on a seasonal basis (typically April to September). The WTP has a capacity of 11.8 mgd but the typical production rate is 5 mgd. The plant is a diatomaceous earth filter plant with two sides that can produce 6 mgd each. Chlorine is used for disinfection. There is no adjustment of pH for corrosion control in the distribution system. The Vacaville WTP does not treat water during the November to March period, when water quality tends to be challenging during storm events.

2.5 California Medical Facility

The California Medical Facility/California State Prison-Solano takes water from the PSC at milepost 14.77. The WTP uses two parallel micro-flocculation package plants rated at 780 gallons per minute with post chlorination. The facility has the capability of blending Solano Project water with water from the City of Vacaville.

2.6 North Bay Regional WTP

The North Bay Regional (NBR) WTP is a regional facility jointly owned by the cities of Fairfield and Vacaville. Water from both the PSC and the State Water Project's North Bay Aqueduct (NBA) is treated at this plant. The NBR WTP takes water from the PSC at milepost 16.85. Water from the NBA is delivered, via pipeline, from Barker Slough. Water from both sources can be blended. The NBR WTP has a design capacity of 40 mgd but the typical production rate is 20 mgd, with 10 mgd going to each of the two cities. The plant is a conventional water treatment plant consisting of pre- and post-ozonation, coagulation and flocculation with cationic and non-ionic polymers, sedimentation, and filtration. The filters are dual media, granular activated carbon/sand gravel. Sodium hypochlorite is used for disinfection and for maintaining a residual in the distribution systems. Caustic soda is used for pH adjustment of the finished water to prevent corrosion in the distribution system. Fluoride is applied to reduce the potential for dental caries.

In February 2012, the NBR WTP was granted approval by DDW to use a Polyaluminum Chloride (JC1687) as the primary coagulant when on a 100% PSC water source. The NBR WTP will continue to use aluminum sulfate as the primary coagulant when on a 100% NBA water source and/or PSC/NBA blend.

2.7 Cement Hill WTP

The Cement Hill WTP, owned and operated by the Suisun-Solano Water Authority, provides water to Suisun City. Water is diverted from the PSC at milepost 19.61. Solano Project water is the only source of water for this WTP. The WTP has a design capacity of 10 mgd but the typical production rate is 4.5 mgd. The plant is a conventional water treatment plant consisting of coagulation/flocculation with polyaluminum chloride, sedimentation, and filtration in multimedia pressure filters. Free chorine is used for disinfection. There have been no changes to the water treatment process in the last five years. Upgrades planned for the future are an additional storage tank, adding aeration to tanks, and upgrades to the SCADA system.

Canal cleaning and storm events are the most challenging conditions for the WTP. When source water is degraded, the plant will shut down occasionally to avoid taking the highly turbid and high TOC water into the plant.

2.8 Waterman WTP

The Waterman WTP, owned and operated by the City of Fairfield, receives water from the PSC at milepost 23.50. This plant only treats Solano Project water and was designed to reliably deliver 30 mgd peak summer flow and at least 6 mgd in the winter. Waterman is a conventional treatment plant consisting of Actiflo (high rate flocculation/sedimentation), intermediate ozonation, and dual media filtration (anthracite over sand). Aluminum Sulfate (Alum) and Poly Aluminum Chlorhydrate (PACL) are interchangeable primary coagulants depending on water quality conditions. Anionic and cationic polymers are used to aid in flocculation and filtration respectively. Sodium hypochlorite provides disinfection and maintains chlorine residual in the distribution system. Caustic soda adjusts pH of the finished water to prevent corrosion in reservoirs and system piping. Fluoride is added to reduce the potential for dental caries.

According to the City of Fairfield, canal cleaning is the biggest raw water quality challenge because influent water characteristics are variable and the composition of the re-suspended canal slurry is unknown. Generally, elevated metals, ammonia, TOC, turbidity and septic odors occur after canal cleaning. In order to address these challenges, operators increase primary coagulant dose, oxidation dose, decrease filtration rates, decrease plant flow rate to increase detention time, and maintain coagulant pH at levels within enhanced coagulation parameters. If septic odors or chlorine demand becomes too high then the WTP will be shut down in order to let the water pass.

2.9 Green Valley WTP

Solano Project water can be diverted at the end of the open canal (milepost 32.33) to the City of Vallejo's Green Valley WTP. Solano Project water is blended with water from Vallejo's Lakes System at this 1 mgd conventional plant. The treatment plant is a conventional package plant, with the MIEX (magnetic ion exchange) system as pretreatment, coagulation and flocculation with polymers, sedimentation, and filtration in multimedia filters consisting of anthracite and sand, and chlorine as post disinfection. As water from lakes Madigan and Frey generally have alkalinities below 20 mg/L, Solano Project water is normally blended with water from the lakes to increase alkalinity and pH. Soda ash may also be added to increase alkalinity and pH. Water in excess of system demands is pumped to a 1.1 million gallon finished water storage tank.

The long detention times in the Lakes System results in difficulties meeting the disinfection byproduct (DBP) MCL of 80 micrograms per liter (µg/L) for total trihalomethanes (TTHMs) and 60 µg/L for haloacetic acids (HAA5). As a result, MIEX was added to the plant to increase TOC removal to produce water that has a TTHM formation potential below 80 µg/L.

2.10 Fleming Hill WTP

Water from the Solano Project's Terminal Reservoir is pumped to the City of Vallejo's Cordelia Complex. The Cordelia Complex is comprised of a 15 MGD reservoir and two pump houses. The reservoir also receives and stores water from the NBA. Water from this reservoir is then pumped to the Fleming Hill WTP or Summit Reservoir and occasionally to the Travis AFB WTP. The Fleming Hill WTP treats both water from Solano Project and NBA. They can be blended or treated individually. The WTP has a design capacity of 42 mgd but the typical production rates range between 14 and 25 mgd. The plant is a conventional WTP with pre and intermediate ozone. Treatment consists of alum/polymer coagulation and flocculation, sedimentation, ozonation and filtration. The dual media filters are granular activated carbon over sand and gravel.

Free chlorine is used for post disinfection and for maintaining a residual in the distribution system. Caustic soda is used for pH adjustment of the finished water to prevent corrosion in the distribution system. Fluoride is applied to reduce the potential for dental caries.

Pre-ozone is used for taste and odor control and enhanced coagulation (increased TOC removal). Intermediate ozone is used for disinfection (CT credit) which delays and reduces chlorine addition to the minimum needed in the distribution system, thus reducing DBP formation. Turbidity, TOC, diatoms, and all other water quality issues affect Fleming Hill just like every other plant on the PSC. Fleming Hill has a very long sedimentation time which helps in times of high turbidity, but the increase in settled water turbidity is still observed seasonally.

2.11 Travis AFB WTP

The Travis Air Force Base (AFB) WTP is operated by the City of Vallejo and provides municipal water solely for the air base. The WTP primarily treats water from the NBA but the City of Vallejo can also convey Solano Project water to the WTP from the Cordelia complex with City owned pump stations and pipelines. The Cordelia Complex is a small forebay that receives both NBA and Solano Project water. From the Cordelia Complex, water is then pumped to the Fleming Hill WTP and/or to the Travis AFB WTP. It is important to note that at the Cordelia Complex, blending ratios of NBA to PSC water are controlled by the Fleming Hill WTP plant operators. If Fleming Hill WTP is using PSC or NBA water, the WTP has the option of receiving the same blend as the Fleming Hill WTP. Travis AFB WTP also has continuous access to 100 percent unblended NBA water via Northgate Tank and Pump Station, which is the primary source of water to the plant.

The Travis AFB WTP is a conventional WTP with a rated capacity of 7.5 mgd and typical production rate of 2.0 to 4.5 mgd. Treatment consists of pre-ozonation, coagulation, flocculation, sedimentation, and filtration. The filters are dual media using granular activated carbon and sand. Sodium hypochlorite is used for primary disinfection and for maintaining a residual in the distribution system. Pre-ozone is utilized for pre-oxidation and taste and odor control.

2.12 City of Benicia

The City of Benicia WTP receives water from the Solano Project via a Terminal Reservoir pump and pipeline, as well as from the NBA, and Lake Herman. The Solano Project water is a secondary supply to the City's NBA entitlement. The majority of the time, Solano Project water is blended with NBA water to reduce the influent TOC concentrations in the NBA water.

In 2014, the City of Benicia and the City of Vallejo installed a screen at the Terminal Reservoir to reduce debris, mostly aquatic plants, from entering the WTP.

The WTP has a rated hydraulic capacity of 12 mgd but the typical production rates range between 3 and 10 mgd. The plant is a conventional water treatment plant consisting of alum/cationic polymer coagulation-flocculation, dual granular activated carbon/sand gravel media filtration and free chorine disinfection. With the additional Solano Project water purchased from SID, the Benicia WTP currently begins pumping 100 percent PSC water once the winter rains arrive (December or January) and continues pumping into late April or May. During the transition from the NBA to the PSC source, there is a one to three day blending scheme as the City switches from one source to the other. Over the reporting period, the Benicia WTP treated 100 percent PSC water only 8 out of 60 months. According to the City, this was because of three main reasons: 1) Higher quality NBA water due to drought conditions, which prolonged the use of NBA water, 2) South Napa Earthquake which broke the PSC raw water transmission line, and 3) Repairs and relocation of City's raw water transmission main due to other projects.

This section provides an overall review of the water quality data available for Putah Creek source water. The sources of raw water quality data include data from the various Putah South Canal (PSC) users, as shown in **Table 3-1**. This section provides a review of the constituents of interest, including an explanation for their selection and a summary of the data obtained for the period of study, for each constituent. The period of study for this watershed sanitary survey is January 2012 through December 2016. It should be noted that some of the water treatment plants (WTP)s treat PSC water year-round and some WTPs blend with other sources, such as the North Bay Aqueduct. For the WTPs which blend sources, only data when the plant was treating 100% PSC water was evaluated. The frequency of data collection varies by constituent.

Table 3-1
Summary of Water Quality Data Evaluated

Agency	Data Collected	100% PSC or blend
Solano County Water Agency	Real-time Turbidity data at Headworks and Terminal Reservoir	N/A
Solano Irrigation District (Gibson Canyon WTP)	Turbidity, coliforms *Cryptosporidium* at Terminal Reservoir	100% PSC
City of Vacaville WTP	Turbidity, coliforms, TOC, pesticides	100% PSC, plant operated seasonally from April to September
City of Fairfield (North Bay Regional WTP)	Turbidity, coliforms, TOC, pesticides, copper	Blend
Suisun Solano Water Authority (Cement Hill WTP)	Turbidity, coliforms, TOC	100% PSC
City of Fairfield (Waterman WTP)	Turbidity, coliforms, TOC, copper	100% PSC
City of Vallejo (Fleming Hill WTP)	Turbidity, coliforms, TOC	Blend
City of Benicia WTP	Turbidity, coliforms, TOC	Blend

Water quality data from the City of Vallejo's Travis AFB WTP data will not be evaluated as the Fleming Hill WTP also receives PSC water from the same pipeline as the Travis AFB WTP. It is preferred to evaluate the Fleming Hill WTP as it treats 100% PSC water more often than the Travis AFB WTP. Water quality data from the City of Vallejo's Green Valley WTP will also not be evaluated since PSC water is always blended with source water from Vallejo's Lakes System prior to treatment.

For assistance with abbreviations and acronyms, the reader is referred to the List of Abbreviations at the front of the Report.

SELECTED CONSTITUENT REVIEW

This section contains a general discussion of selected water quality constituents and the reasons why they were selected for further evaluation. The constituents selected for further review in this report include turbidity, microbial constituents, total organic, carbon, copper and pesticides. The constituents' general characteristics, seasonal and historical trends, and significance with respect to existing and potential future regulations are presented, along with data analysis and review

Turbidity

General Characteristics and Background

Turbidity is the measurement of light scatter in water and provides a measure of the degradation of clarity in water. Clarity is typically degraded by suspended colloids and fine suspended solids such as clay, organic particulates, and microorganisms such as *Giardia* and *Cryptosporidium,* if present. Turbidity is measured to evaluate the efficiency of the treatment process at removing these particles and also to comply with regulatory requirements.

Turbidity was selected for further evaluation since most facilities optimize treatment processes to maximize turbidity removal in order to reduce the potential for pathogens, such as *Giardia* and *Cryptosporidium,* in treated drinking water. Turbidity is monitored throughout the treatment plant to ensure that particles are removed. Turbidity has been assumed to be an indicator constituent for the presence of *Giardia* and *Cryptosporidium*. However, turbidity alone may be a poor predictor of microbiological quality.

High turbidity levels in surface water sources are typically the result of erosion and sediment transport during precipitation and high flow events, and are undesirable because high turbidity may mask the presence of harmful particulates. The principal source of turbidity is general watershed runoff, and can also be contributed by other potential contaminating activities such as wildfires. It is common for turbidities to vary seasonally as a result of precipitation and flow.

Evaluation

Turbidity has been selected for evaluation not only because it is a regulated constituent, but also because it is commonly used as an indicator of general water quality and overall plant performance. **Table 3-2** provides a summary of raw water turbidity data using the daily average data for the WTPs, Headworks and the Terminal Reservoir.

Table 3-2. Turbidity Summary Table, 2012 to 2016

WTP	Range	Average	Median	90th	Number of Samples
Headworks	0.18 - 1090	7.8	2.4	6.6	1581
Gibson Canyon	0.8 - 18	1.9	1.5	3.7	1828
Vacaville	0.75 – 8.2	2.1	1.7	4.2	532
NBR	0.2 - 161	3.1	1.1	3.5	860
Cement Hill	0.6 - 203	5.2	2.8	5.7	1828
Waterman	0.2 - 144	2.5	1.0	3.0	1827
Terminal Reservoir	0.11 - 638	10.3	4.3	21.3	1721
Benicia	1 – 58.3	3.6	1.3	7.4	243
Fleming Hill	0.4 – 38.4	2.9	1.8	5	1639

Figures 3-1 through **3-5** show raw water turbidity over time for each of the WTPs. Benicia WTP was not plotted due to the limited time period that PSC water was treated over the reporting period, as discussed in Section 2. The Cement Hill, NBR, and Waterman WTPs show similar trends, with turbidity peaks above 100 NTU occurring at the same time, due to storm events. For example, all three WTPs have turbidity peaks in December 2012, December 2014 and March 2016. The Fleming Hill WTP has overall lower turbidities as it is located further downstream, as some turbidity has settled out in the canal. The Vacaville WTP does not show the same turbidity peaks as the other WTPs, as it is operated seasonally and does not operate in the winter.

As shown in **Figure 3-2**, the Gibson Canyon WTP has much lower turbidities than the Cement Hill WTP. The Gibson Canyon WTP has lower turbidities since it does not receive water directly off the canal like the Cement Hill WTP. Rather, water is pumped off the PSC by the Eldredge Pumping Plant and then flows into the Bascherini Reservoir before entering the Gibson Canyon WTP. Additionally, the Eldredge Pumping Plant is typically shutdown during times of high turbidity on the PSC.

Figure 3-1.
Vacaville WTP Influent Turbidity, NTU, 2012 to 2016

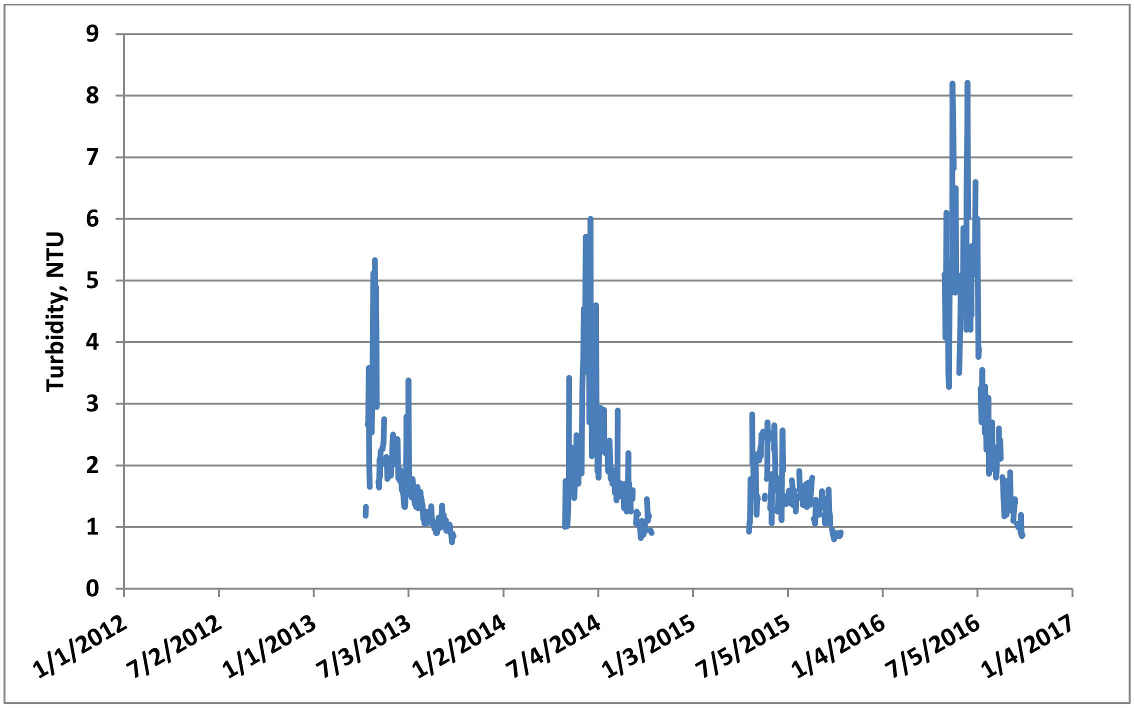


Figure 3-2.
Gibson Canyon and Cement Hill WTP Influent Turbidity, NTU, 2012 to 2016

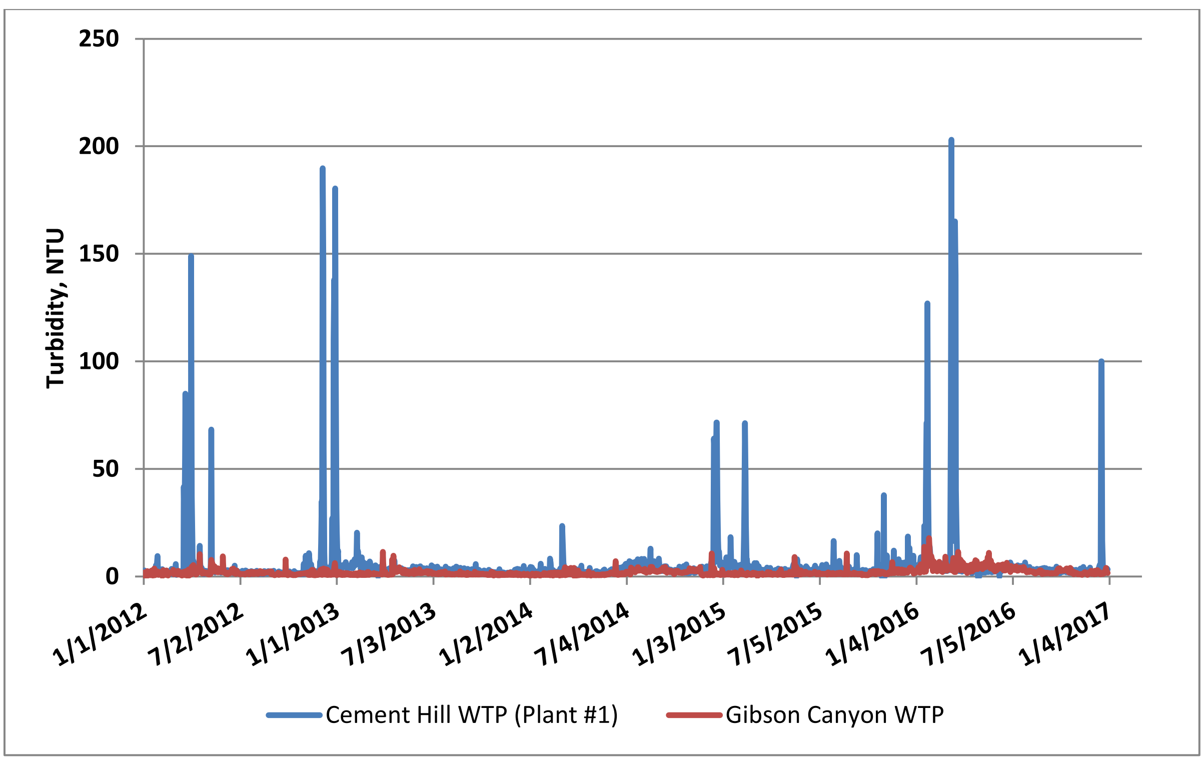


Figure 3-3.
NBR WTP Influent Turbidity, NTU, 2012 to 2016

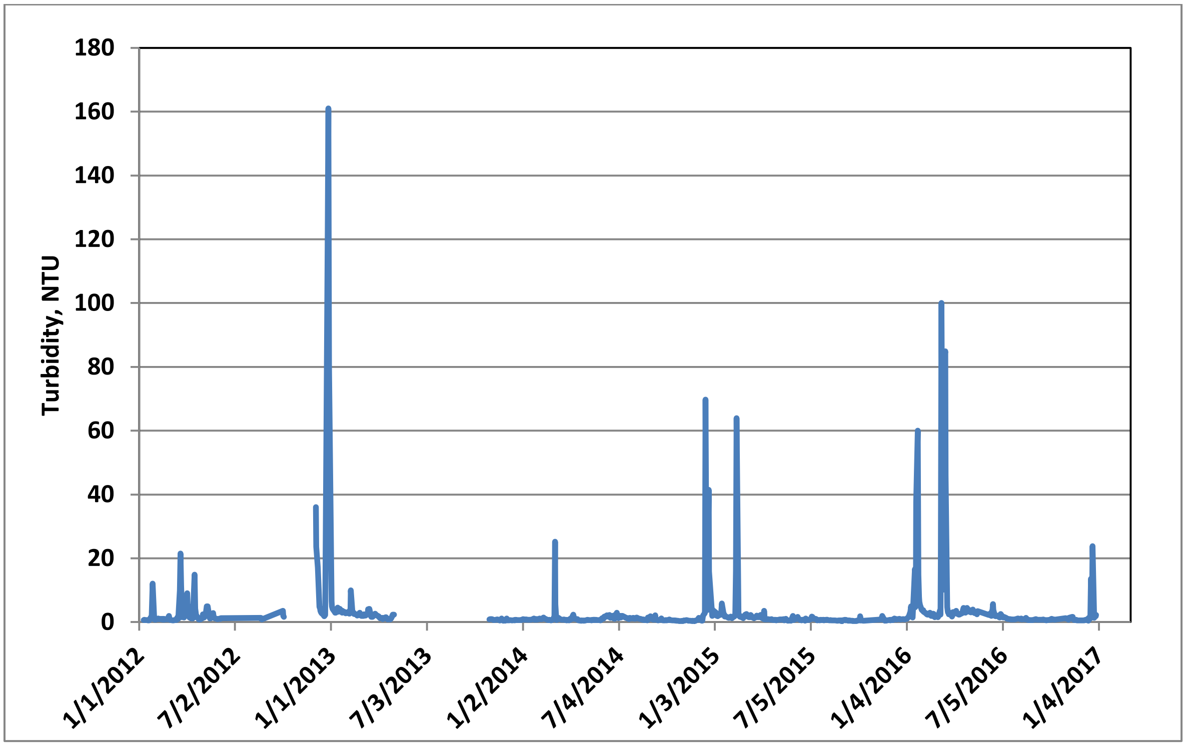


Figure 3-4.
Waterman WTP Influent Turbidity, NTU, 2012 to 2016

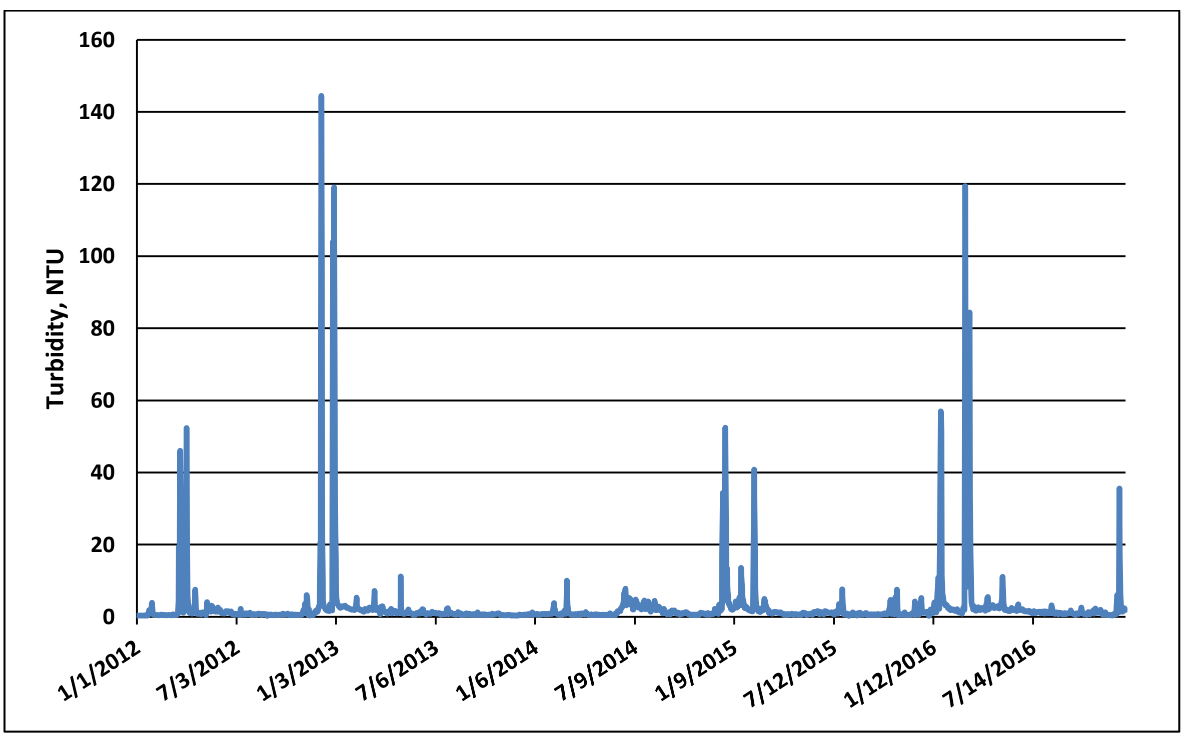
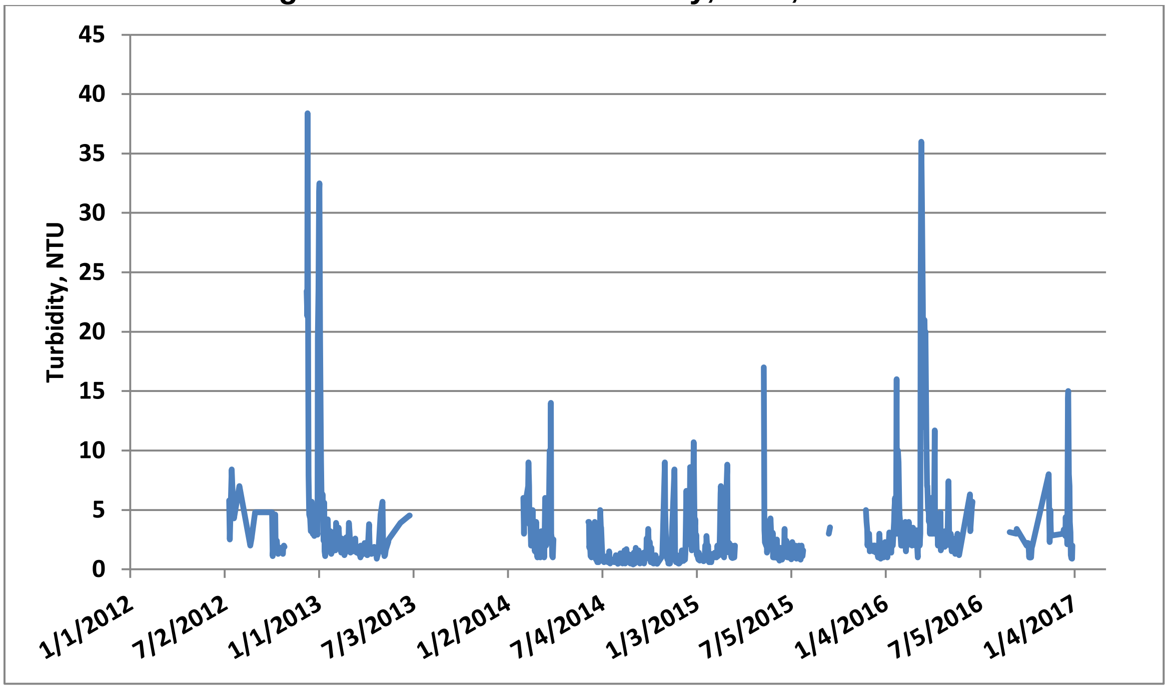
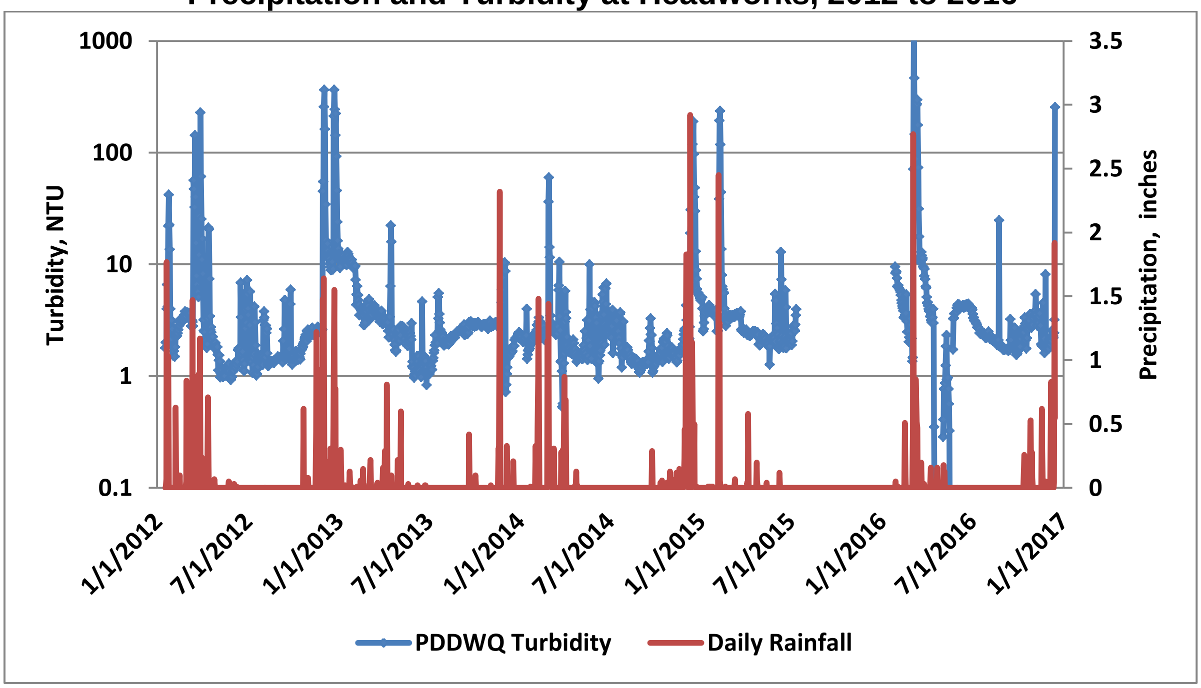


Figure 3-5
Fleming Hill WTP Influent Turbidity, NTU, 2012 to 2016



Overall it can be seen that although the turbidity is normally low, with median turbidities at all locations less than 3 NTU, there are frequent periods where levels exceed that substantially, up to 100 NTU and higher. These excursions are associated with winter storms. **Figure 3-6** shows the relationship between precipitation and turbidity at Headworks.

Figure 3-6.
Precipitation and Turbidity at Headworks, 2012 to 2016



SCWA also has on-line turbidimeters at Headworks and the Terminal Reservoir, which record data every 15 minutes. Storms which occurred in December 2012, December 2014 and March 2016 were plotted using hourly data as shown in **Figures 3-7** through **3-9**. The December 2014 storm was evaluated further as this storm had the highest amount of rainfall in a 24 hour period, at 2.9 inches. The March 2016 storm was evaluated further due to the large peak in turbidity at the Headworks at 1500 NTU.

As shown in **Figure 3-7**, storms can increase turbidity immediately at Headworks, increasing ten-fold from 191 NTU to 1237 NTU within one hour. As expected, the turbidity peaks at Headworks also occur downstream at Terminal Reservoir, but the peaks are much smaller at Terminal Reservoir. Additionally, during large turbidity events, the PSC Headwork gates are often closed for up to 24-hrs, bypassing the peak turbidity events,

Figure 3-7. On-line turbidities at Headworks and Terminal Reservoir - March 2016 Storm

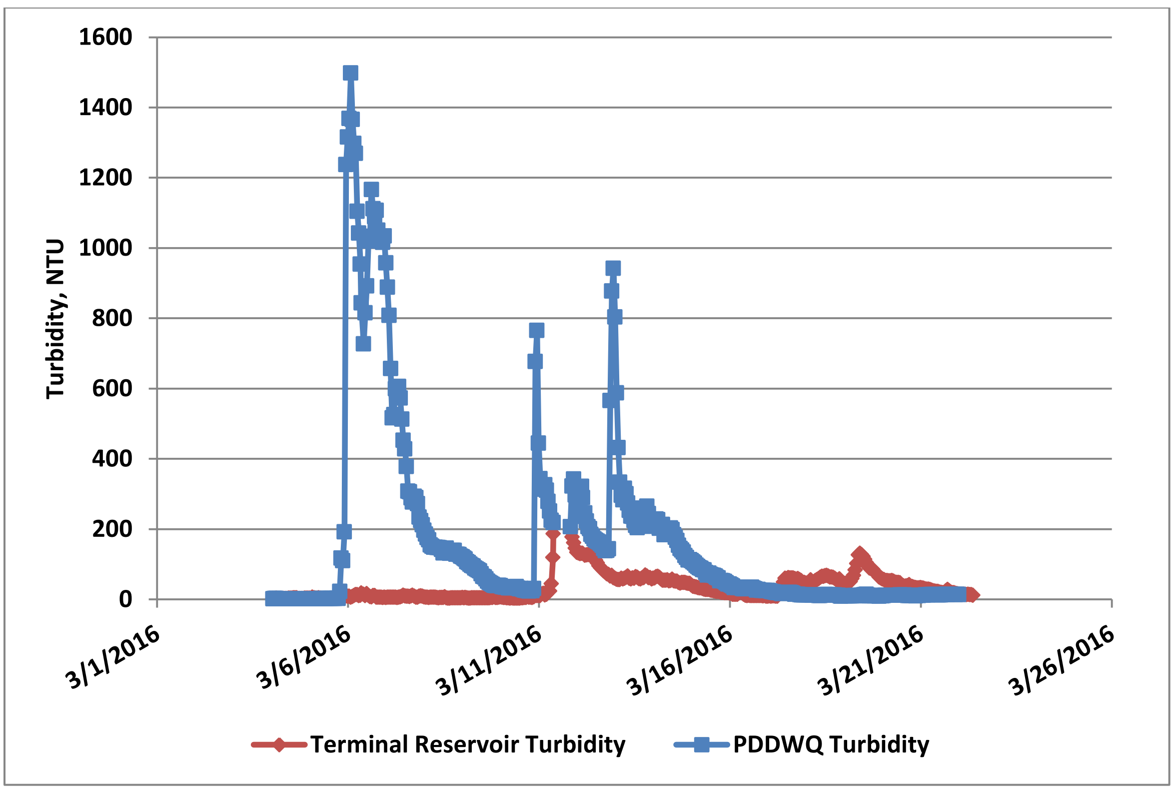


Figure 3-8. On-line turbidities at Headworks and Terminal Reservoir - December 2014 Storm

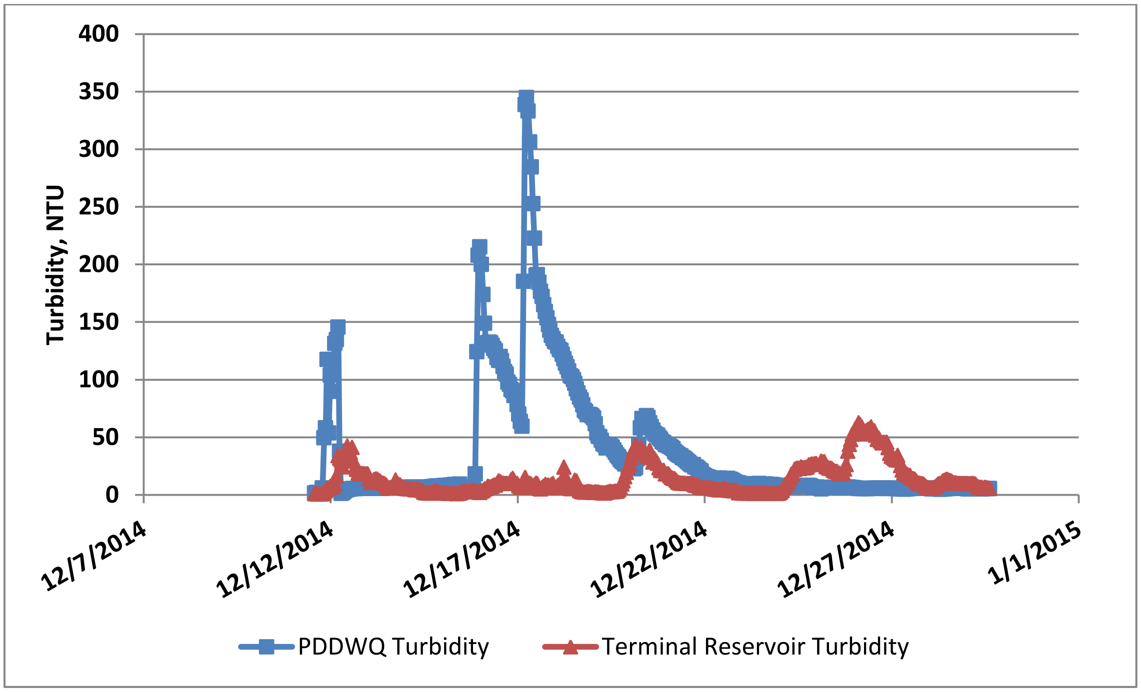
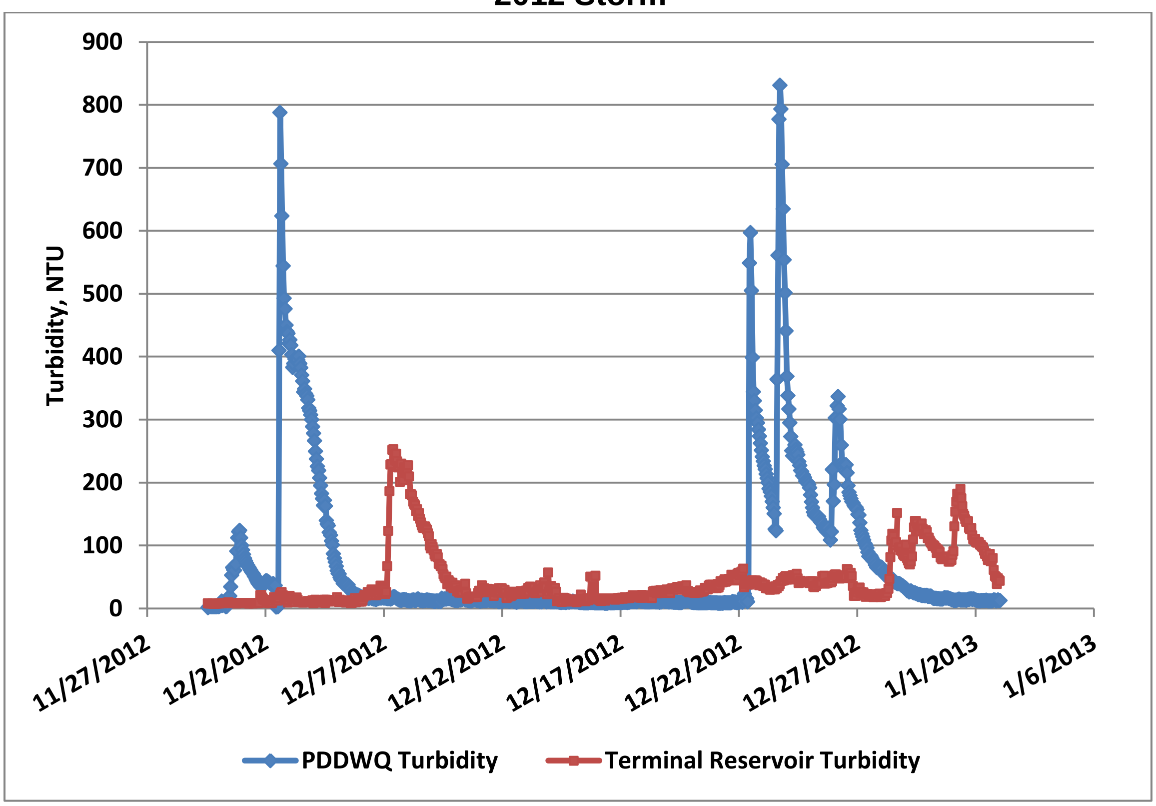


Figure 3-9. On-line turbidities at Headworks and Terminal Reservoir - December 2012 Storm



Summary of Results

- Overall, source water turbidity is normally low, with medians at all locations less than 3 NTU. However, there are frequent periods where levels exceed that substantially, up to 100 NTU and higher. These excursions are associated with winter storms.
- The Cement Hill, NBR, and Waterman WTPs show similar trends, with turbidity peaks above 100 NTU occurring at the same time, due to storm events. For example, all three WTPs have turbidity peaks in December 2012, December 2014 and March 2016.
- Storms can increase turbidity immediately at Headworks, increasing ten-fold from 191 NTU to 1237 NTU within one hour.
- The Fleming Hill WTP has overall lower turbidities as it is located further downstream, as some turbidity has settled out in the canal.
- The Gibson Canyon WTP also has overall lower turbidities as the Eldredge Pumping Plant which pumps water to the WTP is typically shutdown during periods of high turbidities on the PSC.

Microbial Constituents

General Characteristics and Background

The major microbiological constituents of concern include fecal coliform, *E. coli*, *Giardia lamblia*, and *Cryptosporidium parvum*. Generally speaking, pathogenic organisms carried by mammalian species may be infectious to humans although this depends on the species of microorganism. Pathogens infecting other types of animals, such as birds and reptiles, are usually not infectious to humans. However, some types of animals, such as birds, may be vectors for human pathogens. Each of these constituents was identified for further evaluation because they are currently regulated. The presence of these constituents in the raw water governs the overall treatment requirements for the water treatment plants, though detected pathogens and pathogen indicators may not be capable of infecting humans.

Fecal coliform and *E. coli* have been used to indicate the potential presence of pathogenic microorganisms in source waters. Although coliform levels do not correlate well with pathogenic microorganisms, they continue to be used as indicators due to the lack of affordable and reliable direct analytical methods for detecting pathogens. Potential sources of coliform bacteria in the Putah Creek watershed include general watershed runoff, recreation, urban runoff, and grazing.

Giardia lamblia is a species of the protozoa genus *Giardia* that infects humans and can cause the gastrointestinal disease giardiasis. *Giardia* is found in the environment as a cyst from the feces of humans and animals; both wild and domestic animals may be hosts. Sources close to waterbodies have the most potential to introduce viable cysts to the source water. Cysts may be destroyed naturally in the environment by desiccation and/or heat. The cysts are effectively inactivated using chlorine disinfection. The detectability of *Giardia* has been greatly improved with USEPA Method 1623, which is better able to establish concentrations, but still does not determine viability. *Giardia* may be carried in urban runoff and wastewater sources or may be contributed directly as a result of body-contact recreation or animal defecation, including both wild and domestic animals.

Giardia lamblia is currently regulated by the Surface Water Treatment Rule (SWTR) and the Interim Enhanced Surface Water Treatment Rule (IESWTR). Under the Surface Water Treatment Rule (SWTR), the general requirements are to provide treatment to ensure at least 3-log reduction of *Giardia lamblia* cysts and at least 4-log reduction of viruses. Surface water supplies must provide for 3-log reduction of *Giardia* through physical removal and chemical inactivation. Additional reduction may be required for impaired water supplies. The State Water Resources Control Board Division of Drinking Water (DDW) guidance provides that 3-log reduction is appropriate when monthly median levels of total coliform are less than 1,000 MPN/100 mL, fecal coliform or *E. coli* levels are less than 200 MPN/100 mL, or when directly measured confirmed *Giardia* levels are less than 0.01 cysts per liter.

Cryptosporidium parvum is a species of the protozoa genus *Cryptosporidium* that infects humans and can cause the gastrointestinal disease cryptosporidiosis. *Cryptosporidium* is found in the environment as an oocyst principally from the feces of domestic animals, although both wild and domestic animals are known to be hosts. Like *Giardia*, *Cryptosporidium* oocysts may be destroyed naturally in the environment by desiccation and/or heat. Once in the source water, however, viable oocysts are very resistant to traditional chemical inactivation using chlorine. Stronger disinfectants such as ozone or ultraviolet (UV) light are required to inactivate these pathogens. The detectability of *Cryptosporidium* has been greatly improved with USEPA Methods 1622 and 1623, which are able to establish true concentrations, but still do not determine viability. *Cryptosporidium* may be carried in urban runoff and wastewater sources or may be contributed directly as a result of body-contact recreation or animal defecation, including both wild and domestic animals.

Cryptosporidium is currently regulated through the IESWTR and the Long Term 1 ESWTR (LT1ESWTR), which require 2-log reduction, and the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) which potentially requires additional log action based on source water monitoring results for *Cryptosporidium*. Under the IESWTR (applicable to public water systems serving at least 10,000 population) and LT1ESWTR (applicable to public water systems serving fewer than 10,000 population) well-operated conventional and direct water treatment plants are granted a 2-log removal credit for *Cryptosporidium* if they meet all treated water turbidity standards. The LT2ESWTR (applicable to all public water systems) further regulates *Cryptosporidium* and requires additional action (treatment or protection) if the source water quality is determined to be impaired based on the required direct *Cryptosporidium* monitoring of the source, if running annual average presumed levels are greater than 0.075 oocysts per liter.

The monitoring conducted for the LT2ESWTR is discussed first for all treatment plants treating PSC water. This is followed by a discussion of the coliform data collected at the intakes to each of the water treatment plants. To calculate median coliform densities, data results that were reported as non-detectable were set to zero and those results that were reported as greater than an upper limit were set at the upper limit.

Evaluations

Cryptosporidium

The second round of Long Term 2 Enhanced Surface Water Treatment Rule monitoring was conducted from April 2015 to March 2017 by SID. *Cryptosporidium* samples were collected every month at the Terminal Reservoir. Out of the 24 samples, *Cryptosporidium* was detected twice at a concentration of 0.1 oocysts/L in March 2016 and May 2016. The data was submitted to the DDW and all WTPs treating 100 percent PSC water were placed into Bin 1 classification, requiring no additional action for *Cryptosporidium*.

E. coli

Table 3-3 provides a summary of *E. coli* data for the WTPs collecting *E. coli* data.

Table 3-3. *E. coli* Summary Table, 2012 to 2016

WTP	Range	Average	Median	90th	Number of Samples
Gibson Canyon	0 – 920.8	18.2	7	37	260 (weekly)
NBR	0 – 1,733	39.9	10	59.4	1297 (daily)
Cement Hill	0 - 613	28	7	60.1	260 (weekly)
Waterman	0 - 2419	22.7	4.1	31.3	261 (weekly)

Gibson Canyon WTP

E. coli data were collected weekly from 2012 through 2016. *E. coli* densities range from <2 to 920.8 MPN/100mL, with an overall median of 7 MPN/100mL. The monthly median *E. coli* densities are shown in **Figure 3-10**. The *E. coli* monthly medians were well below the 200 MPN/100 mL threshold. These data indicate that 2-log *Cryptosporidium*, 3-log *Giardia,* and 4-log virus removal and inactivation is the appropriate level of treatment.

NBR WTP

E. coli data were collected daily from 2012 through 2016. Since NBR WTP can also treat NBA water, data evaluated was only when the WTP was treating PSC water. *E. coli* densities range from <1 to 1,733 MPN/100mL, with an overall median of 10 MPN/100mL. The monthly median *E. coli* densities are shown in **Figure 3-10**. The *E. coli* monthly medians were well below the 200 MPN/100 mL threshold. These data indicate that 2-log *Cryptosporidium*, 3-log *Giardia,* and 4-log virus removal and inactivation is the appropriate level of treatment.

Cement Hill WTP

E. coli data were collected weekly from 2012 through 2016. *E. coli* densities range from <1 to 613 MPN/100mL, with an overall median of 7 MPN/100mL. The monthly median *E. coli* densities are shown in **Figure 3-11**. The *E. coli* monthly medians were well below the 200 MPN/100 mL threshold. These data indicate that 2-log *Cryptosporidium*, 3-log *Giardia,* and 4-log virus removal and inactivation is the appropriate level of treatment.

Waterman WTP

E. coli data were collected weekly at Bascherini reservoir from 2012 through 2016. *E. coli* densities range from <1 to 2,419 MPN/100mL, with an overall median of 4.1 MPN/100mL. The monthly median *E. coli* densities are shown in **Figure 3-11**. The *E.*

coli monthly medians were well below the 200 MPN/100 mL threshold. These data indicate that 2-log *Cryptosporidium*, 3-log *Giardia,* and 4-log virus removal and inactivation is the appropriate level of treatment.

Fecal Coliform

Table 3-4 provides a summary of fecal coliform data for the WTPs collecting fecal coliform.

Table 3-4. Fecal Coliform Summary Table, 2012 to 2016

WTP	Range	Average	Median	90th	Number of Samples
Vacaville	1 - 236	24.5	14.6	56.3	141 (weekly)
Fleming Hill	0 - 400	22.3	6	60	215 (weekly)
Benicia	2 - 62	14	8	27.6	9 (monthly)

Vacaville WTP

The Vacaville WTP collected weekly fecal coliform from 2012 to 2016. Fecal coliform densities range from 1 to 236 MPN/100mL, with an overall median of 14.6 MPN/100mL. The monthly median fecal coliform densities are shown in **Figure 3-10**. The fecal coliform monthly medians were well below the 200 MPN/100 mL threshold. These data indicate that 2-log *Cryptosporidium*, 3-log *Giardia,* and 4-log virus removal and inactivation is the appropriate level of treatment.

Fleming Hill WTP

The Fleming Hill WTP collected weekly fecal coliform from January 2012 to February 2016, and then switched to *E. coli* from March to December 2016. Samples are collected at the Terminal Reservoir. Fecal coliform densities range from <2 to 400 MPN/100mL, with an overall median of 6 MPN/100mL. The monthly median fecal coliform densities are shown in **Figure 3-11**. The fecal coliform monthly medians were well below the 200 MPN/100 mL threshold. These data indicate that 2-log *Cryptosporidium*, 3-log *Giardia,* and 4-log virus removal and inactivation is the appropriate level of treatment.

City of Benicia

The City of Benicia collected fecal coliform data on a monthly basis. As mentioned in Chapter 2, the City of Benicia was using 100 percent PSC water only eight individual months during the January 2012 to December 2016 reporting period. Based on these eight months, the fecal coliform densities range from 2 to 62 MPN/100mL, with an overall median of 8 MPN/100mL. The fecal coliform monthly medians were well below the 200 MPN/100 mL threshold. These data indicate that 2-log *Cryptosporidium*, 3-log *Giardia,* and 4-log virus removal and inactivation is the appropriate level of treatment.

The DDW recommends using monthly median fecal coliform or *E. coli* levels as a guide for increased *Giardia*/virus treatment requirements, with 200 MPN/100mL as the designated level for increased log reduction. **Figures 3-10** and **3-11** show the monthly medians for either *E. coli* or fecal coliform for each of the WTPs treating PSC water. The only month that the monthly median was above the 200 MPN/100mL trigger threshold was November 2015 at the NBR WTP. Therefore, 2-log *Cryptosporidium*, 3-log *Giardia,* and 4-log virus removal and inactivation is the appropriate level of treatment. Summer months appear to have slightly higher values, with occasional peaks during the winter.

Figure 3-10. Monthly Median *E. coli* or Fecal Coliform at the Vacaville WTP, Gibson Canyon WTP, and NBR WTP

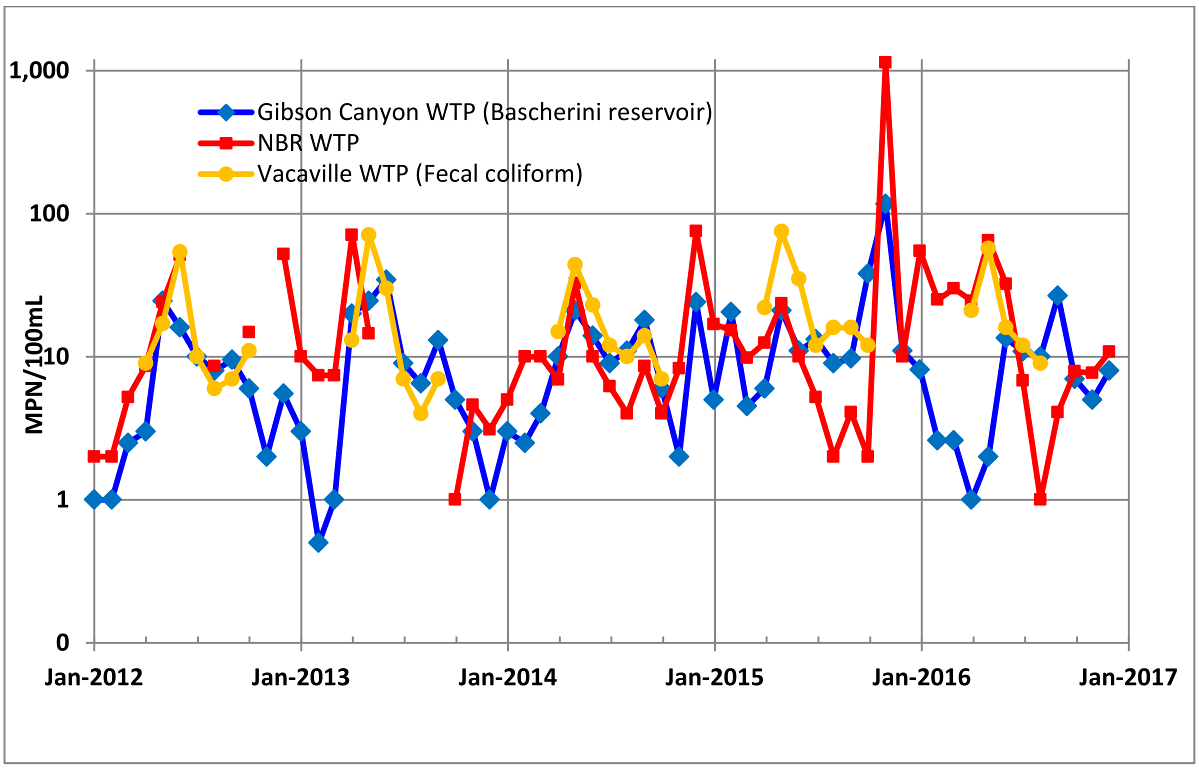
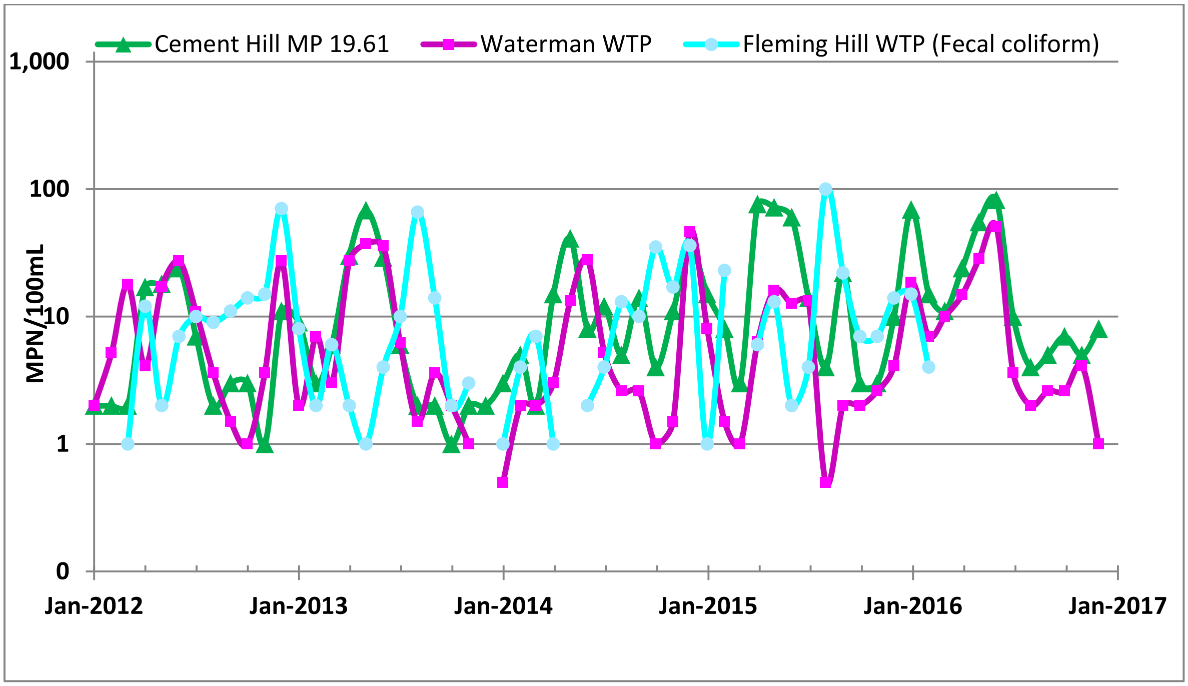


Figure 3-11. Monthly Median *E. coli* or Fecal Coliform at the Cement Hill WTP, Waterman WTP, and Fleming Hill WTP



<u>Total Coliform</u>

Table 3-5 provides a summary of total coliform data for the WTPs.

Table 3-5. Total Coliform Summary Table, 2012 to 2016

WTP	Range	Average	Median	90th percentile	Number of Samples
Vacaville WTP	248 – 14,136	3049	1670	7270	141 (weekly)
Gibson Canyon	38 - 3076	894	547	2419	260 (weekly)
NBR WTP	1 – 28,272	2408	1733	4352	1300 (daily)
Cement Hill WTP	12 – 8,664	1408	1413	2419	260 (weekly)
Waterman WTP	83 – 6,131	1232	921	2419	261 (weekly)
Fleming Hill WTP	20 - 5000	292	100	870	215 (weekly)
Benicia WTP	40 -1161	495	283	1052	9 (monthly)

Monthly medians for total coliform were also calculated for each WTP. As summarized below, there were a number of months when the monthly median was greater than 1,000 MPN/100mL.

- For the Vacaville WTP, 23 out of 33 months were greater than 1,000 MPN, or 69% of the time

- For the NBR WTP, 34 out of 53 were greater than 1,000 MPN, or 64% of the time
- For the Gibson Canyon WTP, 20 out of 60 months were greater than 1,000 MPN, or 33% of the time
- For the Cement Hill WTP, 41 out of 60 months were greater than 1,000 MPN, or 68% of the time
- For the Waterman WTP, 25 out of 60 months were greater than 1,000 MPN, or 41% of the time
- For the Fleming Hill WTP, none of the 52 months were greater than 1,000 MPN
- For the Benicia WTP, 2 out of 9 months were greater than 1,000 MPN, or 22% of the time.

It is unclear as to why total coliform levels are sometimes high. There also does not appear to be a seasonal pattern for the peaks. However, *E. coli,* fecal coliform and *Cryptosporidium* levels are very low, indicating no fecal contamination.

Summary of Results

- The second round of LT2ESWTR monitoring detected *Cryptosporidium* only twice out of 24 monthly samples, with low concentrations at 0.1 oocysts/L.
- Source water fecal coliform and *E. coli* levels are also low, with medians less than 15 MPN/100mL at all locations. Additionally, all monthly medians for fecal coliform and *E. coli* were less than the trigger level of 200 MPN/100mL, except for one month (November 2015) at the NBR WTP.
- Therefore, 2-log *Cryptosporidium*, 3-log *Giardia,* and 4-log virus removal and inactivation is the appropriate level of treatment for all PSC WTPs.

Total Organic Carbon

General Characteristics and Background

Disinfection By-Products (DBPs) are formed when disinfectants added to water react with naturally occurring organic matter or other constituents, such as bromide. The most common DBPs are total trihalomethanes (TTHMs), which are suspected carcinogens. Other DBPs, including haloacetic acids (HAA5), are suspected mutagens and teratogens. Potential sources of organic carbon are plant matter, animal matter, and soil, which can be contributed by general watershed runoff, urban runoff, and fires,

The Stage 1 Disinfectants/Disinfection By-Products (D/DBP) Rule requires varying levels of total organic carbon (TOC) removal if the source water TOC concentrations exceed 2 milligrams per liter (mg/L) and a utility implements conventional filtration. TOC was a selected constituent for further evaluation due to its importance in the formation of DBPs and also as a general indicator of organic contamination in water. All conventional water treatment plants have the ability to remove some TOC.

Evaluation

TOC data were available at the intakes of the Vacaville, NBR, Cement Hill, Waterman, Benicia and Fleming Hill WTPs. **Table 3-6** shows the range, average, median and 90th percentile for TOC over the reporting period. It should be noted that the Vacaville, NBR, and Waterman WTPs sample weekly for TOC, Cement Hill and Benicia WTPs sample monthly, and Fleming Hill WTP sample daily for TOC. Median TOC concentrations are generally between 2 and 5 mg/L. As shown in **Figures 3-12** through **3-15,** the highest TOC concentration for each WTP occurred during the month of December and was storm-related:

- Highest TOC concentration at NBR WTP was 14.5 mg/L on December 5, 2012.
- Highest TOC concentration at Waterman WTP was 7.9 mg/L on December 22, 2014.
- Highest TOC concentration at Cement Hill WTP was 7.4 mg/L on December 13, 2014.
- Highest TOC concentration at Fleming Hill WTP was 8 mg/L on December 8, 2012.

Table 3-6. TOC Summary Table, 2012 to 2016

WTP	Range	Average	Median	90th percentile	Number of Samples
Vacaville WTP	2.5 – 3.3	2.9	2.8	3.2	28 (weekly)
NBR WTP	2.4 – 14.5	3.7	3.4	4.0	196 (weekly)
Cement Hill WTP	2.5 – 7.4	3.2	3.1	3.5	54 (monthly)
Waterman WTP	2.8 – 7.9	3.7	3.5	3.5	298 (weekly)
Fleming Hill WTP	1 - 8	2.2	2	2	1639 (daily)
Benicia WTP	4.65 -6	5	5	5	9 (monthly)

Figure 3-12. Raw Water TOC at NBR Lab Tap, 2012 to 2016

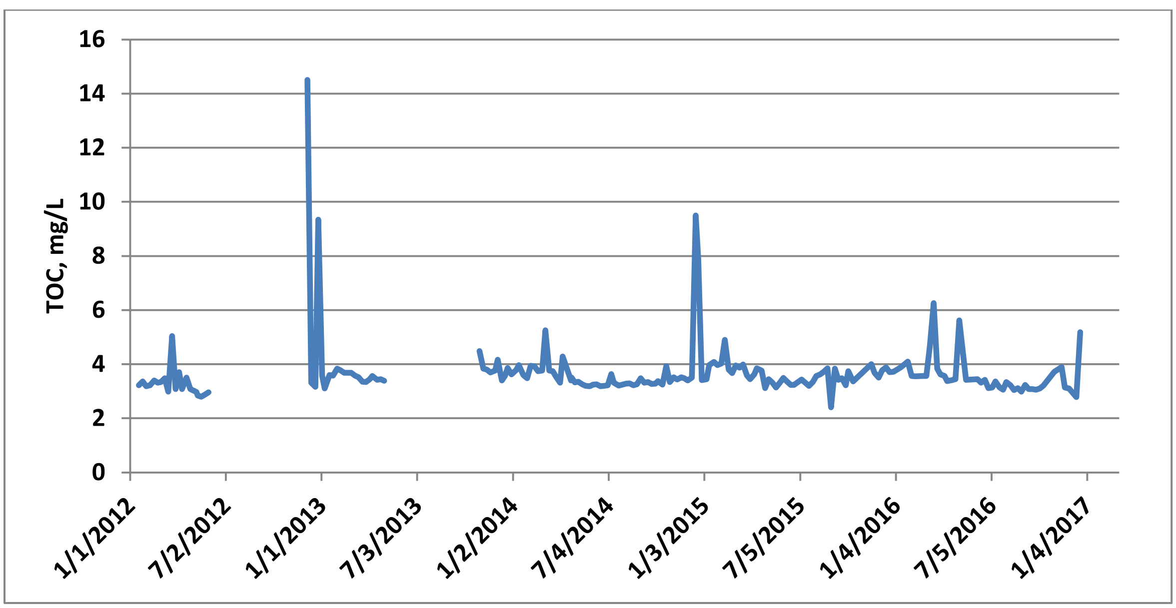


Figure 3-13. Raw Water TOC at Cement Hill WTP, 2012 to 2016

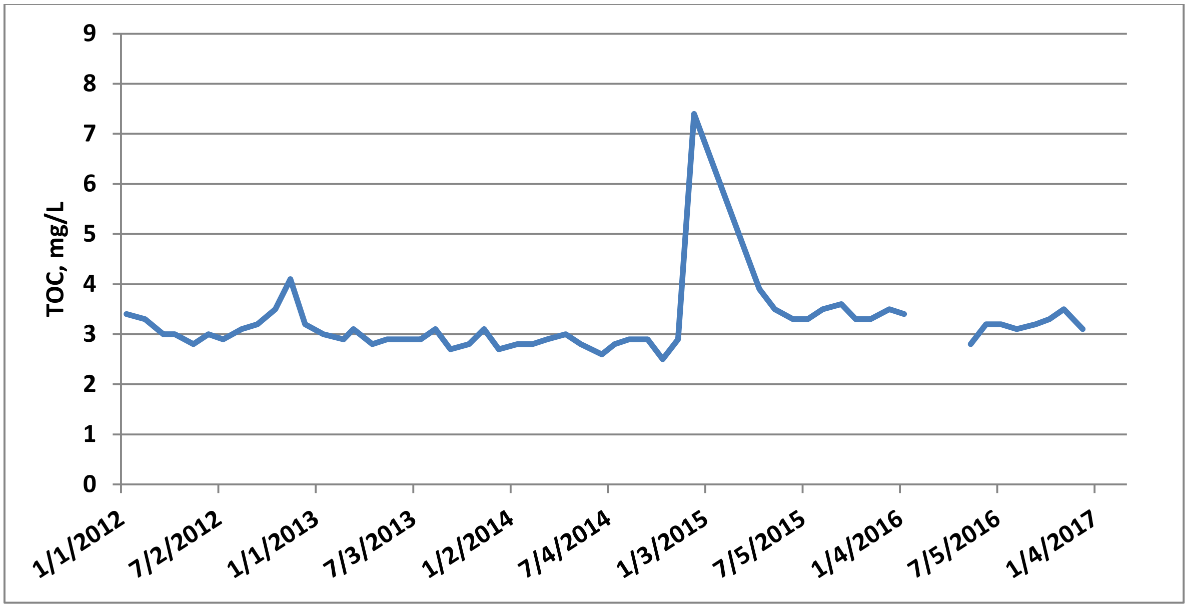


Figure 3-14. Raw Water TOC at Waterman WTP, 2012 to 2016

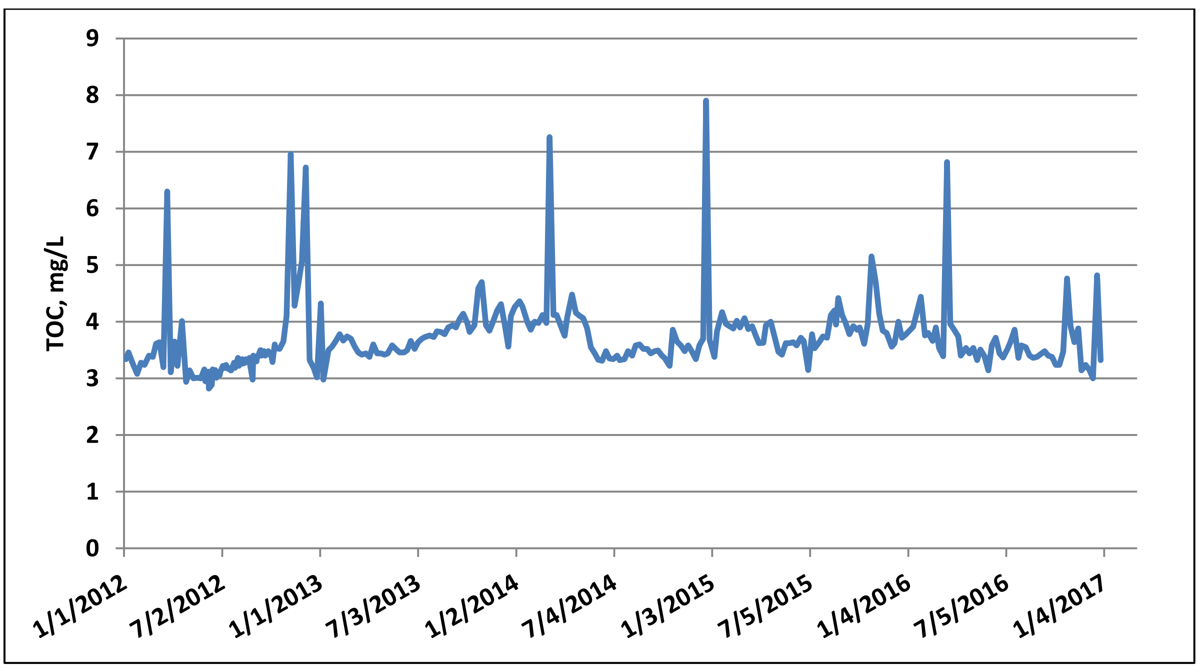
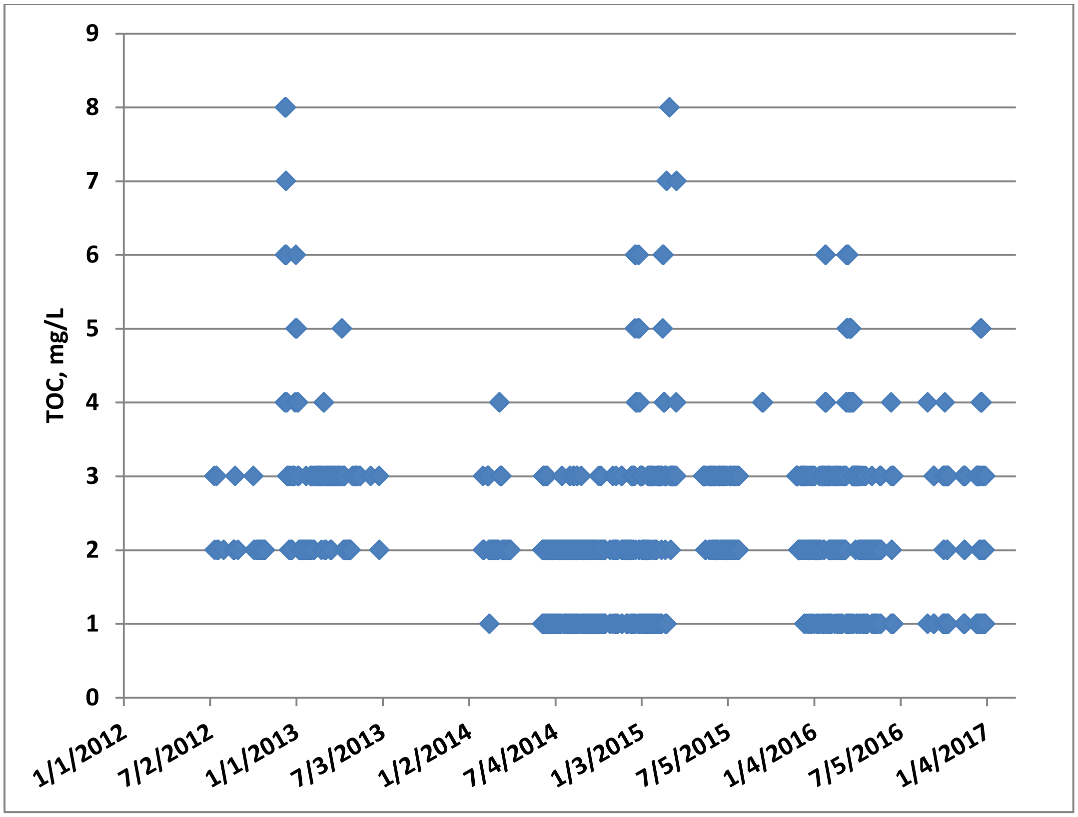


Figure 3-15. Raw Water TOC at Fleming Hill WTP, 2012 to 2016



Enhanced coagulation is required for the plants that treat Solano Project water because the source water TOC is routinely above 2 mg/L and they implement conventional treatment processes. Specifically, 100 percent of samples for all WTPs (except Fleming Hill WTP) were above 2 mg/L at all times during the reporting period. For Fleming Hill WTP, 77 percent of all samples were above 2 mg/L.

Summary of Results

- Median TOC concentrations are generally between 2 and 5 mg/L.
- The highest TOC concentration for each WTP occurred during the month of December and was storm-related.
- Enhanced coagulation is required for the plants that treat Solano Project water because the source water TOC is routinely above 2 mg/L and they implement conventional treatment processes.

Copper

General Characteristics and Background

Copper is a reddish metal that occurs naturally in rock, soil, water, sediment, and air. It has many practical uses and is commonly found in coins, electrical wiring, and pipes. It is an essential element for living organisms, including humans, and in small amounts to ensure good health. However, too much copper can cause adverse health effects, including vomiting, diarrhea, stomach cramps, and nausea. It has also been associated with liver damage and kidney disease.

The Lead and Copper Rule established an "action level" for copper in drinking water. This action level is exceeded if the level of copper in more than 10 percent of the tap water samples collected by a water system is greater than 1,300 mg/L (or 1,300 parts per billion). There is also a secondary MCL of 1 mg/L and a public health goal of 0.3 mg/L for copper.

Evaluation

Copper is collected on a quarterly basis at both the NBR PSC intakes and the Waterman PSC intakes. Copper is also sampled weekly at the lab tap for both the NBR WTP and the Waterman WTP. Over the reporting period, the highest copper concentration measured at the NBR lab tap was 0.107 mg/L on April 7, 2014. It should be noted that all other 143 remaining samples collected at the NBR lab tap were less than 0.050 mg/L. The elevated concentration on April 7, 2014 appears to be related to a copper sulfate treatment which was scheduled for April 3, 2014 at milepost 12.05, which is just upstream of where the NBR WTP takes PSC water (milepost 16.74). The NBR PSC intakes sample was also measured at 0.107 mg/L on April 7, 2014.

The highest copper concentration measured at the Waterman lab tap was 0.114 mg/L on February 24, 2015. There was no corresponding canal sample on this day. Although there was a copper sulfate treatment scheduled on the same day at milepost 23.5, it was confirmed that the treatment occurs immediately downstream of Serpa Check so the elevated concentration at the Waterman WTP is more likely due to an upstream treatment.

With the exception of one other sample with a copper concentration of 0.074 mg/L on May 2, 2012, all other 195 remaining samples collected at the Waterman lab tap were less than 0.050 mg/L.

Overall, all of the copper concentrations measured at the respective lab taps and PSC intakes for the NBR and Waterman WTP were much lower than the action level for the Lead and Copper Rule and the secondary MCL.

Pesticides

General Characteristics and Background

Most synthetic organic chemicals (SOCs) are formulated for, or are by-products from industrial, agricultural, and urban use. Pesticides are a main subgroup of the SOCs used for agriculture and urban application. All water treatment plants have the ability to remove some SOCs, but that varies based on processes.

Evaluation

As discussed further in Chapter 4, the top ten pesticides used along the PSC are copper sulfate, sulfur, glyphosate, mineral oil, copper hydroxide, mancozeb, copper oxychloride, buprofezin, kaolin and petroleum oil. Of these chemicals, only copper and glyphosate have drinking water standards.

Volatile organic chemicals (VOCs) and SOCs are collected quarterly at the NBR PSC intakes by the City of Fairfield. No VOCs or SOCs were detected at the NBR PSC intakes, except for one detection of picloram in October 2016 at 0.1 µg/L. There were no detections of glyphosate.

The City of Vacaville samples annually for ten insecticides and pesticides (aldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorobenzene, hexachlorocyclopentadiene, lindane, methoxychlor, and toxaphene). All samples were nondetectable over the reporting period.

Trihalomethanes and Haloacetic Acids

Evaluation

The annual Water Quality Reports prepared by each water provider treating PSC water were reviewed to determine compliance with the treated water standards of 80 µg/L for TTHMs and 60 µg/L for HAA5. The water providers are generally meeting the standards for TTHMs and HAA5. The WTPs with the highest averages for TTHMs are the Gibson Canyon and Cement Hill WTPs.

For the Gibson Canyon WTP, the 2015 TTHM average was 82 µg/L, which is above the MCL. The TTHM average was elevated due an unusually high result of 97 µg/L during the first quarter of 2015. In order to minimize THM formation, system operations were modified to ensure that tank levels were drawn down and refilled every day. Also, a mixer was installed in one of the tanks to keep the water moving, and aerators were installed in several of the tanks to help volatilize disinfection byproducts out of the water. The remaining quarterly sampling during 2015 was in compliance.

For the Cement Hill WTP, the 2016 TTHM average was 87 µg/L, which is above the MCL. The TTHM average was elevated due to one of the four test locations above the

MCL. Daily testing of all sites was started for 22 days while operational changes were made. All TTHMs sampling results after November met the regulatory requirements.

SECTION 4 – WATERSHED CONTAMINANT SOURCES REVIEW

This section contains an evaluation of the eight potential contaminant sources selected for review for the current Update. Eight potential contaminating activities (PCAs) were selected for review as part of the current Update: (1) spills, (2) recreation, (3) agriculture, (4) canal cleaning, (5) lateral sources, (6) grazing, (7) urban runoff and (8) fires. These PCAs were selected based on their presence in the watershed and their potential to impact Putah Creek and PSC water quality.

The 1993, 2001, and 2006 watershed sanitary surveys provide a comprehensive description of the watershed and potential contaminant sources along Putah Creek below Monticello Dam and along the PSC. Agreement was reached with the State Water Resources Control Board Department of Drinking Water (DDW) that the 2012 Update would focus on a few of the more significant contaminant sources, and a similar approach was taken for the 2017 Update.

SPILLS

Background

A hazardous material spill or leak into a surface water body could occur as the result of a vehicular traffic accident, pipeline leak or spill, wastewater treatment plant spill, or other incident. In the event of a leak or spill, timely notification is critical to ensure that the water treatment plant operators are provided with sufficient time and information to best respond to potential treatment concerns.

Related Constituents

The most common spills are related to oil and petroleum products or sewage. Therefore, typical constituents of concern range from volatile organic compounds (VOCs) and hydrocarbons to microbial constituents (i.e. viruses, pathogens, *Giardia, Cryptosporidium*). However, hazardous materials emergencies can involve a virtually infinite number of chemicals or chemical combinations.

Occurrence in Watershed

The main transportation route through the interdam reach is Highway 128.

Information on spills was queried from two sources: 1) the Office of Emergency Services (OES) Response Information Management System (RIMS) archived database, and 2) the State Water Resources Control Board's (SWRCB) California Integrated Water Quality System (CIWQS) database on sanitary sewer overflows (SSOs).

There were no spills occurring over the reporting time period and within the watershed. Additionally, there were no known instances of illegal dumping in the PSC. Although most of the canal is fenced, there are numerous vehicle and pedestrian bridges that provide access to the canal for illegal dumping of materials. SID staff drives along the canal three times a week to check for such activity.

Regulation and Management

When a hazardous materials spill or leak of a reportable quantity occurs, notification to an emergency response agency is required by state and federal law. A sewage spill is required to be reported if 1,000 gallons or more are released. An oil or petroleum product spill is required to be reported if 42 gallons or more are released. Any other hazardous materials spill is required to be reported if there is a reasonable belief that the release poses a significant present or potential hazard to human health and safety, property, or the environment. When a hazardous materials spill or leak occurs, it is the owner's or operator's responsibility to notify the local designated emergency response agency, which is called the Certified Unified Program Agency (CUPA), as well as the OES.

California Emergency Management Agency

OES developed the Response Information Management System (RIMS) as part of the development of the State's Standardized Emergency Management System (SEMS). The purpose of RIMS is to provide a single point for tracking the status and progress of hazardous materials spills statewide. Only registered users can input data into RIMS, but anyone can access the website to review current or archived OES cases.

The archived cases, including those from 1993 through 2017, can be accessed at:
http://www.caloes.ca.gov/FireRescueSite/Pages/Spill-Release-Reporting.aspx

Summary of Findings for Spills

- Overall, there were no spills in the watershed and no direct impacts to the PSC.

RECREATION

Background

Recreational uses along Putah Creek consist primarily of camping, picnicking, hiking, and fishing. Boating is allowed in Lake Solano, but only non-motorized boats.

Related Constituents

Body contact recreation in general has long been known to be a source of pathogen contamination, resulting partly from personal sanitary conduct and partly from a natural shedding process. Pathogens shed by recreationalists include bacteria, viruses, and protozoa. Moreover, because their origin is human, microorganisms shed by recreationalists are transmittable to other humans.

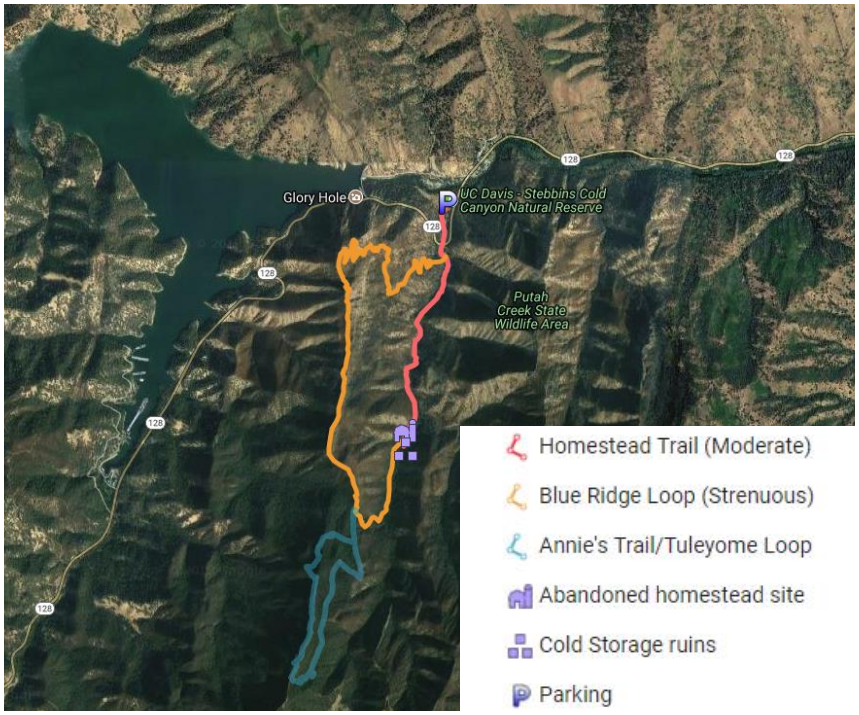
Occurrence in Watershed

Stebbins Cold Canon Reserve

Stebbins Cold Canyon Reserve is a 638 acre reserve set in a steep, north-facing canyon of the northern Coast Range, managed by the University of California Davis (UC Davis) and primarily dedicated to research and teaching. The reserve is on the south side of Putah Creek, immediately below Monticello Dam. The reserve is open to the public year-round from sunrise to sunset and has up to 50,000 to 60,000 visitors per year, a significant increase from the 30,000 visitors per year reported in 2012 and the 5,000 visitors per year reported in 2006. Recreational usage has increased steeply in the last couple of years due to an increase in the number of publications that list the reserve as a hiking destination (Personal Communication, Jeffrey Clary, UC Davis). Starting in 2012, UC Davis undergraduate interns involved in the Student Education Outreach Program organized and lead guided hikes of the area which also increased recreational usage. However, the guided hikes have not resumed since the 2015 Wragg Fire, which closed the Reserve entirely from July 2015 to May 2016.

Figure 4-1 shows the trail network for the reserve. The trails are pedestrian only, no dogs are allowed. Additionally, there is a single portable restroom located in the parking lot which was installed in January 2013.

Figure 4-1 Trail Network for Stebbins Cold Canyon Reserve



Canyon Creek Resort

Canyon Creek Resort Recreational Vehicle (RV) Park is located adjacent to Putah Creek, just below Monticello Dam. This is a private membership resort that is open year-round, with peak occupancy between May and September. There are 127 camping sites, 2 swimming pools, and 2 dump stations. Swimming and wading in Putah Creek is permitted but discouraged by the RV Park owners.

Putah Creek Fishing Access Parks

The five access locations that collectively make up the Putah Creek Fishing Access Parks are located on approximately 150 acres, along a 3.25-mile stretch of creek, on the north side of Putah Creek, starting 7 miles west of the town of Winters. The property is owned by the State Department of Fish and Wildlife – Wildlife Conservation Board and is operated and maintained under a long-term lease by Yolo County Department of Parks and Recreation. The park offers picnic tables, barbecues, fishing, parking and sanitary facilities. A day use fee is required. The five sites are used primarily for fishing and for access to the creek. The Department of Parks and Recreation estimates that there are 19,900 vehicles annually to sites 1, 3, and 4. This is based on vehicle trip counters that were installed on four weekends (quarterly) for one year. Many recent improvements have been made to the Putah Creek Parks sites that include native plant restoration, natural trails, picnic tables, fishing platforms and restrooms facilities.

Lake Solano County Park

Lake Solano Regional Park, located on the southern side of Putah Creek, opened in 1973. The park offers camping, picnicking, swimming, boating, and fishing on 45 acres of land and approximately 110 acres of water. Solano County operates the park under a management agreement with the U.S. Bureau of Reclamation. According to the County, there were about 69,000 park visitors in 2016.

There is a day-use area, campground, boat launch and boat rental, and a Nature Center. There is also a 0.5 mile shoreline interpretive trail that runs between the campground area and the Nature Center. There are a total of 61 campsites, 41 sites with utilities and 20 sites for tents. Boat rentals are only on weekends and holidays, from Easter to end of September. No motorized boats (gas or electric-powered) boats are allowed.

According to the County, future improvements to the drinking water well are planned. The Solano County Water Agency-Lower Putah Creek Coordinating Committee would like to construct a weir for sediment retention across the mouth of Pleasants Creek. If this project goes forward, the County hopes to construct a trail crossing to link the day use area with the youth area campground downstream.

Summary of Findings for Recreation

- Although there are many types of recreation occurring in the watershed, there are very few activities which occur in water, except for boating in Lake Solano. There is minimal to no body contact recreation.

- However, the number of visitors to the Stebbins Cold Canyon Reserve and Putah Creek Fishing Sites has increased in the past five years.

AGRICULTURE

Background

Agricultural-related activities within the watershed are crops and nurseries.

Related Constituents

Nurseries and agricultural crops can impact water quality through their use of fertilizers and pesticides.

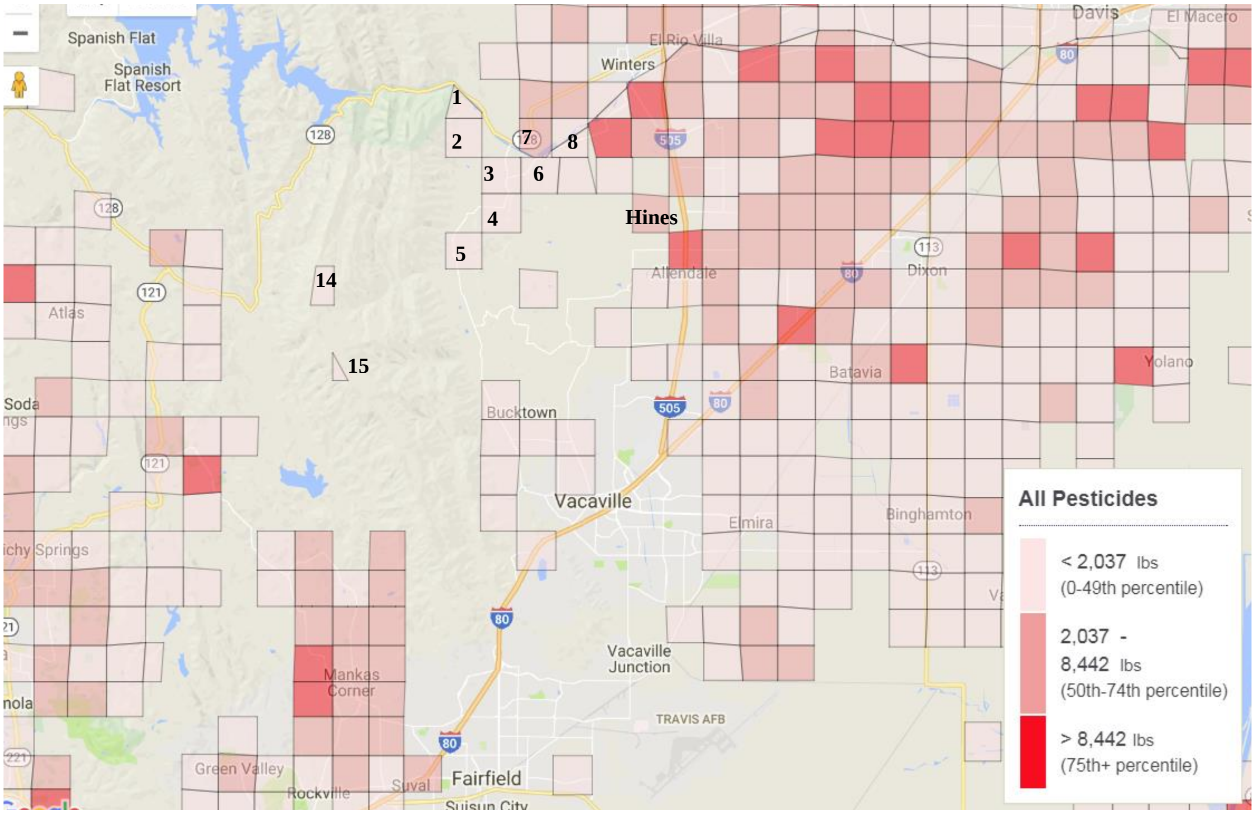
Occurrence in Watershed

A small amount of land is devoted to agriculture in the Lake Solano watershed between Monticello Dam and the Putah Diversion Dam. Although agricultural practices can result in increased loads of suspended solids, nutrients, and organic carbon in receiving waters, pesticides are the primary concern. As shown in **Figure 4-2**, the California Environmental Health Tracking Program Pesticide Mapping Tool (http://cehtp.org/page/pesticides/pesticide_mapping_tool_overview) was used to identify specific parcels (approximately 1 X 1 mile) where pesticides were used in the study watershed from 2012 to 2015 and could impact Putah Creek. **Table 4-1** indicates what crops are grown on each of the individual parcels, and **Table 4-2** provides a summary of the top ten chemicals used on the total of these parcels, based on weight. Crop information was obtained from the California Department of Pesticide Regulation and chemical usage was obtained from the California Environmental Health Tracking Program.

Table 4-1. Crops Grown in Putah Creek Watershed

Parcel	Crop Type
1 (Four Winds Growers)	Outdoor Container Plants, Greenhouse Plants
2	Walnuts
3	Walnuts
4	Apples, Peach
5	Grapes, Olives
6	Walnuts
7	No records
8	Cherry, Prune, Walnuts
14	Grapes
15	No records

Figure 4-2. Parcels Identified for Pesticide Usage from 2012 to 2015 which drain to Putah Creek



Source: California Environmental Health Tracking Program

It should be noted that there are nurseries and crops along the PSC, but chemical usage information was not compiled for these parcels as there is no direct connection to the PSC. As shown in **Figure 4-2**, Hines nursery, Lester Farms (right of parcel 8) and Eldridge Farms (right of Lester Farms) all have heavy chemical usage.

Table 4-2. Top Ten Pesticides used on Parcels which drain to Putah Creek, 2012 to 2015

Chemical Used	Lbs. Used from 2012 to 2015
Copper Sulfate	4,148
Sulfur	3,005
Glyphosate	1,290
Mineral Oil	1,216
Copper Hydroxide	1,100
Mancozeb	767
Copper Oxychloride	279
Buprofezin	261
Kaolin	238
Petroleum Oil	236

Sulfur fungicides are used for the control of powdery mildew and can be effective against most species of pest mites, brown rot, rust, and scab. Mineral oil pesticides are considered one of the safest methods in controlling pests, especially scale insects and mealybugs. Glyphosate is a broad spectrum, systemic, contact herbicide used to control weeds.

Parcel 7 had the highest overall chemical usage per year and had the highest usage of glyphosate (1032 lbs. out of 1,290 lbs. total for all parcels).

Related Water Quality Issues and Data Review

Copper and glyphosate are the only pesticides listed in **Table 4-2** for which drinking water standards has been established. No VOCs or SOCs were detected at NBR's PSC intake, except for one detection of picloram in October 2016 at 0.1 µg/L. There were no detections of glyphosate.

The City of Fairfield collects weekly samples of copper at the NBR WTP and Waterman WTP influent, respectively. Over the reporting period, the highest copper concentrations by location was 114 µg/L on February 24, 2015 at the Waterman WTP and 107 µg/L on April 7, 2014 which are both well below the secondary MCL of 1 mg/L.

Regulation and Management

Regional Water Quality Control Board, Central Valley Region

In 2014 the Regional Board finalized and adopted the Irrigated Lands Regulatory Program (ILRP) as the long-term solution for irrigated agricultural discharges. The ILRP addresses discharge of wastes (e.g., sediments, pesticides, nitrates) from commercial irrigated lands. These wastes can harm aquatic life or make water unusable for drinking water or agricultural uses. The goal of the ILRP is to protect surface water and groundwater and to reduce impacts of irrigated agricultural discharges to waters of the State. Two orders were adopted by the Regional Board for coalitions in the Sacramento River watershed; R5-2014-0030 – Waste Discharge Requirements General Order for Growers within the Sacramento River Watershed That are Members of a Third-Party Group (Sacramento River Watershed) and R5-2014-0032 – Waste Discharge Requirements General Order for Sacramento Valley Rice Growers (Sacramento Valley Rice Growers).

The Sacramento Valley Water Quality Coalition (SVWQC) was developed to comply with the Discharges from Irrigated Lands Regulatory Program. It consisted of a monitoring program and management practices where the monitoring data indicated the need. The SVWQC covers all non-rice irrigated crops in the Sacramento Valley, including wild rice and pastureland. The SVWQC is divided into ten sub-watersheds. The Interdam Reach falls into the Solano and Yolo subwatersheds. Both the Solano Resource Conservation District (RCD) and Dixon RCD are signatories to the SVWQC for the Solano subwatershed, and Yolo County Farm Bureau is signatory to the SVWQC for the Yolo subwatershed. The Dixon RCD website states that approximately 95% of the eligible irrigated acres in Solano County are currently enrolled and there are three monitoring sites that are monitored on a regular basis to determine compliance with Regional Board water quality limits. However, a review of the 2015 SVWQC monitoring plan shows that none of the monitoring sites in the Solano and Yolo subwatersheds are relevant to the InterDam reach.

Source Water Protection Activities

The 2014 Agricultural Orders require growers to self-inspect, implement best management practices, conduct water quality monitoring either as a group or individual, and submit farm information to either their coalition or the Central Valley Water Board, including farm evaluations and nitrogen management data. Information from the Dixon RCD website states that growers also must attend an educational workshop on water quality and the protection of surface and groundwater.

Summary of Findings for Agriculture

- There are limited crop areas within the watershed, namely walnuts and grapes.
- Commercial growers are required to be enrolled in the Central Valley Regional Water Quality Control Board's Irrigated Lands Program, and most growers are likely participating in the Sacramento Valley Water Quality Coalition, through either Solano RCD, Dixon RCD, or the Yolo County Farm Bureau.
- Although there are nurseries and crops grown along the PSC, chemical usage for these parcels were not included as the water cannot drain to the PSC.
- Copper and glyphosate are the only pesticides used in the watershed draining to Putah Creek for which drinking water standards have been established. Monitoring data of PSC water shows low levels of copper and no detections of glyphosate.

LATERAL SOURCES

Background

There are a number of sediment sources in the watershed. There are direct drains along the PSC, overtopping events into the PSC and Interdam Reach tributaries, which are defined as tributaries between Monticello Dam and the Putah Diversion Dam. Other lateral sources such as canal bank surface erosion, canal bank mass failures, and atmospheric deposition were studied previously by the SCWA and were determined to be less of a concern compared to direct drains and overtopping events.

Sediment is a concern, not only due to potentially high turbidities reaching the water treatment plants that treat PSC water, but also because more sediment is also related to more growth of aquatic vegetation in the PSC.

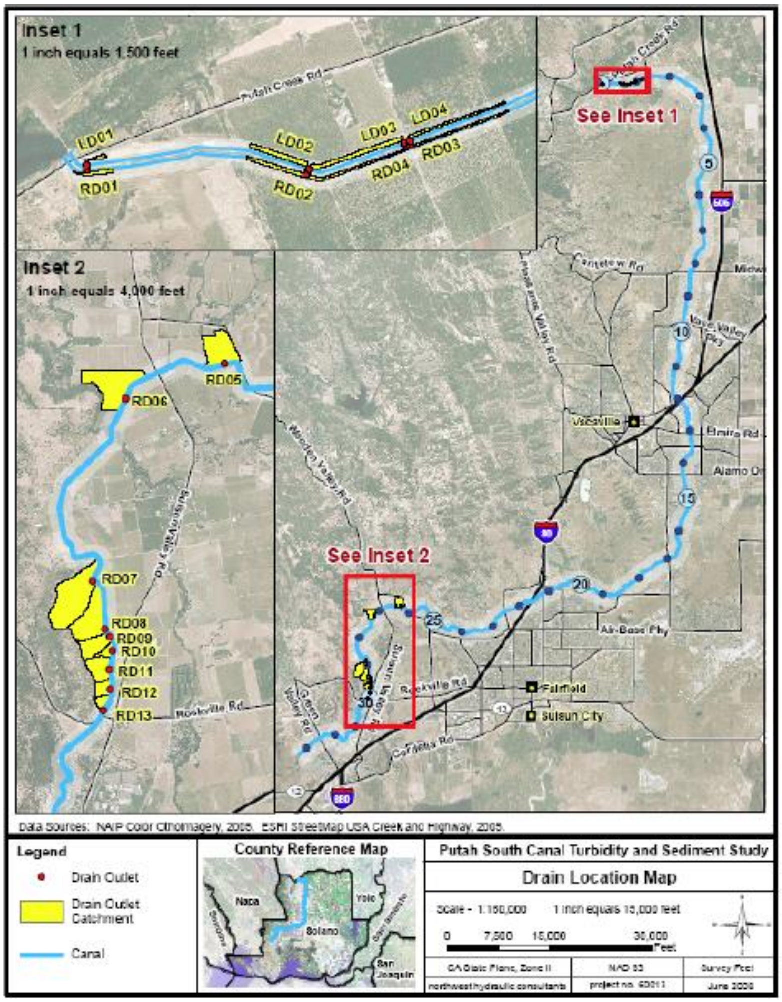
Occurrence in Watershed

A study conducted by Northwest Hydraulic Consultants (NHC) in 2010 for SCWA determined that near the PSC Headworks, there is a short portion of the right-of-way that drains to the canal via eight drains, and there are also nine drains in Suisun Valley, as shown in **Figure 4-3.**

According to the study conducted by NHC, drain #6 receives the number one ranking for largest sediment yield because of its large watershed and routine cultivation such that nearly the entire surface is freshly disturbed prior to the rainy season. Drain #5 received the second highest ranking for largest sediment yield because of its smaller watershed area but similar agricultural use. Drains #2-4 receive a high ranking, even though they do not drain off right-of-way lands, because the native surface access road is routinely bladed throughout the reach which disturbs and exposes fine sediments to erosion during each subsequent rainy season. However, gravel mulch was recently applied to access roads near drains #2 through #4 that drain into the PSC. Application of gravel mulch prevents the access road from being bladed, which can lead to sediment runoff into the canal.

Although drains #7-13 drain the largest cumulative area, it does not yield much sediment as the land is open space (and may no longer be grazed) and is relatively undisturbed.

Figure 4-3. Location of Drains to the PSC



Another lateral source of sediment is inflows from overtopping flows. During large storm events, runoff enters the canal when flooding occurs alongside the canal and the canal is overtopped or when culverts carrying local streams across the canal are overtopped. Large amounts of sediment enter the canal during these events. The last overtopping event was in 2008. There were no overtopping events in the reporting period.

The study conducted by NHC in 2010 also determined that Pleasants Creek is the most significant source of sediment to Lake Solano. As a result, SCWA completed a subsequent study in 2012 to evaluate the feasibility of a new alternative intake, upstream of Pleasants Creek (Summers Engineering, 2012). The proposal was to install a pump station along Putah Creek upstream of Pleasants Creek, and construct a pipeline from the pump station to the PSC inlet. If a pump station and pipeline could be constructed at a location above Pleasants Creek, the water quality should be less turbid and could be diverted directly into the PSC to meet the winter demand flow. The pipeline would bypass Lake Solano. The total estimated cost for the project was $3.6 million in 2012 which was cost-prohibitive.

Source Water Protection Activities

There were best management practices implemented to reduce erosion and sediment entering the PSC, which will be discussed in the next section on canal cleaning. For example, gravel mulch was applied to access roads that drain into the PSC.

Summary of Findings for Lateral Sources

- Lateral sources likely did not contribute as much sediment to the PSC during the reporting period as the reporting period was dry. The last overtopping event was in 2008.
- Additionally, SCWA implemented a number of best management practices (BMPs) to reduce erosion and sediment from entering the PSC.

CANAL CLEANING

Background

As referenced in the 2012 WSS, a 2010 study conducted by NHC determined that Lake Solano is the primary source of aquatic vegetation in the canal. Tubers, plant fragments, seeds, rhizomes and turions enter the canal through the Headworks and propagate in the canal. The vegetation loading occurs during the spring through summer period when vegetation growth in Lake Solano is at its peak.

Due to the growth of aquatic plants in the canal, and algal blooms in the canal, the SID has to spend a significant amount of resources to clean the canal and address algal blooms. Unfortunately, the process of canal cleaning causes a short-term degradation in water quality for the WTPs, causing the WTPs to shut down temporarily during and after cleaning. The use of copper sulfate to control algae and the vegetation population is also of concern due to drinking water regulations for copper.

Occurrence in Watershed

Aquatic vegetation surveys were conducted in 2007 and 2011. The prevailing macrophyte species observed in the 2007 and 2011 vegetation surveys were the Eurasion watermilfoil, sago pondweed, and horned pondweed (NHC 2010)(Peffer 2013). The aquatic vegetation is present year-round but optimal growth is observed in the spring and summer months. According to the 2011 survey conducted by Peffer, the macrophyte density in the PSC increased with distance downstream. The trend is likely due to the decrease in water velocity and increase in sediment accumulation downstream. The macrophyte density was highest in the Mankas, Suisun, and Van Every checks which tend to be some of the most problematic areas.

Various types of filamentous algae were observed along the PSC. The dominant species detected in the 2007 and 2011 surveys was Cladophora, green algae. The algae attach itself to the sides and bottom of canal and blooms from April to September. In 2011, the highest algal density was observed in Suisun check.

Source Water Protection Activities

<u>Putah South Canal Headworks Improvements Study</u>

In order to address vegetation entering the PSC from Lake Solano, SCWA conducted and completed a Putah South Canal Headworks Improvements study in October 2012. The original diversion structure and headworks facilities were constructed in the late 1950s and it was determined that the headworks structure experienced high volumes of vegetation and sedimentation loading at the inlet structures trashracks. Although the old existing screening was found to remove approximately 90 percent of all vegetative loading from Lake Solano, the remaining 10 percent flowed through the screens and into the PSC, and is estimated at approximately 5 tons of biomass each year. NHC estimated each ton of plant fragments flowing into the PSC generates approximately 60 tons of new plant growth in the canal. The feasibility study evaluated alternatives for a new automatic screening or raking process at the Headworks. The report gave the highest ranking to the Ovivo Gripper rake for automatic cleaning at the Headworks. The gripper rake was installed in 2015 to 2016.

Additional best management practices that were tested/implemented after the study were:

-Gravel mulch was applied to access roads that drain into the PSC. This prevents the access road from being bladed, which can lead to sediment runoff into the canal.
-Gravel mulch was applied to the inside canal banks that have low regrowth potential.
-Blanket application of herbicides along the inside canal banks was eliminated, and switched to application of broadleaf herbicides.
-Weir boards at PSC Headworks radial gates were installed to trap sediment, but were discontinued as it was ineffective.
-Acrylic copolymers were applied on canal banks, but were discontinued as it was ineffective.
-“Floc-logs” were installed inside or at bottom of direct drains, but was discontinued as it was ineffective.

<u>Alternative Canal Cleaning Methods</u>

SCWA also conducted a study on alternative canal cleaning methods in 2015. SCWA contracts with the SID for operation and maintenance of the PSC. SID typically conducts an annual PSC cleanout to remove sludge buildup and restore canal capacity. Sludge accumulation is undesirable because it reduces the canal capacity, blocks water intakes, impacts water quality and leads to increased vegetation in the canal. The current PSC cleanout involves fully draining the canal check-by-check and using bobcats, a crane and a long reach excavator to mechanically remove the sludge. The sludge is set in drying pits along the canal to dry. It takes two months to clean the entire canal and approximately three days to clean one segment of the canal between check structures. The cleanout is conducted during the fall (mid October through December).

Although the current cleanout method can remove the coarse sediment and large aquatic vegetation, it does not remove the fluid-like sludge and fine sediment. Days after the cleanout, the re-suspended sediment settles in the canal and the sediment accumulation resumes. According to the City of Fairfield (Waterman WTP), the worst water quality occurs after cleaning when the upstream checks are recharged. The residual canal sludge that was deposited on the canal floor is resuspended, creating turbidity plumes downstream.

On occasion, the PSC water quality is so poor, that the WTPs will temporarily shut down or seek alternative water sources. Water quality issues caused by canal cleaning are high chlorine demand, septic odors, elevated metals (iron, manganese and copper), TOC, TSS, ammonia and turbidity.

Typically the sediment depth increases downstream and the sludge thickness range from less than an inch to one foot. Low flows during the winter period allow the suspended solids to settle and deposit along the canal. Currently, the annual cleanout costs about $250,000 per year. The long-term goal of examining alternative cleanout methods is to improve the sediment and vegetation removal, decrease operational concerns for PSC users, and meet or reduce cleanout costs.

The study concluded that there were two recommended solutions: “optimal” and “balanced”. The optimal solution recommended the suction dredge and mechanical harvester for sludge removal and centrifuge for dewatering. The suction dredge is optimal because it can handle high concentrations of fine sediment and aquatic vegetation while the canal is in full operation. The balanced solution recommended a submersible pump attached to a long-reach excavator for sludge removal. For dewatering, the belt press, sludge thickener, and centrifuge were comparable, with the centrifuge being the superior option other than cost. After the study was completed, SCWA requested contractor bids to conduct suction dredging. The bids came back at approximately $600,000 per mile. This solution was determined to be too costly, as the current cost to clean 33 miles of the PSC is $250,000.

Copper Sulfate Treatments

Copper sulfate is applied to the canal from April to October to control algal growth. Copper sulfate may be applied either as a slug of granular material or as a liquid injection for a period of 3 to 4 hours. SID distributes an annual treatment schedule to all PSC users such that users can determine if they want to avoid the water treated by copper sulfate or not. The secondary MCL for copper in drinking water is 1 mg/L.

As discussed in Section 3, the NBR WTP and the Waterman WTP sample weekly for copper. Most samples, if not all samples, had copper concentrations of less than 50 µg/L. However, the two highest copper concentrations could be related to copper sulfate treatments.

For example, the highest copper concentration observed over the reporting period at the NBR WTP was 107 µg/L on April 7, 2014. A copper sulfate treatment was scheduled on April 3, 2014 at milepost 12.05 which is just upstream of where the NBR WTP takes PSC water at milepost 16.74. The highest copper concentration over the reporting period at the Waterman WTP was 114 µg/L on February 24, 2015. Although there was a copper sulfate treatment scheduled on the same day at milepost 23.5, it was confirmed that the treatment occurs immediately downstream of Serpa Check so the elevated concentration at the Waterman WTP is more likely due to an upstream treatment.

Like the two studies above, SCWA is continually testing new methods in which water quality could be improved or protected. Overall, the general consensus is that copper sulfate is not effective in the PSC to control algal blooms. In the summer of 2017, three alternative algaecides were tested, due to concern with high copper levels found in canal sludge. The three algaecides tested were:

- Green Clean, a peroxide based algaecide
- SeClear, a copper based algaecide, and
- F-30, a copper based algaecide.

The study measured the effectiveness using visual inspection and measurement of total and dissolved copper over distance and time from the application point. Since dissolved copper is the chemically available copper that is most effective as an algaecide, it was desired to verify if dissolved copper concentrations remained high and stable over distance and time. Unfortunately the study did not find a suitable alternative algaecide. Green Clear was not effective at all. SeClear was effective but only maintained 40 to 50 percent of copper in the dissolved state. F-30 was the most effective, and maintained a high percentage of copper in the dissolved state, but was only effective for a short distance (0.5 mile).

Summary of Findings for Canal Cleaning

- The SCWA has undertaken a number of studies to reduce sediment and vegetation from entering the canal and also to improve canal cleaning methods. The installation of the Ovivo Gripper rake for automatic cleaning at the Headworks in 2015/2016 is reducing the amount of vegetation that was previously entering the PSC.

- Alternative algaecides were tested in 2017, but further studies are needed. SCWA is currently engaged in bench scale studies.

- Although copper levels are well below the MCL, elevated concentrations may be attributed to copper sulfate treatments to control algal blooms.

GRAZING

Background

Grazing occurs on both pasturelands and rangelands. Pastureland is irrigated rangeland. Discharges from pasturelands and runoff from rangeland may carry *Cryptosporidium*. Calves are known to be able to transmit *Cryptosporidium*.

Occurrence in Watershed

For areas below the Monticello Dam, very limited areas of the watershed have livestock grazing capacity. Some of the Lake Solano watershed may receive drainage from areas that are lightly grazed, including land along Pleasants Valley Road. A field visit conducted in 2006 indicated that the livestock graze very near the tributary creeks, with limited or no fencing to prevent their entry into the watercourse.

Information is available on the number of cattle and sheep that graze in Solano County but not specifically on land that drains to Putah Creek and the PSC. However, the numbers provide a general picture of livestock/sheep populations in the watershed. The total livestock population in Solano County, including both rangeland and dairy cows was 34,951 in 2005 and 23,400 in 2016, which is a 33 percent decrease. There were also 44,607 sheeps and lambs in Solano County in 2005, and 59,000 sheep and lambs in 2016, which is an increase of 32 percent.

The greatest risk of microbial contamination occurs during periods when there is flooding that results in local stream overtopping the canal. There were no overtopping events during the study period. Additionally, Long Term 2 Enhanced Surface Water Treatment Rule monitoring conducted at the Putah South Canal Terminal Reservoir from April 2015 to March 2017 showed *Cryptosporidium* was detected in only 2 of 24 samples collected at 0.1 oocysts/L. Therefore, the risk of *Cryptosporidium* contamination to the PSC appears to be very low.

Summary of Findings for Grazing

- Although the number of sheep and lambs has increased in Solano County, this is most likely occurring outside of the study watershed, as limited areas in the watershed have livestock grazing capacity.

- Based on results from LT2ESWTR monitoring, the risk of *Cryptosporidium* contamination to the PSC appears to be very low.

URBAN RUNOFF

Background

Urban runoff (URO) occurs on a year-round basis and includes wet and dry weather discharges. Wet weather runoff results from seasonal storms. Wet weather runoff is of relatively short duration and can have highly variable pollutant concentrations. Because of the high degree of imperviousness, urban areas typically generate higher per acre volumes of runoff than undeveloped or agricultural lands. Dry weather runoff results from activities such as lawn irrigation and car washing.

Related Constituents

Data on urban runoff discharges indicate that the runoff is turbid, a source of TOC, a source of bacteria, a source of nutrients, and a source of other constituents such as pesticides and organic compounds. Generally, the impact is greater during the wet season, immediately following a first-flush event.

Occurrence in Watershed

Solano County is the only municipality required for storm water permit coverage in the watershed. Information on the County's program was obtained from the Storm Water Multiple Applications and Report Tracking System (SMARTS) database. Activities completed by Solano County are described in Source Water Protection Activities below.

As stated in the 2012 Update, all urban runoff in the cities of Vacaville and Fairfield is conveyed over or under the canal. Other runoffs from drains as described in the Lateral Sources section are draining rural areas.

Regulation and Management

State Water Resources Control Board

The Clean Water Act requires the State Water Resources Control Board and the Regional Boards to regulate the discharge of stormwater from a number of sources. For Phase I, these sources included large (populations greater than 250,000) and medium (population from 100,000 to 250,000) sized municipalities, most industrial sites, and construction activities of one acre or more.

For Phase II, the State Water Resources Control Board adopted a General Permit for the discharge of stormwater from small MS4s to provide permit coverage for smaller municipalities and non-traditional MS4s, such as military bases, public campuses, and prison and hospital complexes.

On February 5, 2013, the proposed final draft of the Phase II Small MS4 General Permit was adopted and became effective on July 1, 2013. Solano County and the City of

Benicia are covered under Phase II. The cities of Fairfield, Vallejo and Suisun City are covered under Phase I. The cities of Vacaville and Dixon are covered under Phase II.

Existing Source Water Protection Activities

Some of the activities completed by Solano County to address storm water are:

- Developed and distributed educational materials to construction site operators,
- Began implementation of storm water public education and outreach,
- Maintained inventory of all industrial and commercial facilities that could discharge pollutants to the MS4,
- Implemented annual pollution prevention and good housekeeping training for Solano County staff,
- Inspected and verified no illicit discharge to the MS4

Summary of Findings for Urban Runoff

- Currently, the Interdam Reach has more rural than urban uses, so urban runoff is minimal.

- Since urban runoff in the cities of Vacaville and Fairfield are conveyed over or under the PSC, the only time urban runoff enters the canal is during overtopping events. There were no overtopping events during the reporting period.

- The County performs many activities to prevent pollutants from entering the MS4 such as street sweeping, maintenance and cleaning of the MS4 system, conducting inspections, and identification of illicit discharges and connections.

FIRES

Background

The aftermath of a wildfire or prescribed burn can alter source water quality. In general, the load of dissolved substances to streams will increase following a wildfire, due to increased runoff. Increased runoff can occur following a fire because the formation of a hydrophobic organic layer in the soil increases the water repellency of soils (DeBano, 2000). A 2004 USGS study revealed that measurable effects of fires on streamwater quality are most likely to occur if the fire was severe enough to burn large amounts of organic matter, if windy conditions were present during the fire, if heavy rain occurred following the fire, and if the fire occurred in a watershed with steep slopes and soils with little cation-exchange capacity (USGS, 2004).

Related Constituents

The magnitude of the effects of fire on water quality is dependent on how fire characteristics (frequency, intensity, duration, and spatial extent of burning) interact with watershed characteristics (weather, slope, soil type, geology, land use, timing of regrowth of vegetation, and burn history). This interaction is complex and highly variable so that even fires in the same watershed can burn with different characteristics and produce variable effects on water quality. Typically, storm water runoff from burned forested areas contains high concentrations of phosphorus, nitrogen, dissolved organic carbon, sediment, and metals such as mercury, lead, and arsenic.

Occurrence in Watershed

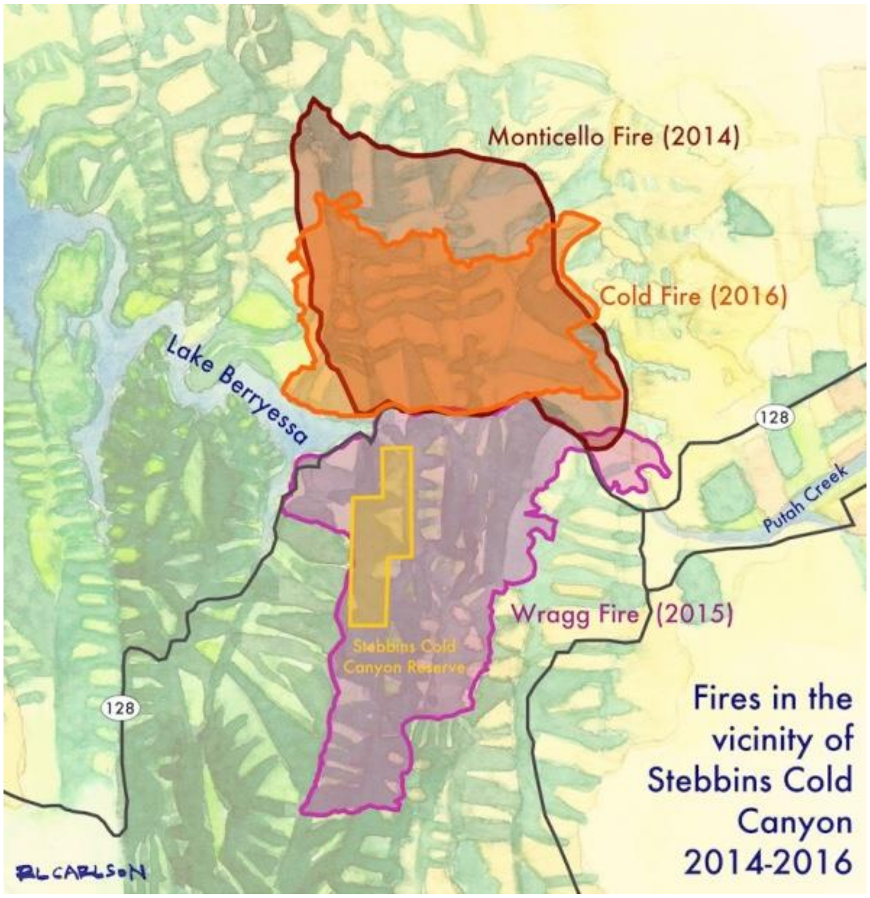
There were three wildfires in the interdam reach over the reporting period. **Table 4-3** contains information about these fires and **Figures 4-4** show the fire burn areas for each fire. It should be noted that 60 percent of the interdam watershed was burned.

Additionally, wildfires occurred upstream of Lake Berryessa during the reporting period, such as the Valley Fire, Rocky Fire, and Jerusalem Fire. SCWA was particularly concerned about the impact to the PSC WTPs after the Valley Fire, and therefore decided to conduct post-fire water quality monitoring in January and March 2016, as discussed below.

Table 4-3. Wildfires in the Putah Creek Watershed, 2012 to 2016

Fire Name	Dates or Date Started	Acres Burned
Monticello	7/4-7/12/14	6,488
Wragg	7/22/15	8,051
Cold	8/2-8/12/16	5,731

Figure 4-4. Burn Area for the Monticello, Wragg and Cold Fires



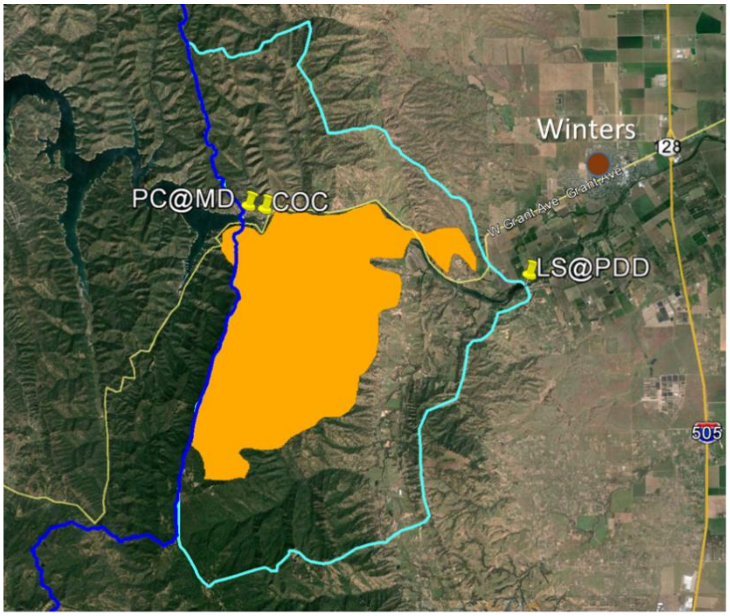
Related Water Quality Issues and Data Review

After a fire has occurred, the natural vegetation on hillsides is denuded, and therefore increased erosion of soils is expected to occur during the first rains immediately following a fire. Additionally, a fire can cause the soils to become hydrophobic.

SCWA hired a consultant to conduct post-fire watershed assessment for each of the fires. Generally, both the Monticello and Cold Fire had small to moderate effects on sediment reaching Putah Creek. Both fires burned at low intensity and covered similar burn areas.

The post-fire watershed assessment conducted for the Wragg Fire concluded that a lot of sediment was observed in Cold Creek, which drains directly into Putah Creek just below the Monticello Dam. This observation supports the findings from water quality sampling conducted by SCWA after the Wragg Fire. Within the Interdam reach, samples were collected at Putah Creek at Monticello Dam, Cold Canyon Creek at Putah Creek and at Lake Solano at the Putah Diversion Dam (as shown in **Figure 4-5**) during three storm conditions on January 6, March 7 and March 11, 2016. Samples were also collected upstream of Lake Berryessa, but those sites are not relevant to this report.

Figure 4-5. Water Quality Sampling Locations in Interdam Reach, January and March 2016 for Post-Fire Assessment



Samples were collected for Title 22 minerals and metals, as well as TOC and physical parameters. **Figures 4-6** through **4-8** show that the Cold Canyon Creek site had the worst water quality of all the interdam reach sites, particularly for sediment.

Figure 4-6. Post-Fire Water Quality Sampling Results for TSS

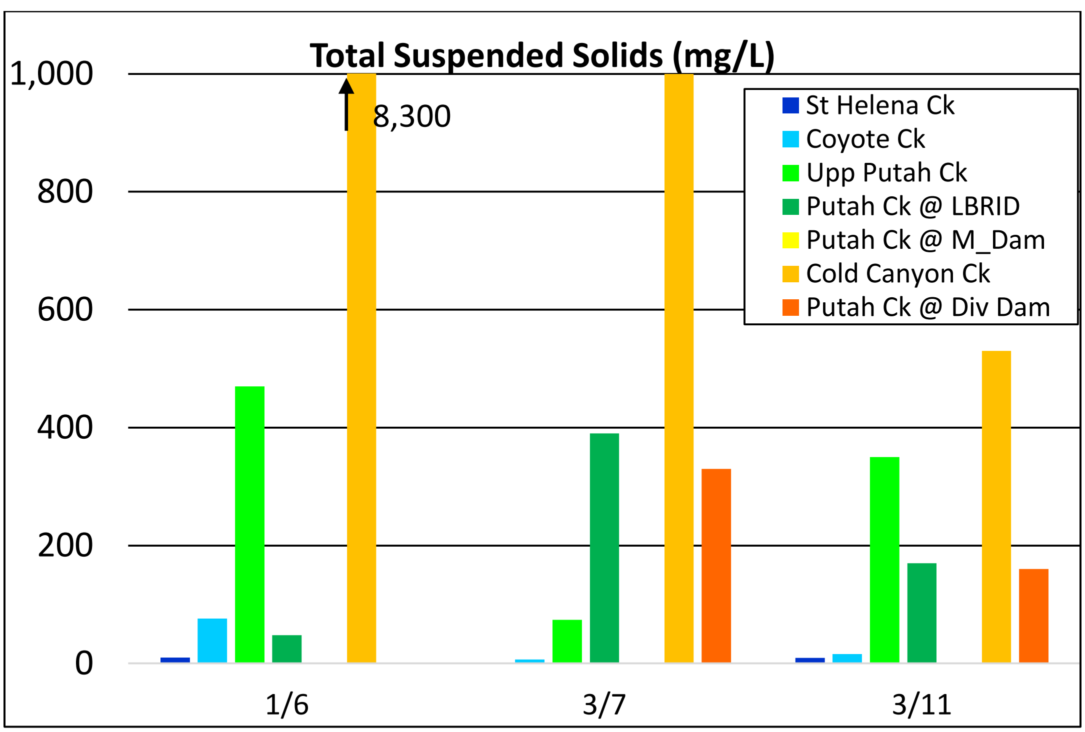


Figure 4-7. Post-Fire Water Quality Sampling Results for TOC

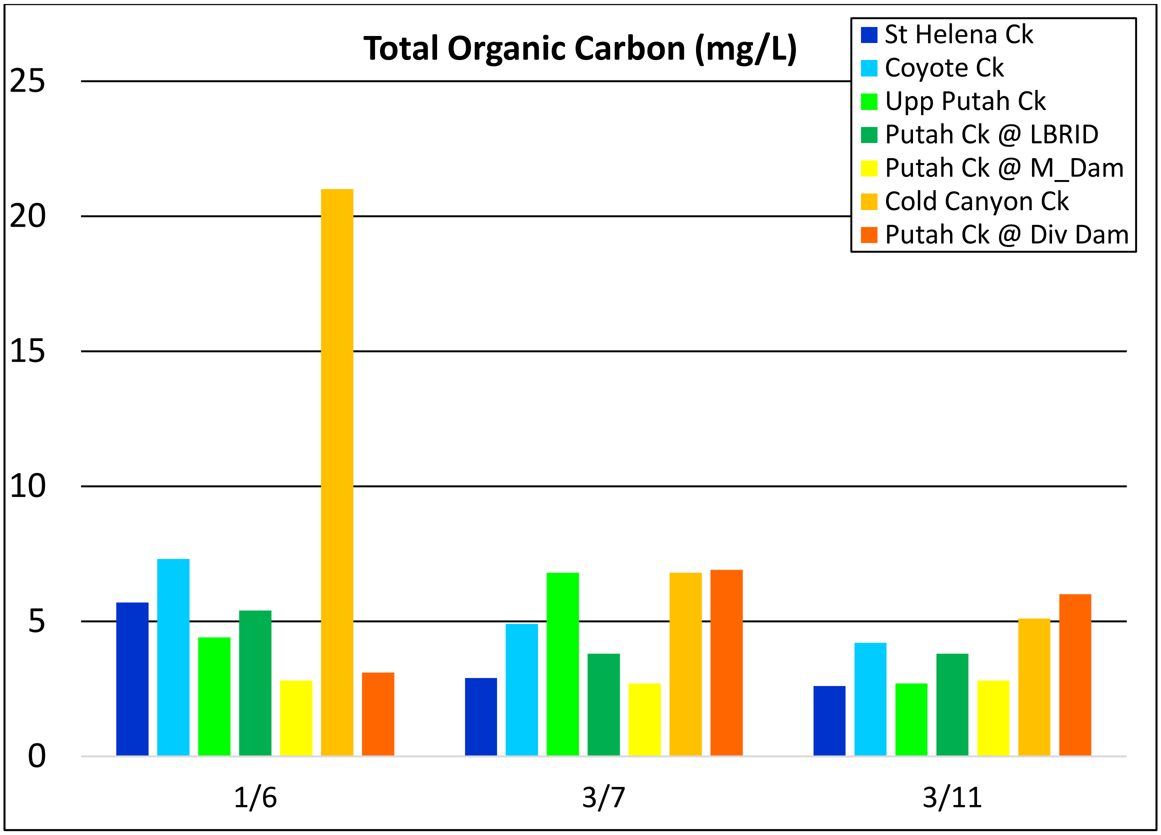
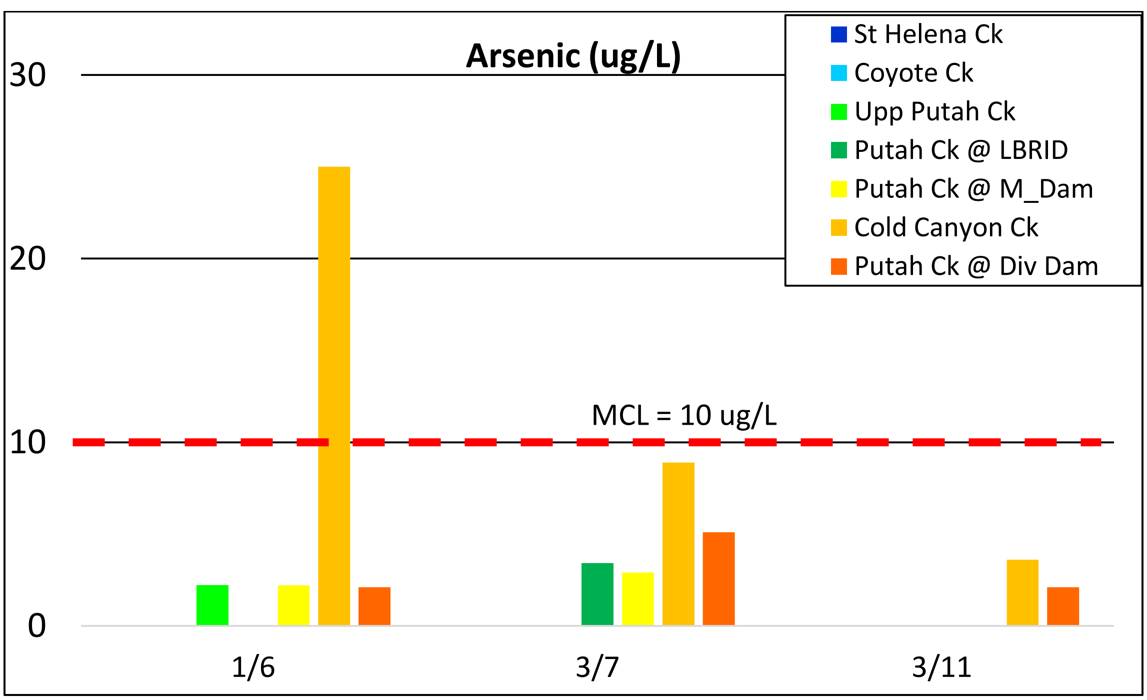


Figure 4-8. Post-Fire Water Quality Sampling Results for Arsenic



Summary of Findings for Fires

- Approximately 60 percent of the watershed was burned over the reporting period. However, there were no impacts to the WTPs treating PSC water.
- SCWA conducted post-fire watershed assessments after each of the Monticello, Wragg and Cold wildfires. SCWA also conducted water quality monitoring after the Wragg wildfire.

SECTION 5 – KEY FINDINGS AND RECOMMENDATIONS

This section consists of a discussion of key findings, update on recommendations from the 2012 watershed sanitary survey and a list of current recommendations.

KEY FINDINGS

Water Quality

Turbidity

- Overall, source water turbidity is normally low, with medians at all locations less than 3 NTU. However, there are frequent periods where levels exceed that substantially, up to 100 NTU and higher. These excursions are associated with winter storms.
- The Cement Hill, NBR, and Waterman WTPs show similar trends, with turbidity peaks above 100 NTU occurring at the same time, due to storm events. For example, all three WTPs have turbidity peaks in December 2012, December 2014 and March 2016.
- Storms can increase turbidity immediately at Headworks, increasing ten-fold from 191 NTU to 1237 NTU within one hour.
- The Fleming Hill WTP has overall lower turbidities as it is located further downstream, as some turbidity has settled out in the canal.
- The Gibson Canyon WTP also has overall lower turbidities as the Eldredge Pumping Plant which pumps water to the WTP and is typically shutdown during periods of high turbidities on the PSC.

Microbial Constituents

- The second round of LT2ESWTR monitoring detected *Cryptosporidium* only twice out of 24 monthly samples, with low concentrations at 0.1 oocysts/L.
- Source water fecal coliform and *E. coli* levels are also low, with medians less than 15 MPN/100mL at all locations. Additionally, all monthly medians for fecal coliform and *E. coli* were less than the trigger level of 200 MPN/100mL, except for one month (November 2015) at the NBR WTP.
- Therefore, 2-log *Cryptosporidium*, 3-log *Giardia,* and 4-log virus removal and inactivation is the appropriate level of treatment for all PSC WTPs.

Total Organic Carbon

- Median TOC concentrations are generally between 2 and 5 mg/L.
- The highest TOC concentration for each WTP occurred during the month of December and was storm-related.
- Enhanced coagulation is required for the plants that treat Solano Project water because the source water TOC is routinely above 2 mg/L and they implement conventional treatment processes.

Copper

- All of the copper concentrations measured at the respective lab taps and PSC intake locations for the NBR and Waterman WTP were much lower than the action level for the Lead and Copper Rule and the secondary MCL for copper.

Pesticides

- Volatile organic chemicals (VOCs) and SOCs are collected quarterly at the NBR Canal by the City of Fairfield. No VOCs or SOCs were detected at the NBR PSC intake, except for one detection of picloram in October 2016 at 0.1 µg/L. The City of Vacaville samples annually for ten insecticides and pesticides and all samples were nondetectable over the reporting period.

Potential Contaminant Sources

Spills

- Overall, there were no spills in the watershed and no direct impacts to the PSC.

Recreation

- Although there are many types of recreation occurring in the watershed, there are very few activities which occur in water, except for boating in Lake Solano. There is minimal to no body contact recreation.
- However, the number of visitors to the Stebbins Cold Canyon Reserve and Putah Creek Fishing Sites have increased in the past five years.

Agriculture

- There are limited crop areas within the watershed, namely walnuts and grapes.
- Commercial growers are required to be enrolled in the Central Valley Regional Water Quality Control Board's Irrigated Lands Program, and most growers are likely participating in the Sacramento Valley Water Quality Coalition, through either Solano RCD, Dixon RCD, or the Yolo County Farm Bureau.
- Although there are nurseries and crops grown along the PSC, chemical usage for these parcels were not included as the water cannot drain to the PSC.
- Copper and glyphosate are the only pesticides used in the watershed draining to Putah Creek for which drinking water standards have been established. Monitoring data of PSC water shows low levels of copper and no detections of glyphosate.

Lateral Sources

- Lateral sources likely did not contribute as much sediment to the PSC during the reporting period as the reporting period was dry. The last overtopping event was in 2008.
- Additionally, SCWA implemented a number of best management practices (BMP)s to reduce erosion and sediment from entering the PSC.

Canal Cleaning

- The SCWA has undertaken a number of studies to reduce sediment and vegetation from entering the canal and also to improve canal cleaning methods. The installation of the Ovivo Gripper rake for automatic cleaning at the Headworks in 2015/2016 is reducing the amount of vegetation that was previously entering the PSC.

- Alternative algaecides were also tested in 2017, but further studies are needed. SCWA is currently engaged in bench scale studies.
- Although copper levels are well below the MCL, elevated concentrations may be attributed to copper sulfate treatments to control algal blooms.

Grazing

- Although the number of sheeps and lambs have increased in Solano County, this is most likely occurring outside of the study watershed, as limited areas in the watershed have livestock grazing capacity.
- Based on results from LT2ESWTR monitoring, the risk of *Cryptosporidium* contamination to the PSC appears to be very low.

Urban Runoff

- Currently, the Interdam Reach has more rural than urban uses, so urban runoff is minimal.
- Since urban runoff in the cities of Vacaville and Fairfield are conveyed over or under the PSC, the only time urban runoff enters the canal is during overtopping events. There were no overtopping events during the reporting period.
- The County performs many activities to prevent pollutants from entering the MS4 such as street sweeping, maintenance and cleaning of the MS4 system, conducting inspections, and identification of illicit discharges and connections.

Fires

- Approximately 60 percent of the watershed was burned over the reporting period. However, there were no impacts to the WTPs treating PSC water.
- SCWA conducted post-fire watershed assessments after each of the Monticello, Wragg and Cold wildfires. SCWA also conducted water quality monitoring after the Wragg wildfire.

UPDATE ON 2012 RECOMMENDATIONS

The 2012 Update recommended several actions that SCWA, SID, and water providers treating PSC water should take to protect source water quality in the PSC. These recommendations and the agencies' responses are discussed in **Table 5-1.**

Table 5-1. Recommendations from 2012 Watershed Sanitary Survey and Update

2012 Update Recommendation	Summary of Actions Taken by SCWA
SCWA should work with UC Davis to determine the cost and feasibility of installing and maintaining portable restroom facilities at Stebbins Cold Canyon Reserve.	UC Davis has installed a portable restroom facility at the trailhead location in the lower parking area.

2012 Update Recommendation	Summary of Actions Taken by SCWA
SCWA should maintain its current policy of not allowing urban runoff to be discharged to the PSC except under extreme storm conditions. As rural land is converted to urban uses, developers should be required to route the urban runoff over or under the canal. SCWA should monitor growth in the Winters area and, if growth proceeds to the west along Lake Solano and upper Putah Creek, SCWA should insist that Winters develop a storm water management plan that addresses protection of drinking water quality.	The policy remains the same. The City of Winters worked with consultants from Wallace Kuhl Associates to prepare a comprehensive storm water management plan in 2017. The City of Winters is currently not required to submit a storm water management plan to the Regional Board due to its small population size.
The studies that are currently being conducted by SCWA on alternative methods of cleaning the canal should be accompanied by TOC monitoring to determine if the alternative cleaning methods reverse the trend in TOC concentrations.	The studies and field trials are still ongoing. Additionally, TOC levels do not appear to be increasing.

RECOMMENDATIONS

Table 5-2 presents the recommendations developed for this Fourth Update, listed by subject area and not by priority. Development of recommendations for watershed management actions that are economically feasible and within the authority of the SCWA, SID and other PSC water users is critical. Recommendations will be implemented as resources are available.

Table 5-2
Recommendations for 2017 Watershed Sanitary Survey

Recommendation	Basis for Recommendation
Continue to evaluate algaecides in lieu of copper sulfate.	Copper sulfate is not effective and there is concern with copper levels in sludge.
Continue field trials for alternative cleaning methods.	Canal cleaning continues to create challenging water quality conditions.
Continue real-time monitoring during storm events to monitor turbidity slugs in canal.	Real-time monitoring can provide advanced warning of degraded water quality during storm or overtopping events.
Annually track pesticide data collected by City of Fairfield and City of Vacaville to determine if any pesticides are detected.	Pesticides are used in the watershed and usage may increase in the future.
Explore possibility of adding another restroom at Stebbins Cold Canyon Reserve.	The increase in visitor usage may justify an additional restroom.

APPENDIX A
BIBLIOGRAPHY AND LIST OF CONTACTS

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Email Communication, Jeff Anderson, Associate Parks Planner, Yolo County Parks Division, (530)406-5038

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